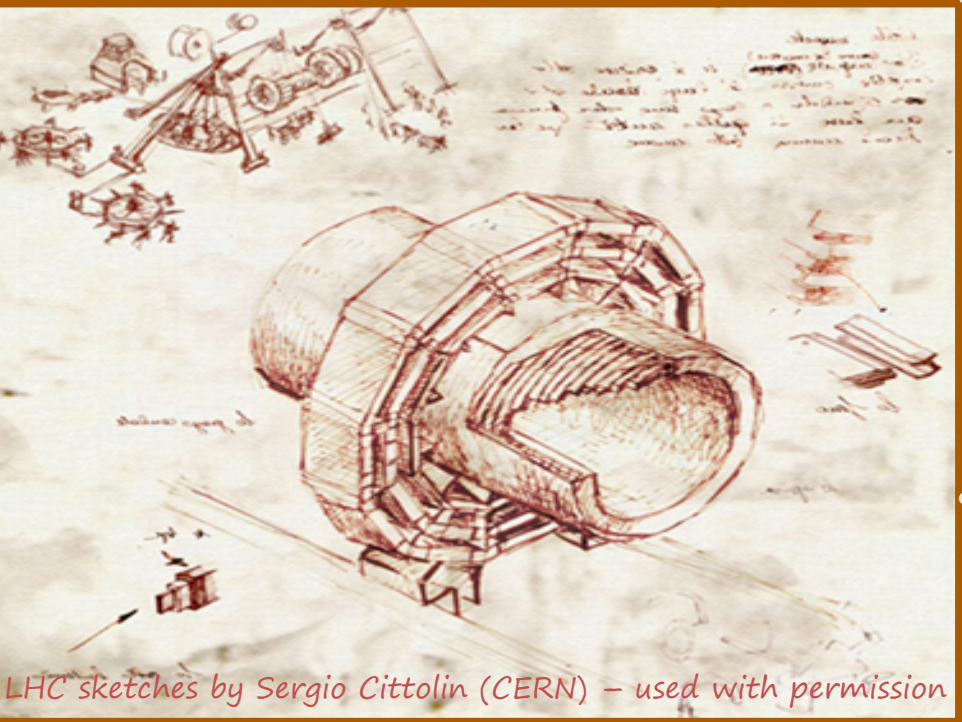
John Adams Institute for Accelerator Science

Science and the Art of Inventiveness



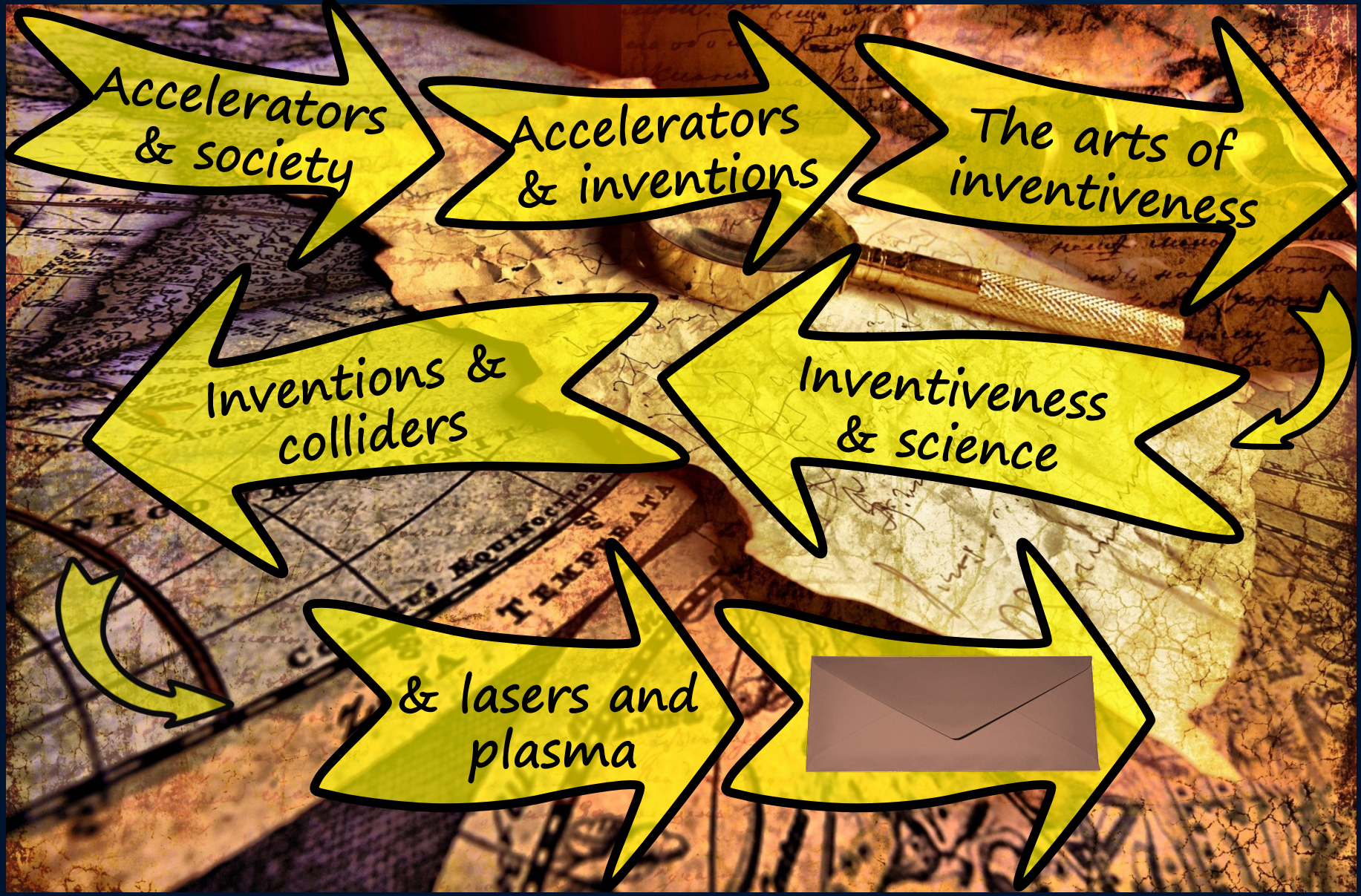
LHC sketches by Sergio Cittolin (CERN) – used with permission

Andrei A. Seryi
John Adams Institute

European Advanced Accelerator Workshop

18 September 2015

Travel route



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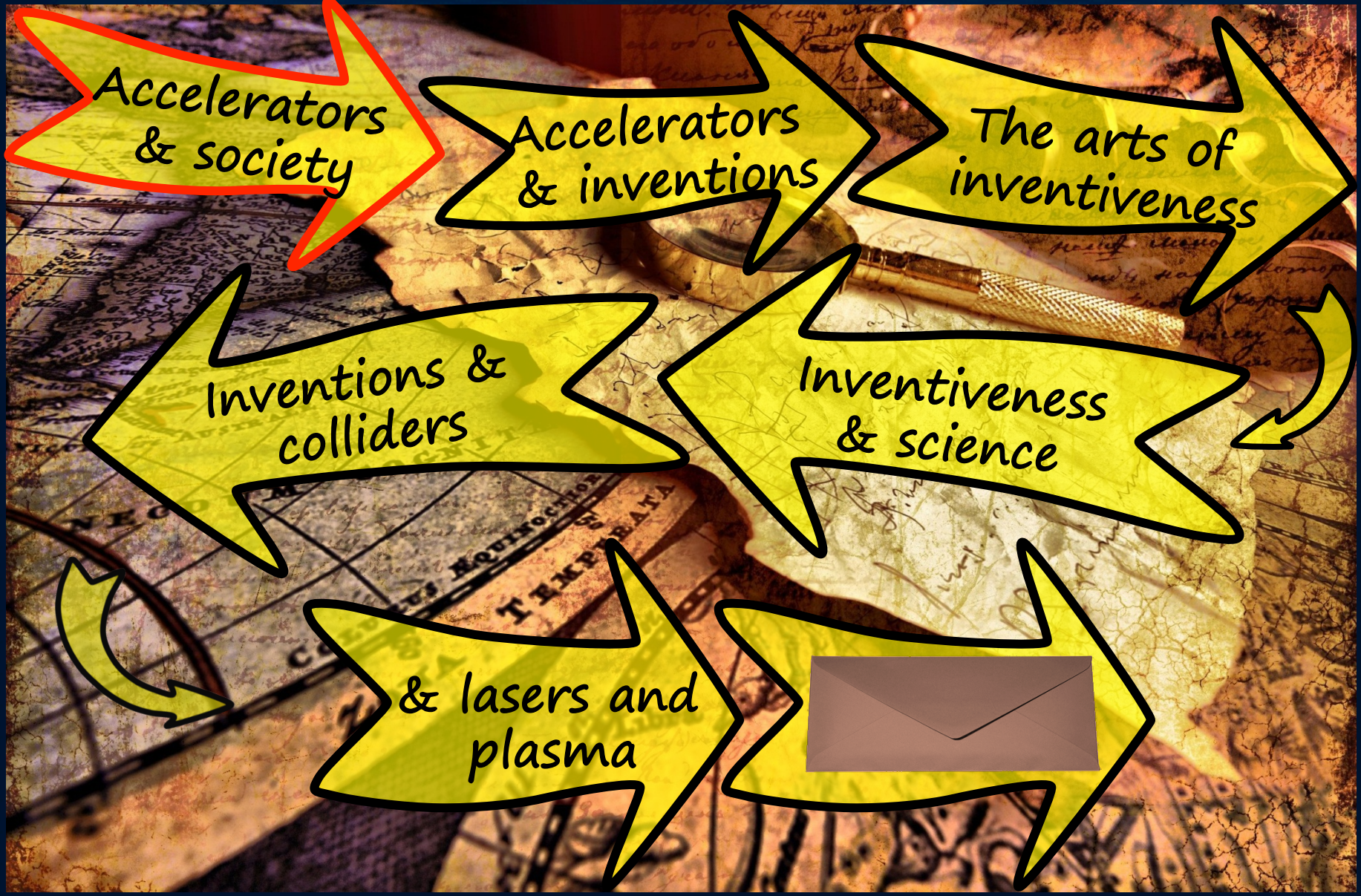
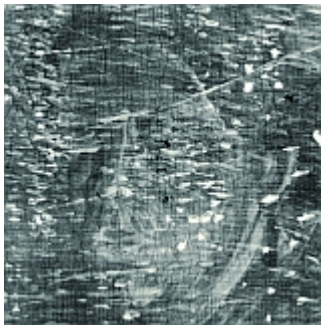


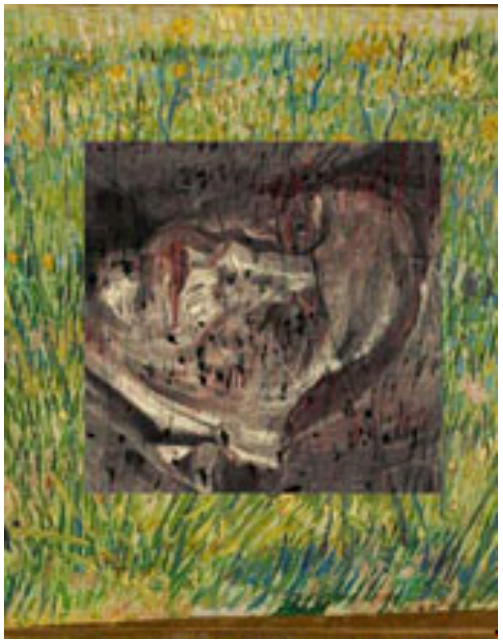
Accelerators can study art

Patch of Grass, spring 1887, F583/JH1263, KM 105.264 (30,8 x 39,7 cm), Kröller-Müller Museum
(Photo: Rik Klein Gotink)

This painting “Patch of grass” by Vincent van Gogh was the first one analysed by a particle accelerator



It showed a portrait of a woman underneath



http://photon-science.desy.de/news__events/research_highlights/archive/visualizing_a_lost_painting_by_vincent_van_gogh/index_eng.html

Accelerators in archaeology

The interior of samples can be studied using accelerators without destroying them

Pottery from Armenia, dating back to 1300 BC, is set up for a synchrotron experiment

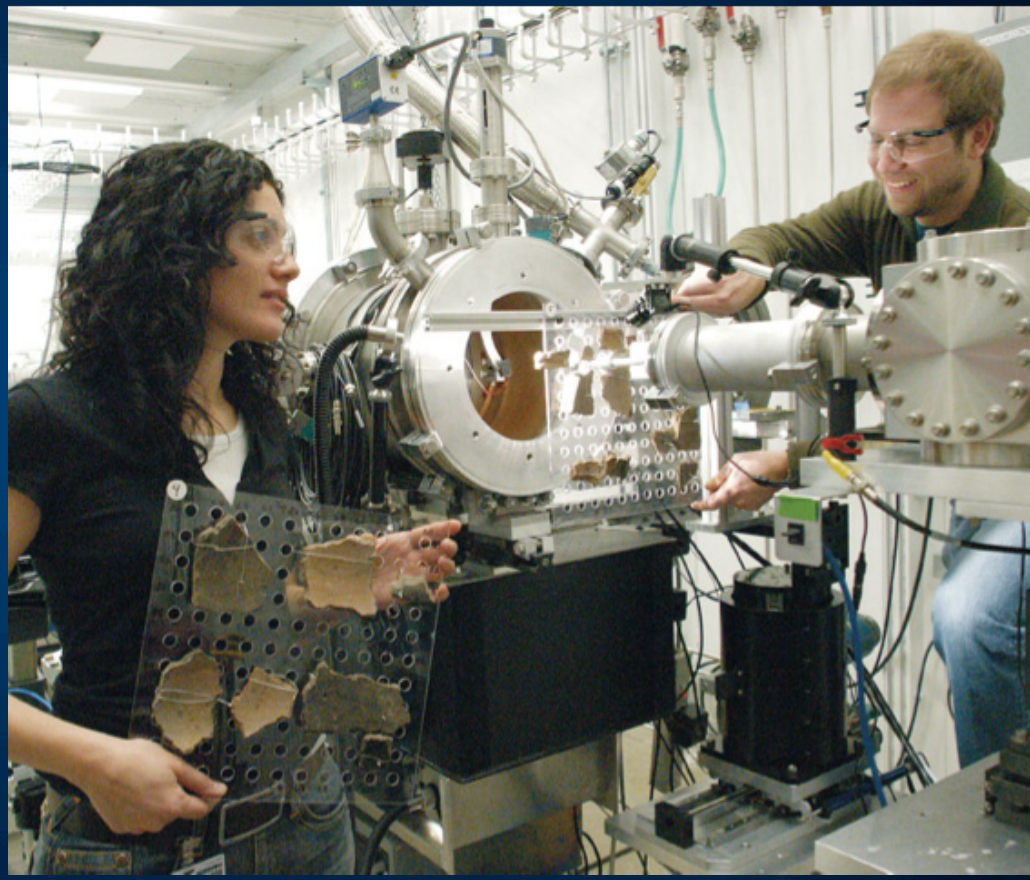


Image: Argonne National Laboratory

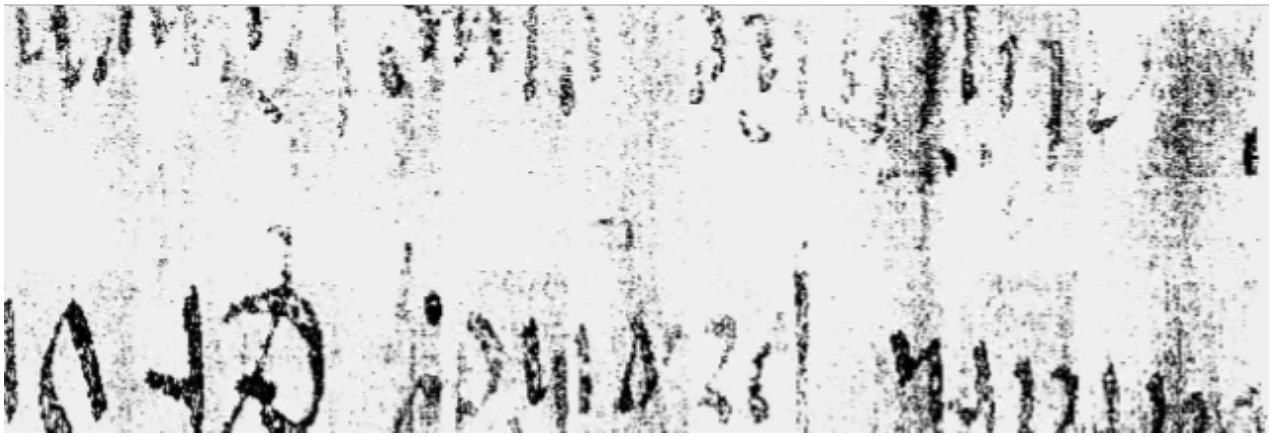
Particle accelerators can read hidden text

Accelerators can detect the X-ray 'signature' of iron in ancient pigments

Photo: Graham Davis & Tim Wess

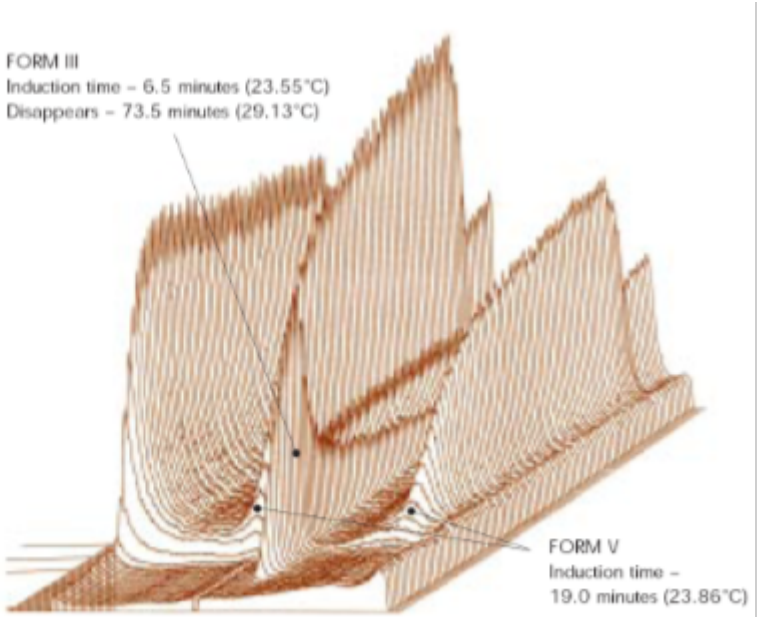
A written message can be revealed even on a folded manuscript which is too brittle to open

This method has also been used to analyse manuscripts and paintings that have layers of information from different authors



Accelerators can make food taste better

Cadbury used X-rays from a particle accelerator to study how cocoa crystallises

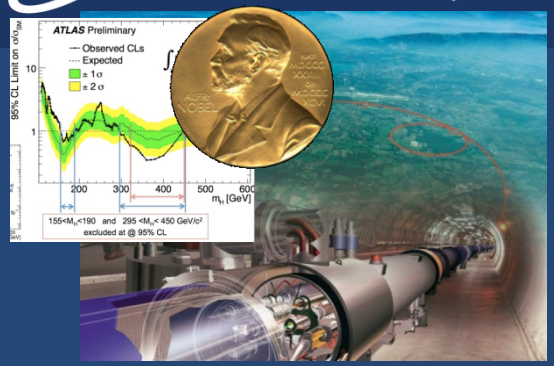


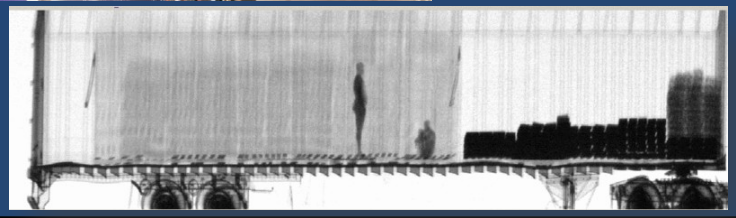
Of the six possible crystal forms, the fifth (form V) produces the best quality chocolate

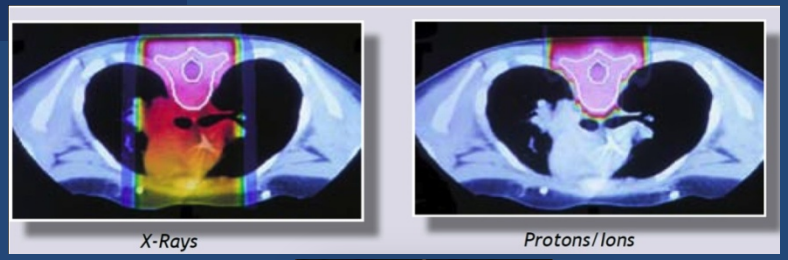
Particle accelerators for medical use

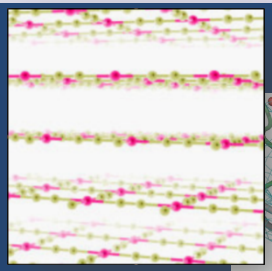
Most of them are used to treat cancer with X-ray beams (radiotherapy)

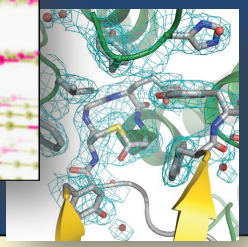
Accelerators for science and society

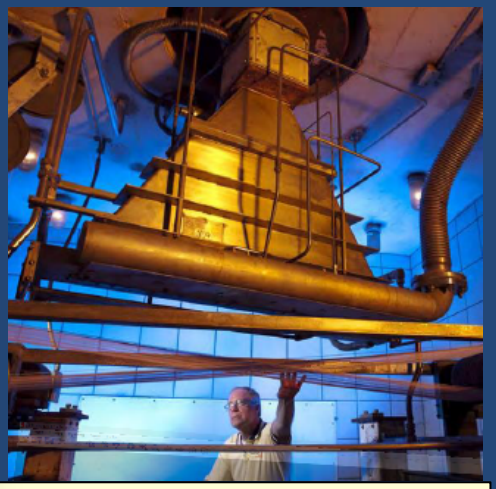












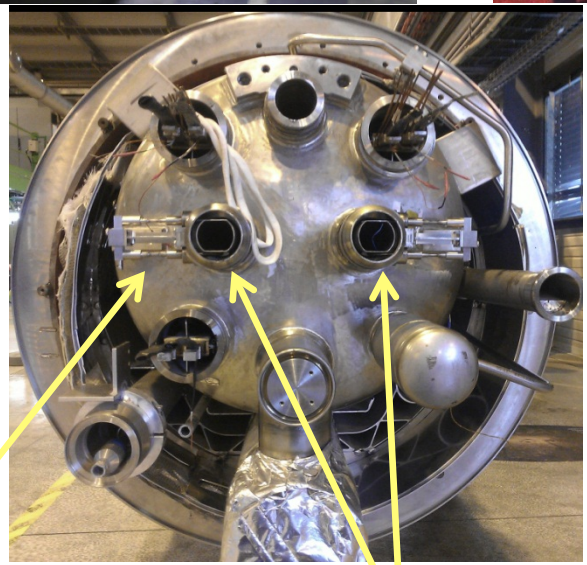
Accelerators: high energy physics, nuclear physics, healthcare, security, energy, life science, novel materials, industry…

Tens of millions of patients receive accelerator-based diagnoses and treatment each year in hospitals and clinics around the world

All products that are processed, treated, or inspected by particle beams have a collective annual value of more than $500B

The fraction of the Nobel prizes in Physics directly connected to accelerators is about 30%

Accelerators and fundamental discoveries - Large Hadron Collider



He-II vessel

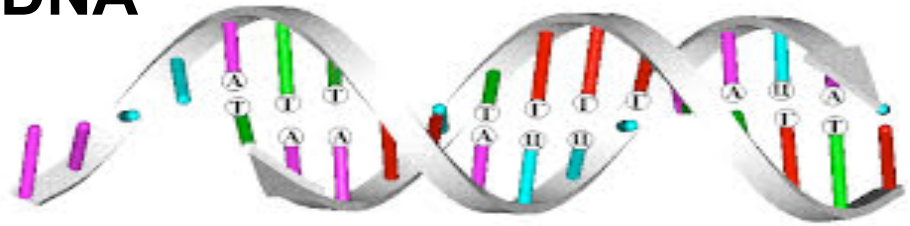
Beam pipes

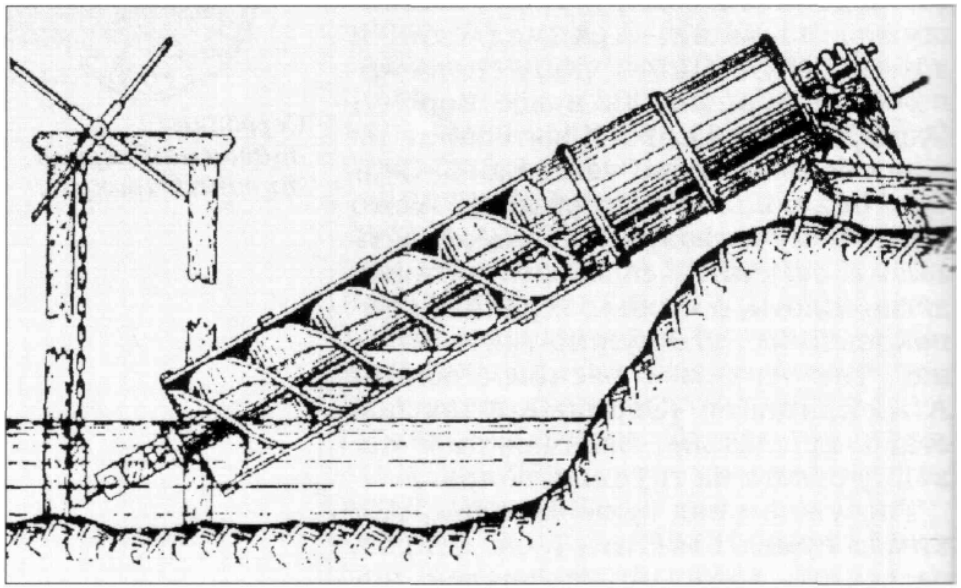
Peter Higgs and Francois Englert, Nobel prize 2013

Accelerator science and inventions…

Accelerator science demonstrates rich history of inventions, often inspired by the nature itself

DNA





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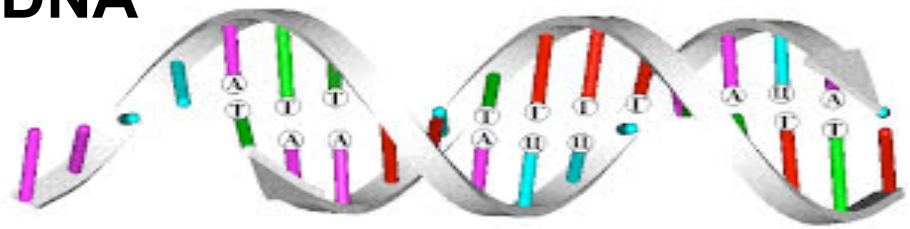
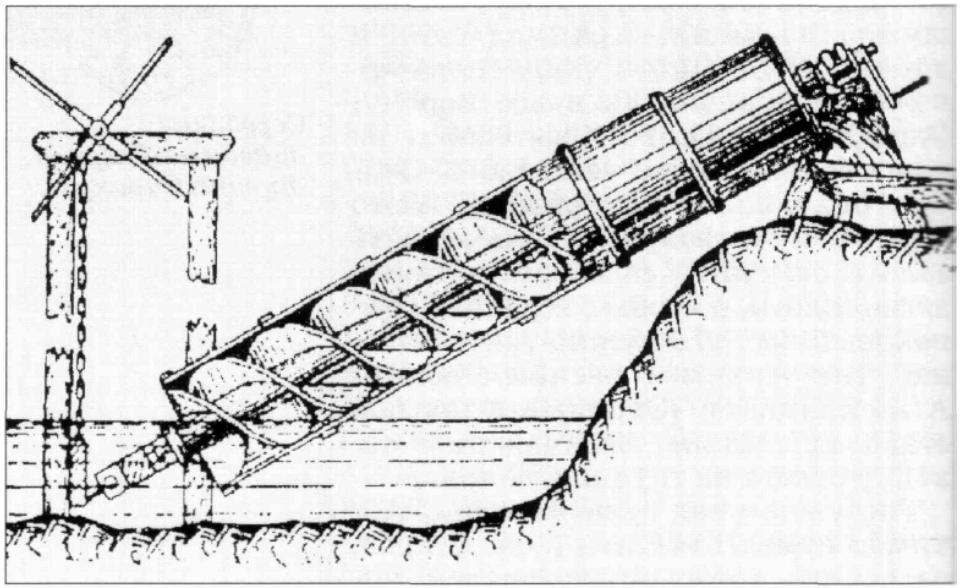
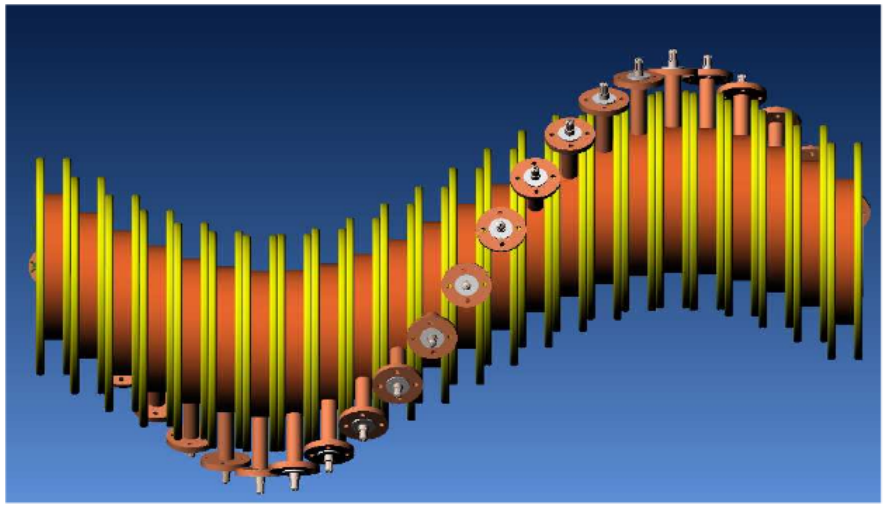




Muon Collider cooling channel … may have been inspired by the shape of DNA



Integrated Helical Solenoid, absorbers and accelerating resonators

Motivation behind inventions

Technical inventions often inspired by nature itself

Were people the inventors of gears?

Motivation behind inventions

Technical inventions often inspired by nature itself (could be)

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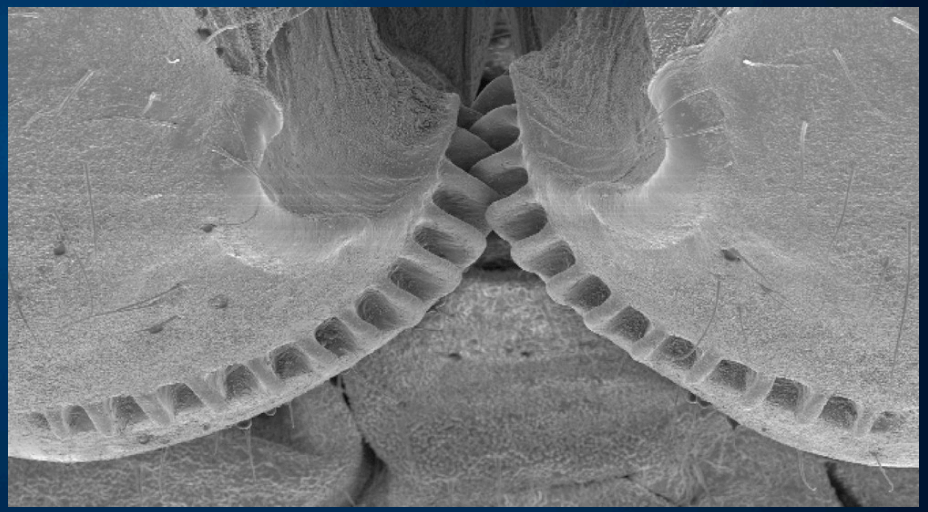

Insects have used them for millions of years!

Interacting Gears Synchronize Propulsive Leg Movements in a Jumping Insect, **Science**, 13 Sep 2013, M.Burrows, G.Sutton

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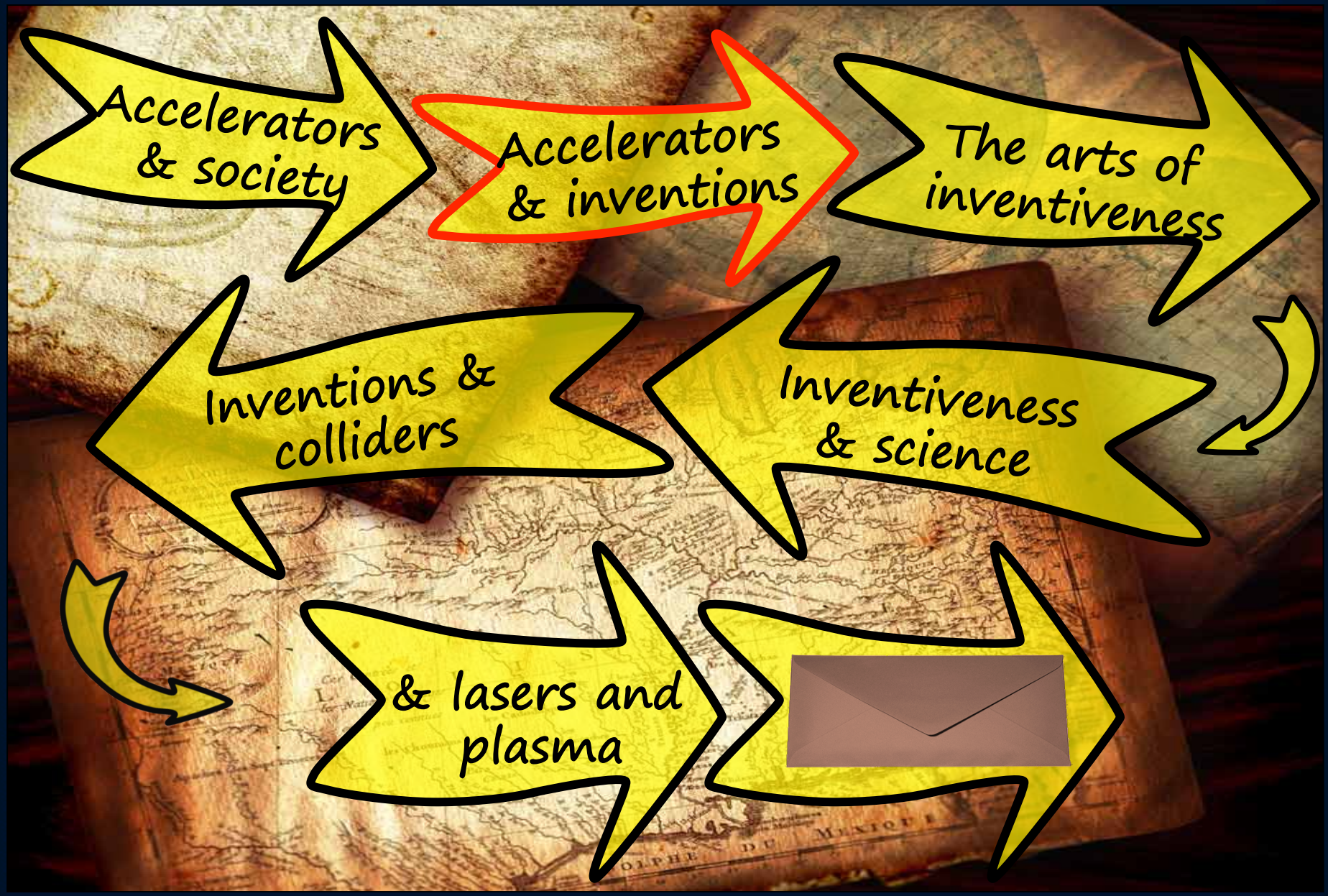
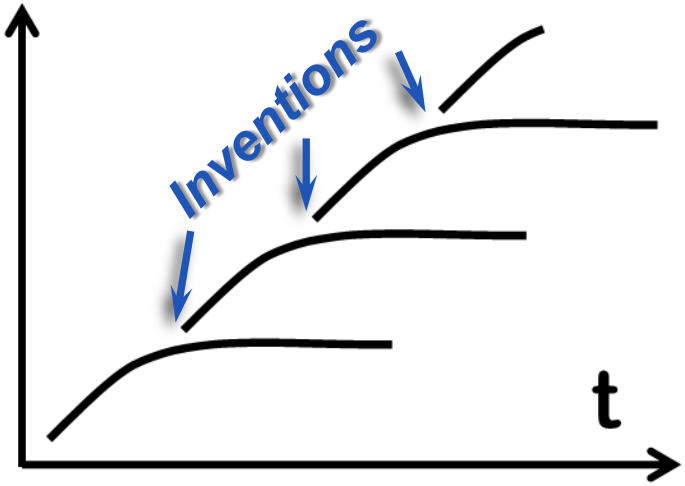
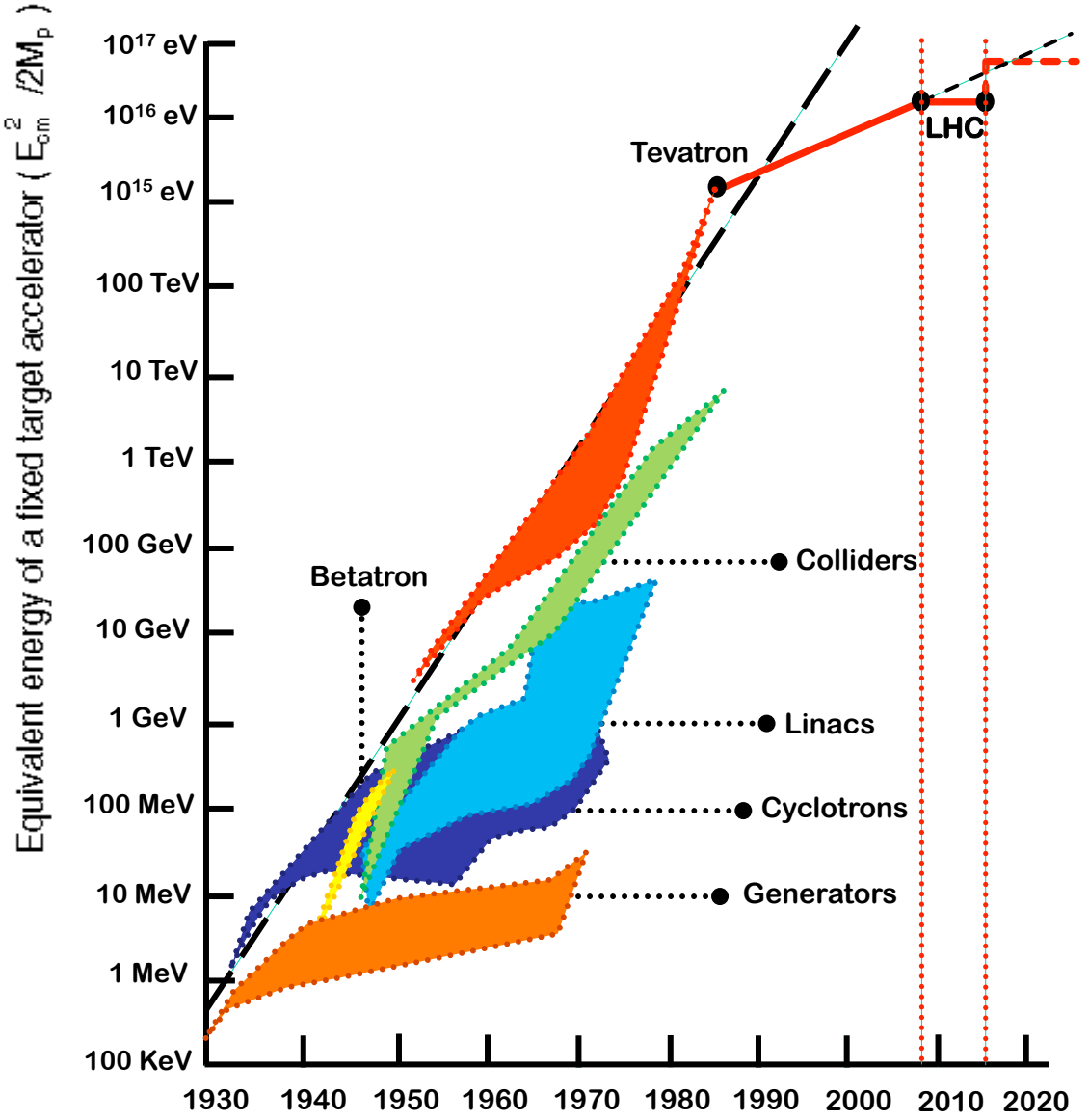


"Livingston plot"

- History of accelerators…
- …and evolution *(and saturation)* of particular technologies of acceleration, and birth of the new technologies *via inventions*





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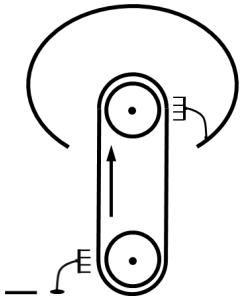
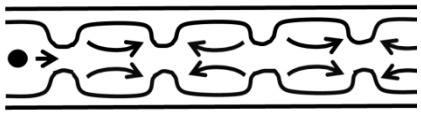
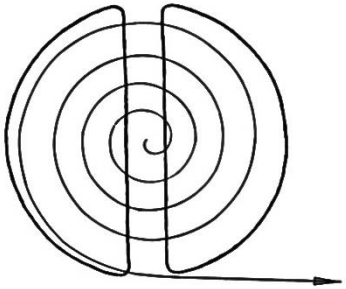
Accelerators – selected inventions



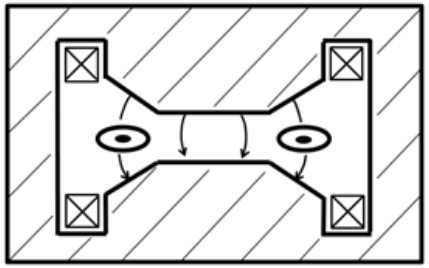
Electrostatic Acc.



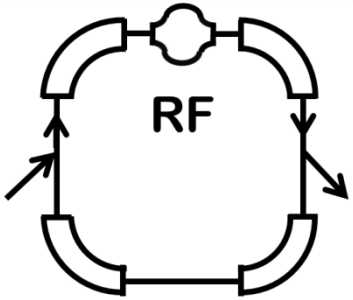
Resonant Linear Acc.



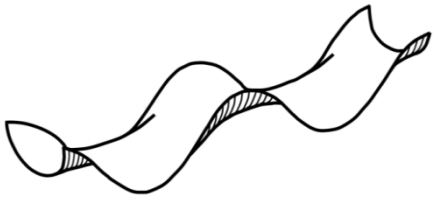
Cyclotron



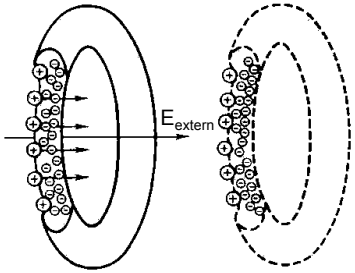
Betatron



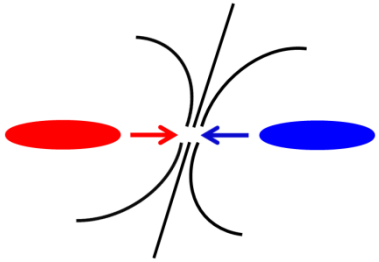
Synchrotron



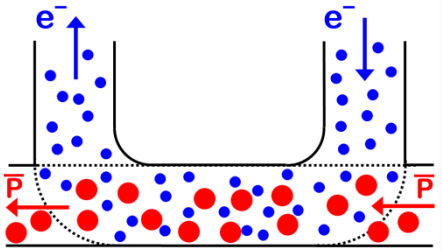
Strong focusing



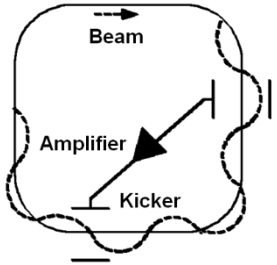
Collective acceleration



Colliders

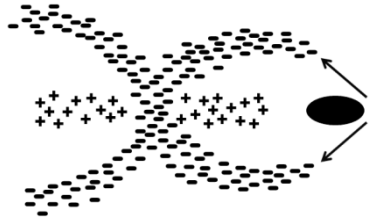


Electron cooling



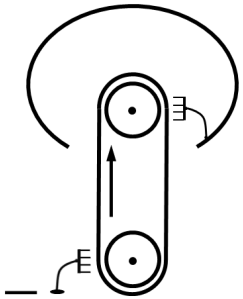
Stochastic cooling

SC magnets and RF



Plasma acceleration

Accelerators – selected inventions



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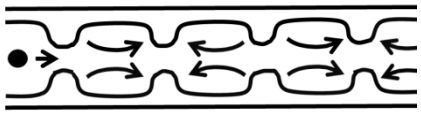

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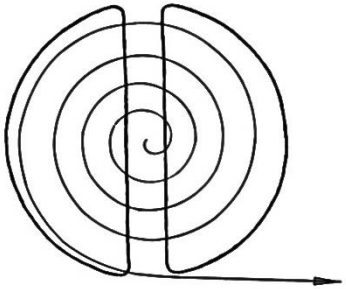

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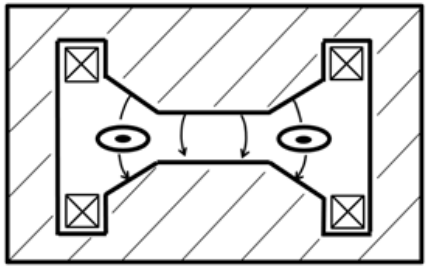

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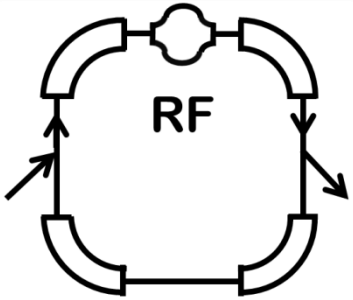

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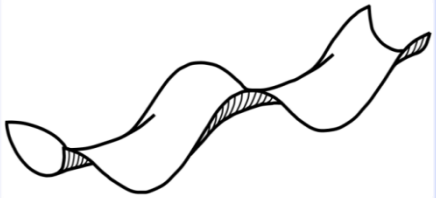

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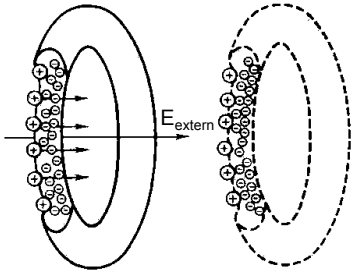

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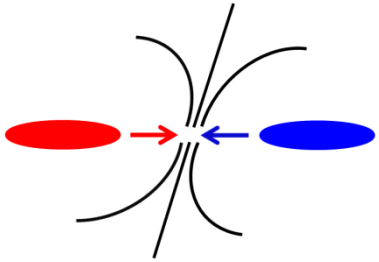

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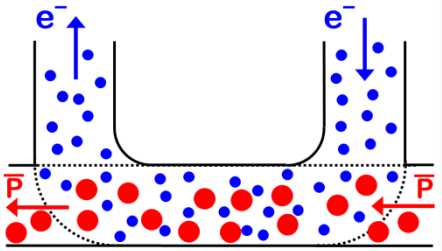

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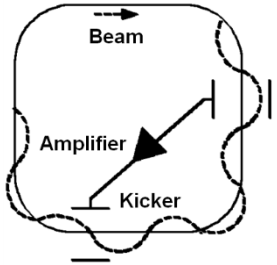

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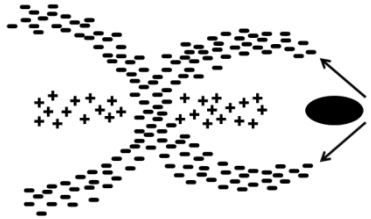

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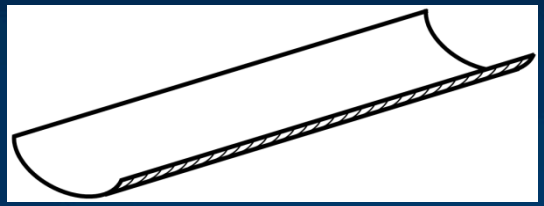
- 1979 plasma acceleration -> Tajima & Dawson proposes acceleration in plasma excited by laser;
- 1980 to now superconducting magnets -> developed in various labs to increase the beam energy;
- 1980 to now superconducting RF -> developed in various lab to increase the RF gradient;
- 1990 to now photon collider; crab waist collision; integrable optics… inventions continue…

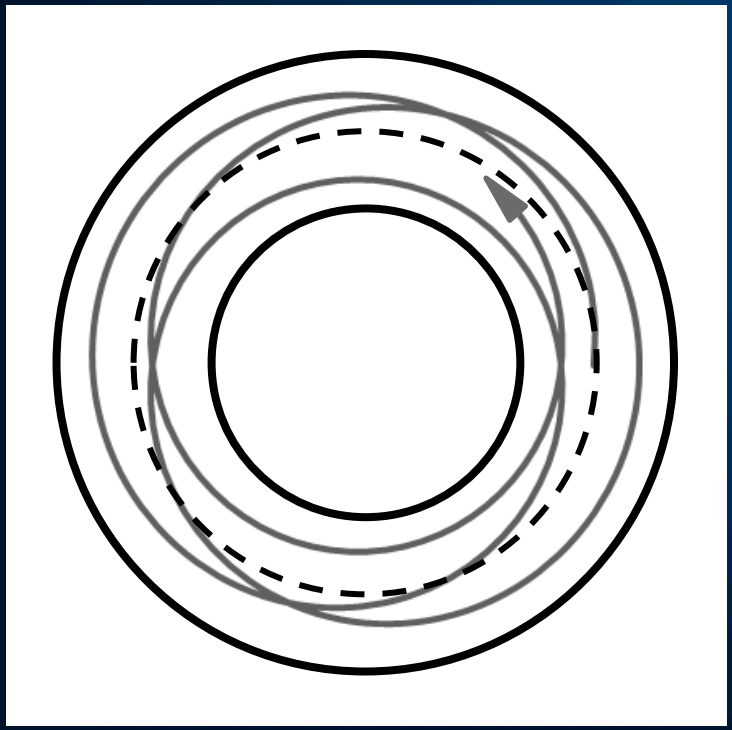
Although Christophilos was first, this invention usually attributed to Courant and Snyder - the Christophilos patent was pointed out after the Cosmotron team had announced the idea

Focusing

Focusing is needed to keep the particle trajectories near the centre

The analogy with the motion in the gutter



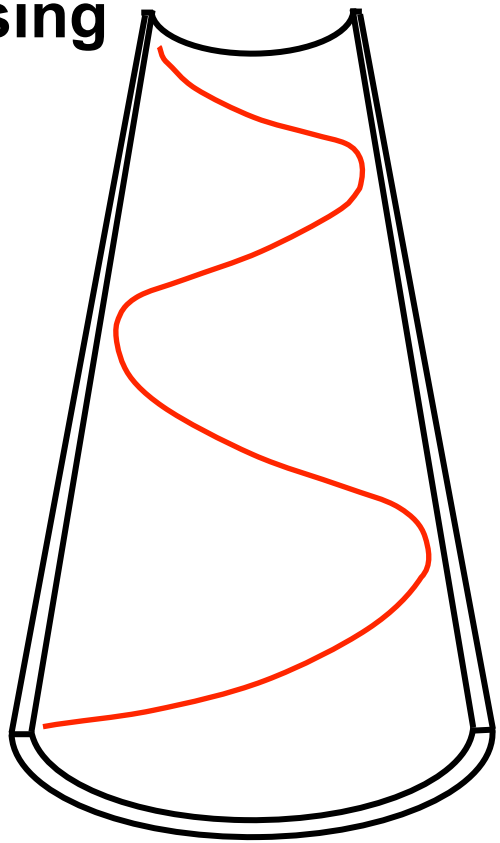


The first accelerators had weak focusing with spatial period greater than the perimeter of the accelerator

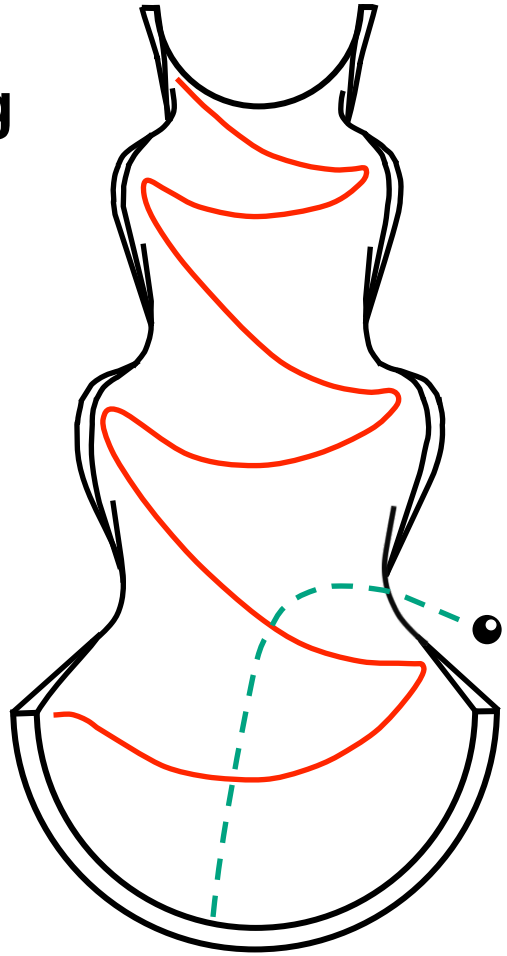
The trajectories of particles in an accelerator with weak focusing

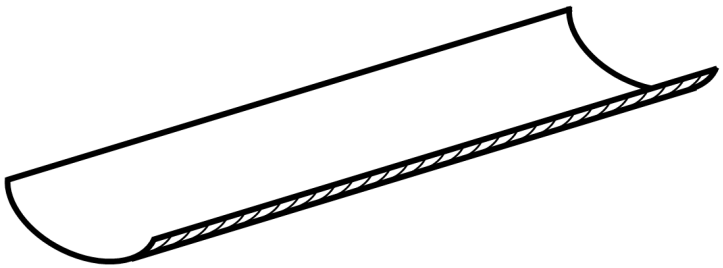
Weak and strong focusing

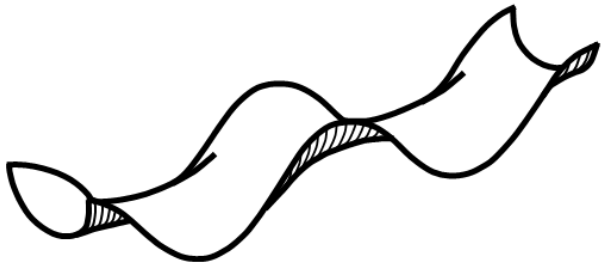
Weak focusing



Strong focusing

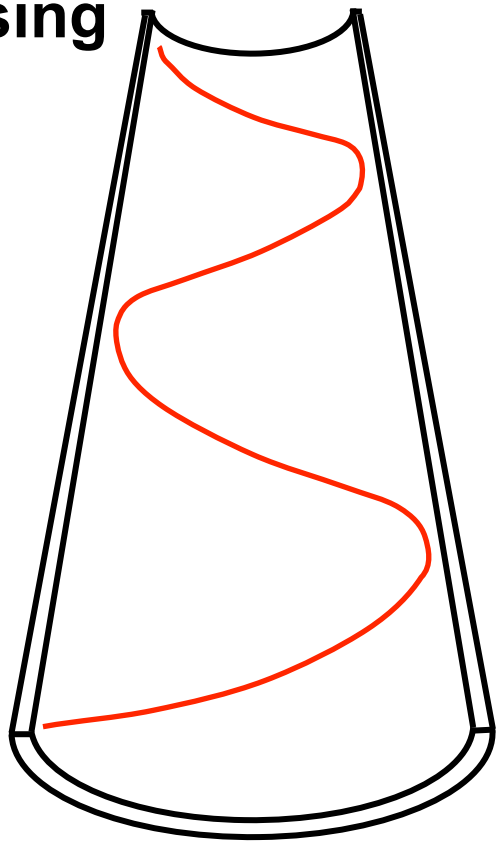






Weak and strong focusing

Weak focusing



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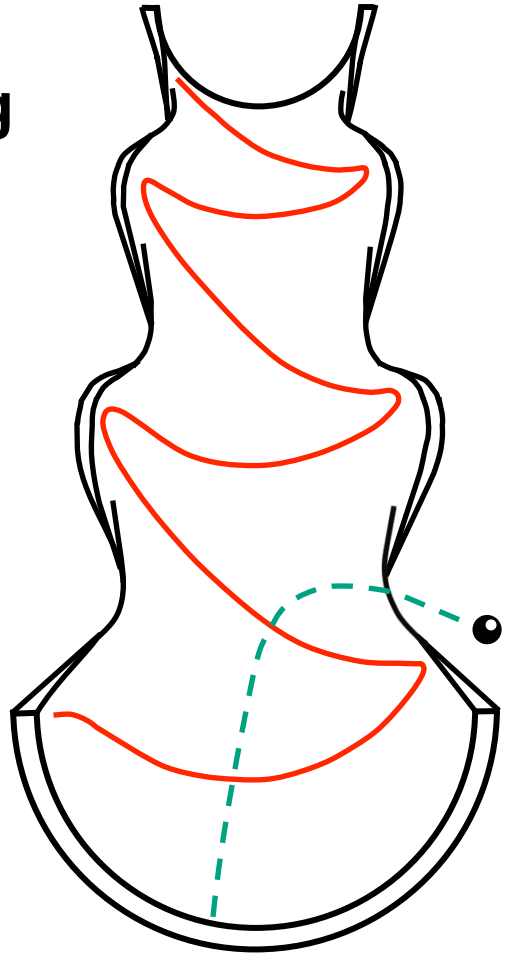
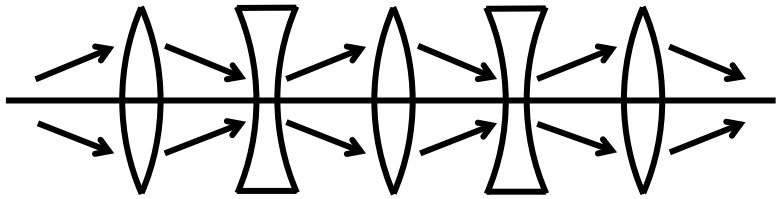
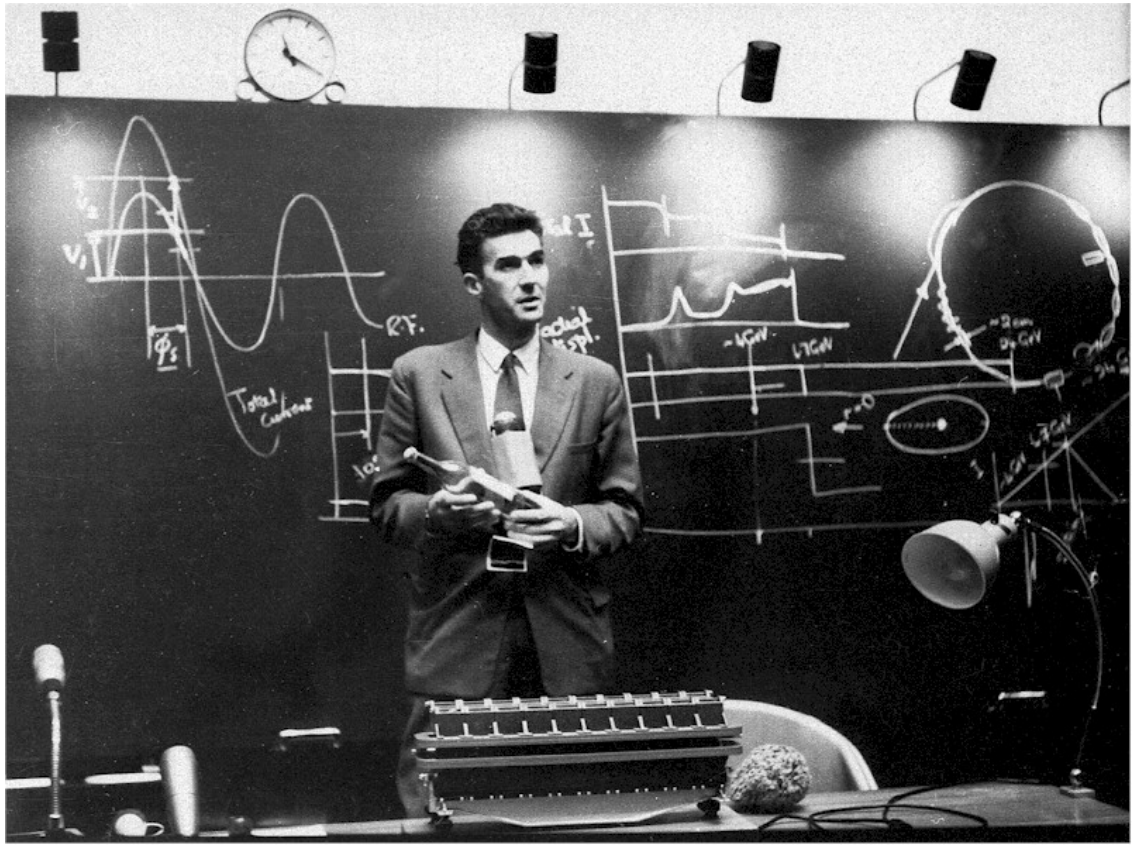




Strong focusing and JA history

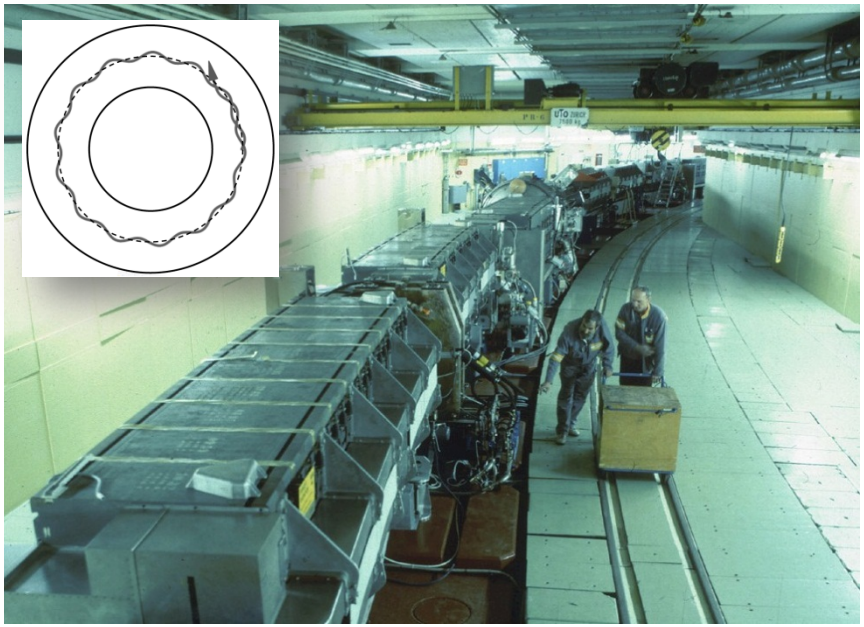
John Bertram Adams led the realization of the first strong-focusing proton accelerator.

This was the courageous decision – to cancel (in Oct 1952) the already approved 10 GeV weak focusing accelerator for a totally innovative 25 GeV Proton Synchrotron.



On the photo above Sir John Adams is announcing (on 25 Nov 1959) that CERN's PS just reached 24GeV and passed the Dubna's Synchrophasotron world record of 10GeV. This image shows Adams addressing the audience with a token of the victory – a bottled polaroid photograph showing the 24 GeV pulse in the machine ready to be sent back to the Joint Institute for Nuclear Research at Dubna as a sign that CERN had broken Dubna's record of 10 GeV.

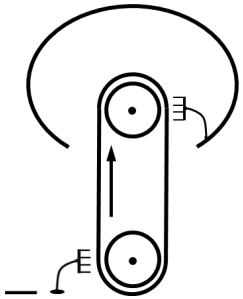
Weak and strong



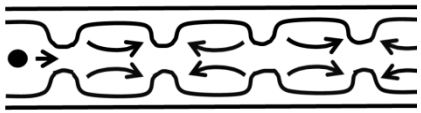
10 GeV weak-focusing Synchrophasotron built in Dubna in 1957, the biggest and the most powerful for his time. It is ~60m diameter ring, and its magnets weigh 36,000 tons and it was registered in the Guinness Book of Records as the heaviest in the world.

CERN's Proton Synchrotron, the first operating strong-focusing accelerator, reached 24 GeV in 1959. It is a ~200-m diameter ring, weight of magnets 3,800 tons.

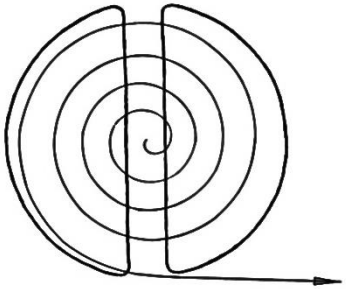
Accelerators – selected inventions



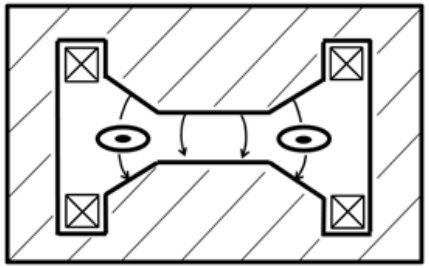
Electrostatic Acc.



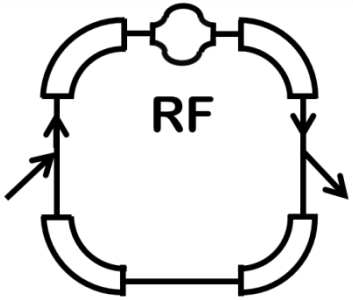
Resonant Linear Acc.



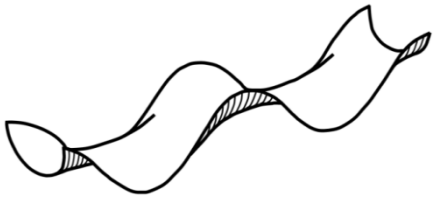
Cyclotron



Betatron



Synchrotron



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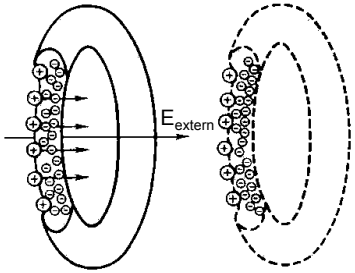
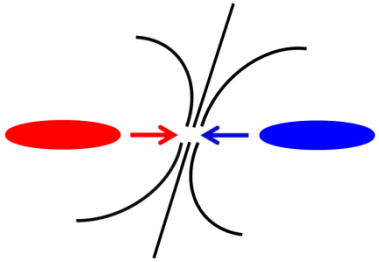
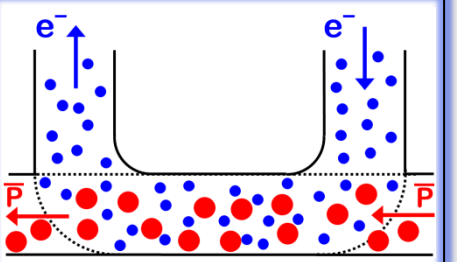


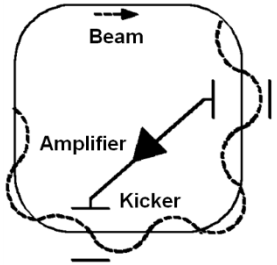
Collective acceleration



Colliders

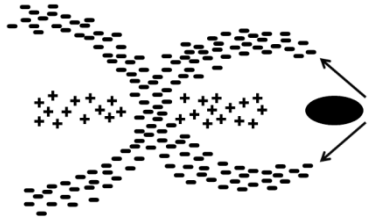


Electron cooling



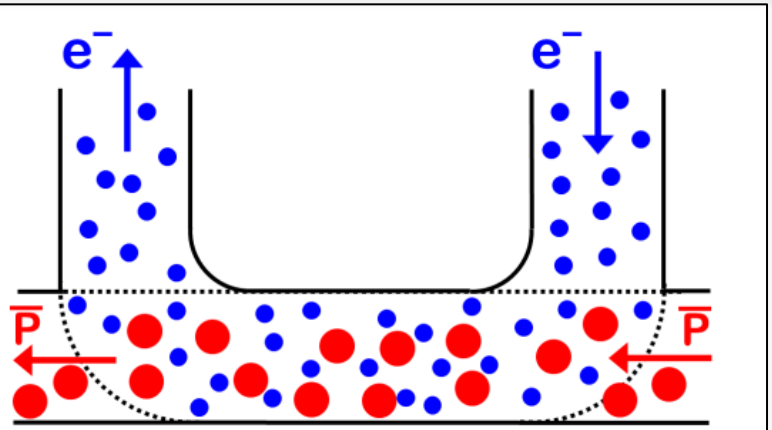
Stochastic cooling

SC magnets and RF



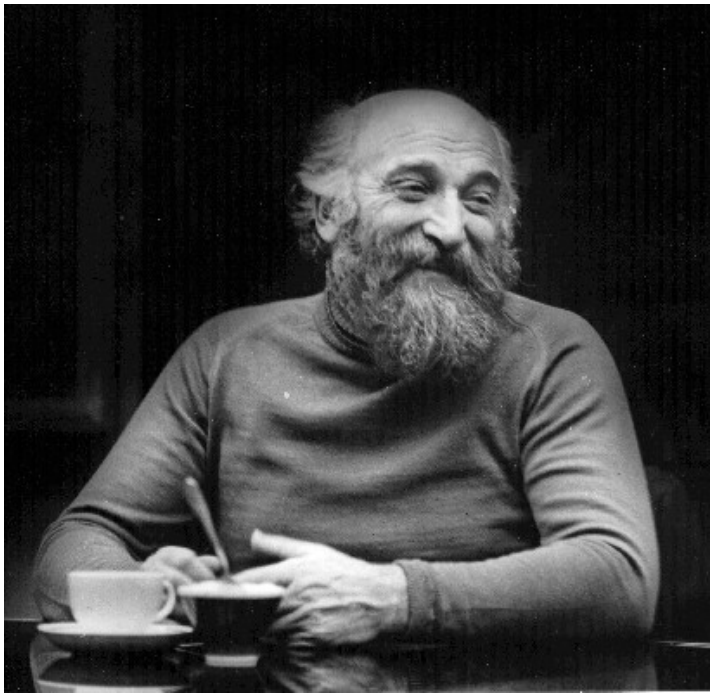
Plasma acceleration

Beam cooling



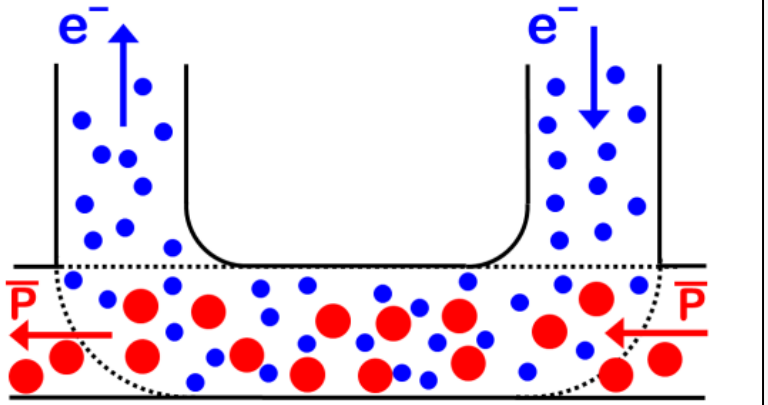
Electron cooling

Cooling is necessary especially for antiparticles such as antiprotons



A.M. Budker - founder and first director of the Institute of Nuclear Physics, Novosibirsk. Author of many inventions in the field of physics, including the idea of electron cooling.

Beam cooling



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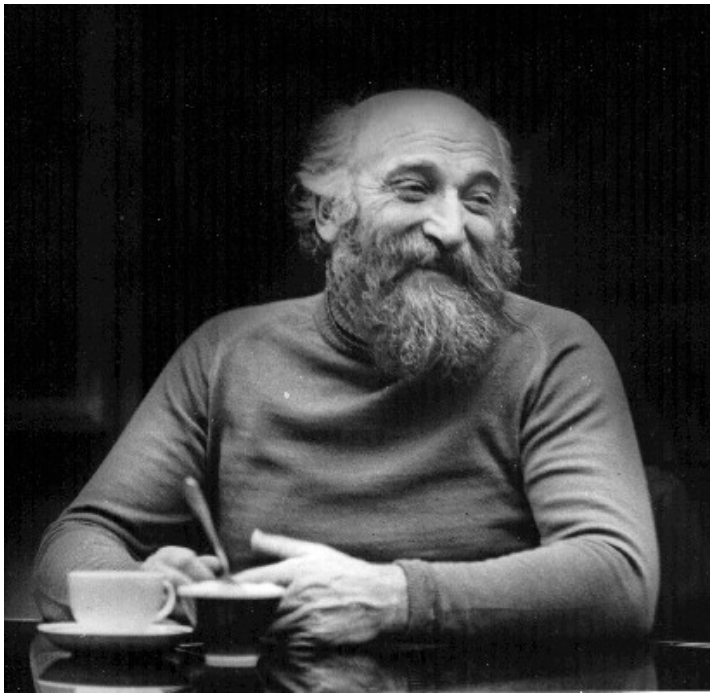

When electron cooling was first proposed, the common opinion was "brilliant idea, but unfortunately non-realistic"

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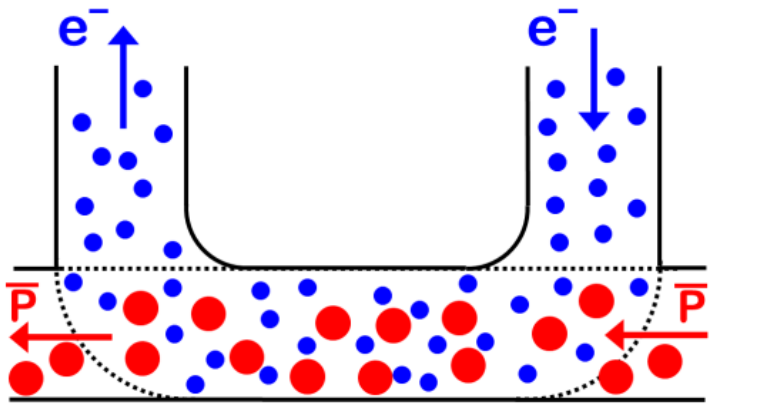
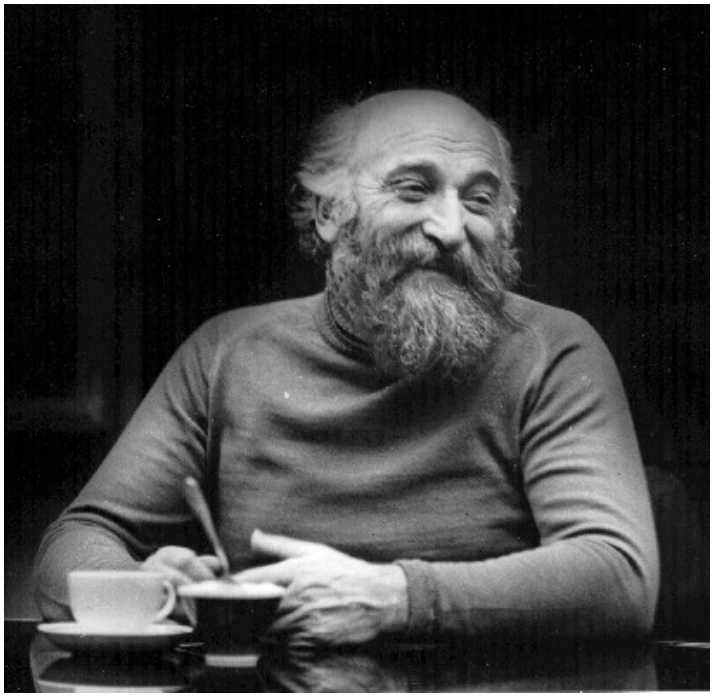
Beam cooling



Electron cooling

First e-cooler at BINP

Cooling is necessary especially for antiparticles such as antiprotons



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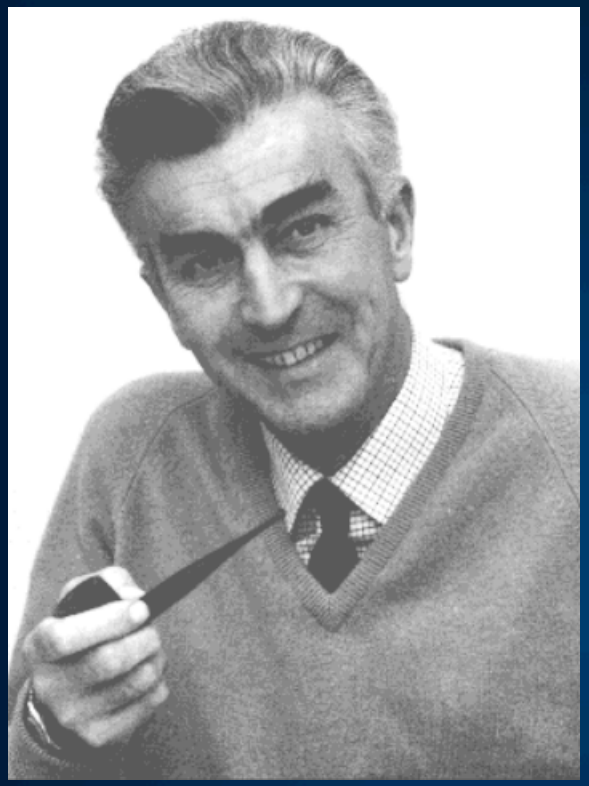
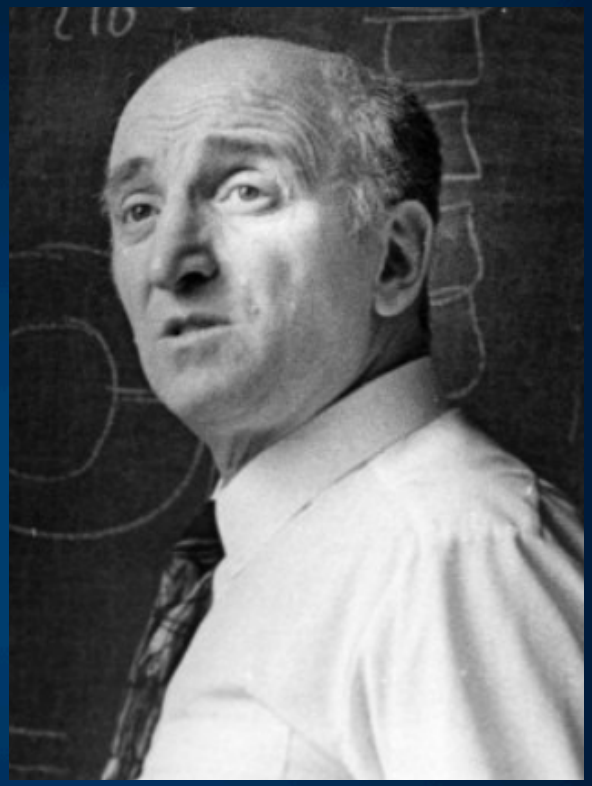
One more connection





Sir John Adams – unique combination of scientific and engineering abilities

A.M. Budker – was once called by Lev Landau a "relativistic engineer"

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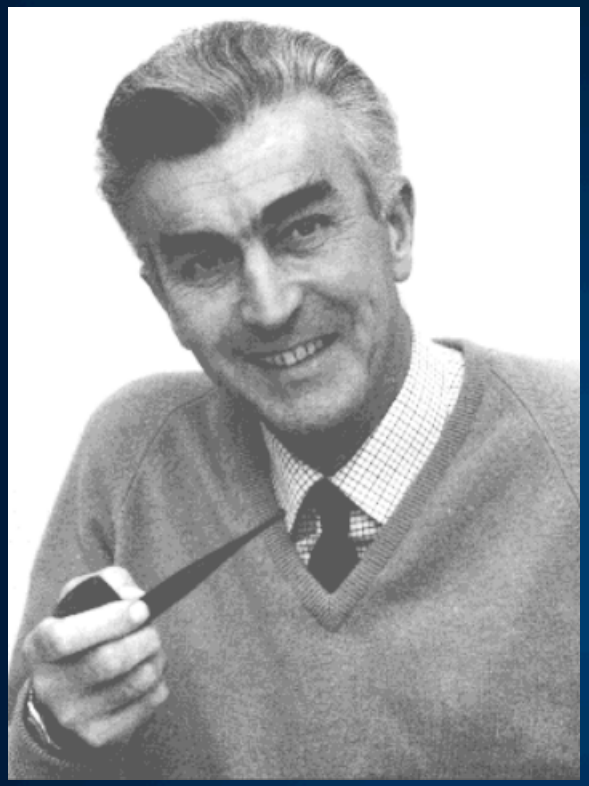

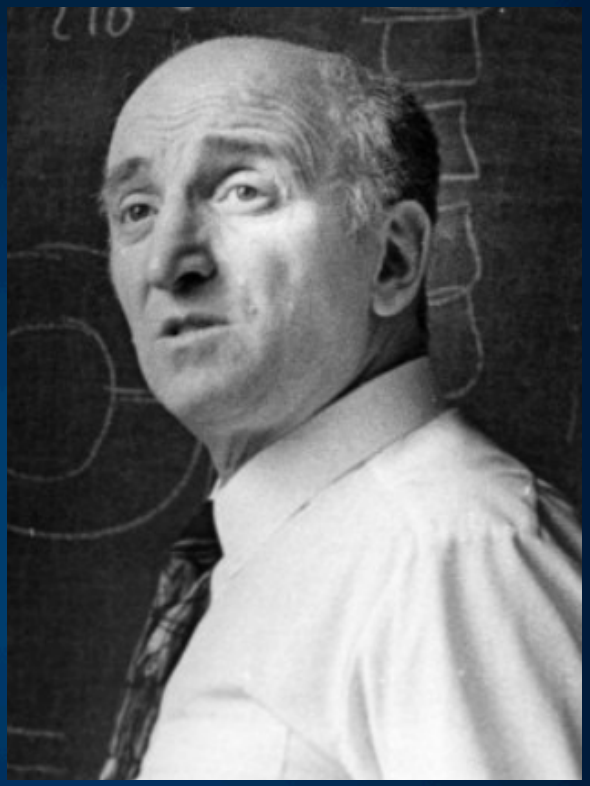

Sir John Adams – unique combination of scientific and engineering abilities

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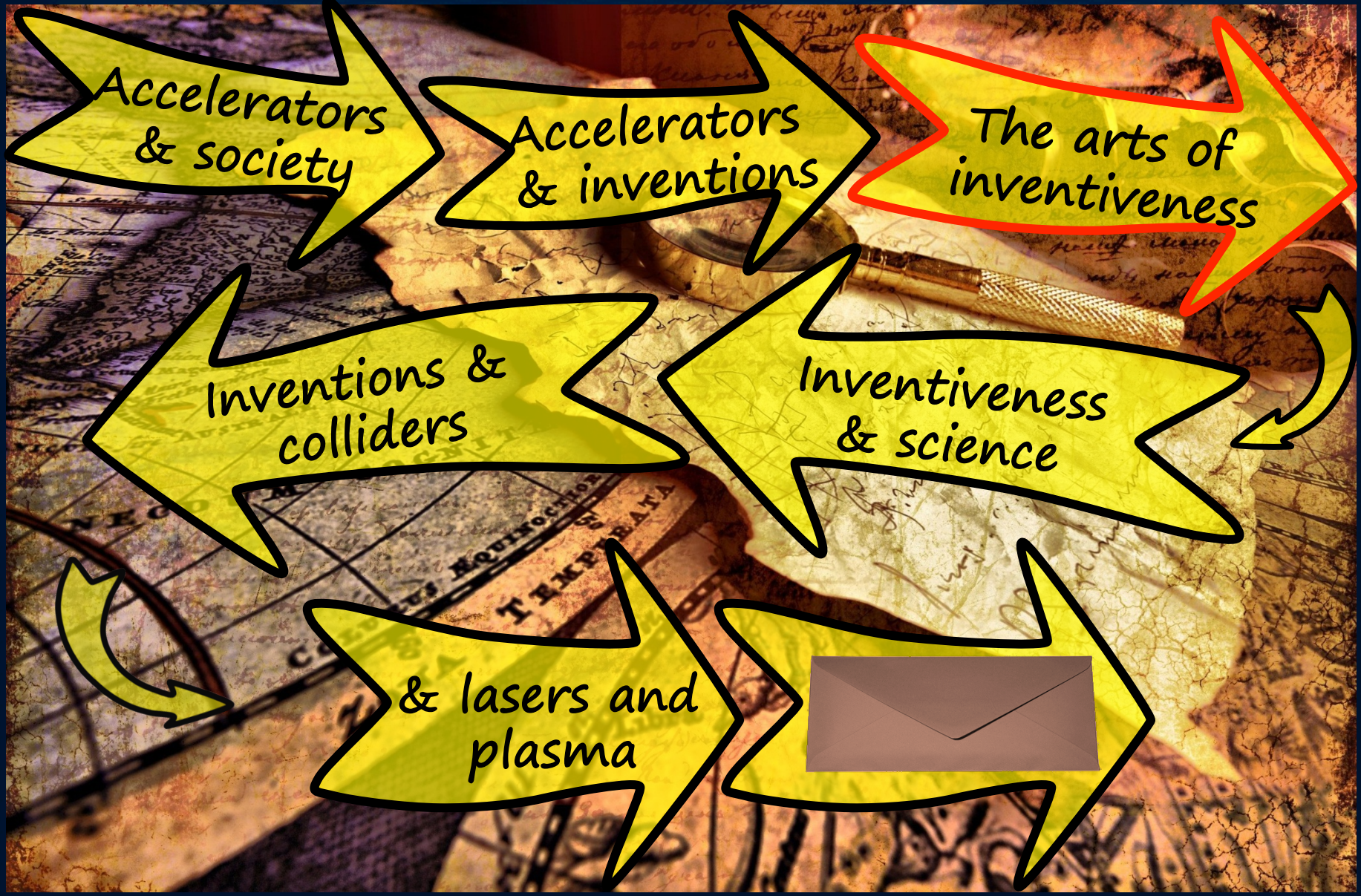
…and the art of inventiveness that we are about to discuss came from engineering

Travel route



How to invent more efficiently?

Forbes

Haydn Shaughnessy, Contributor
I write about enterprise innovation.

TECH | 3/07/2013 @ 6:32AM | 72,570 views

What Makes Samsung Such An Innovative Company?

What was that magic bullet?
…wait a few slides…

But it was [redacted] that became the bedrock of innovation at Samsung. And it was introduced at Samsung by [redacted] whom Samsung had hired into its Seoul Labs in the early 2000s.

In 2003 [redacted] led to 50 new patents for Samsung and in 2004 one project alone, a DVD pick-up innovation, saved Samsung over $100 million. [redacted] is now an obligatory skill set if you want to advance within Samsung.

How to invent – evolution of the methods

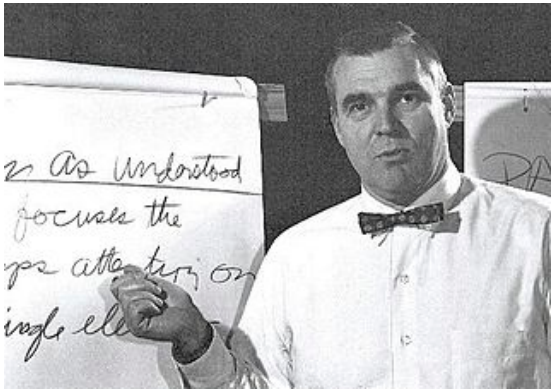
- **Brute-force or exhaustive search**
  - consider any possible ideas
- **Brainstorming**
  - psychological method which helps to solve problems and to invent
  - The main feature of brainstorming – separate the process of idea generation from the process of their critical analysis
  - The method of brainstorming did not meet expectations
    - **the absence of feedback, which is the power of the method, is simultaneously its handicap, as feedback is needed for development and adjusting of an idea**

Alex Osborn (1888 – 1966)

The author of brainstorming Alex Osborn introduced the method around 1950s

How to invent – evolution of the methods

- **Synectics – improved Brainstorming**
- **Features of Synectics:**
  - **Permanent groups for problem solving**
    - **whose members with time become less sensitive to critics and more efficient in problem solving**
  - **Emphasis on the importance to see familiar behind unknown and vice versa**
    - **which should help to solve a new and unfamiliar problem with known methods**
  - **Importance of a fresh view at a problem**
  - **Use of analogies to generate fresh view**
    - **direct (any analogy, e.g. from nature);**
    - **empathic (attempting to look at the problem identifying yourself with the object);**
    - **symbolic (finding a short symbolic description of the problem and the object);**
    - **metaphorical (describing the problem in terms of fairy-tales and legends);**



Attempting to improve brainstorming, George Prince (on the photo) and William Gordon introduced the method of Synectics

Synectics : use of analogies

– **Use of analogies to generate fresh view**
  - **…**
  - **empathic (attempting to look at the problem identifying yourself with the object);**
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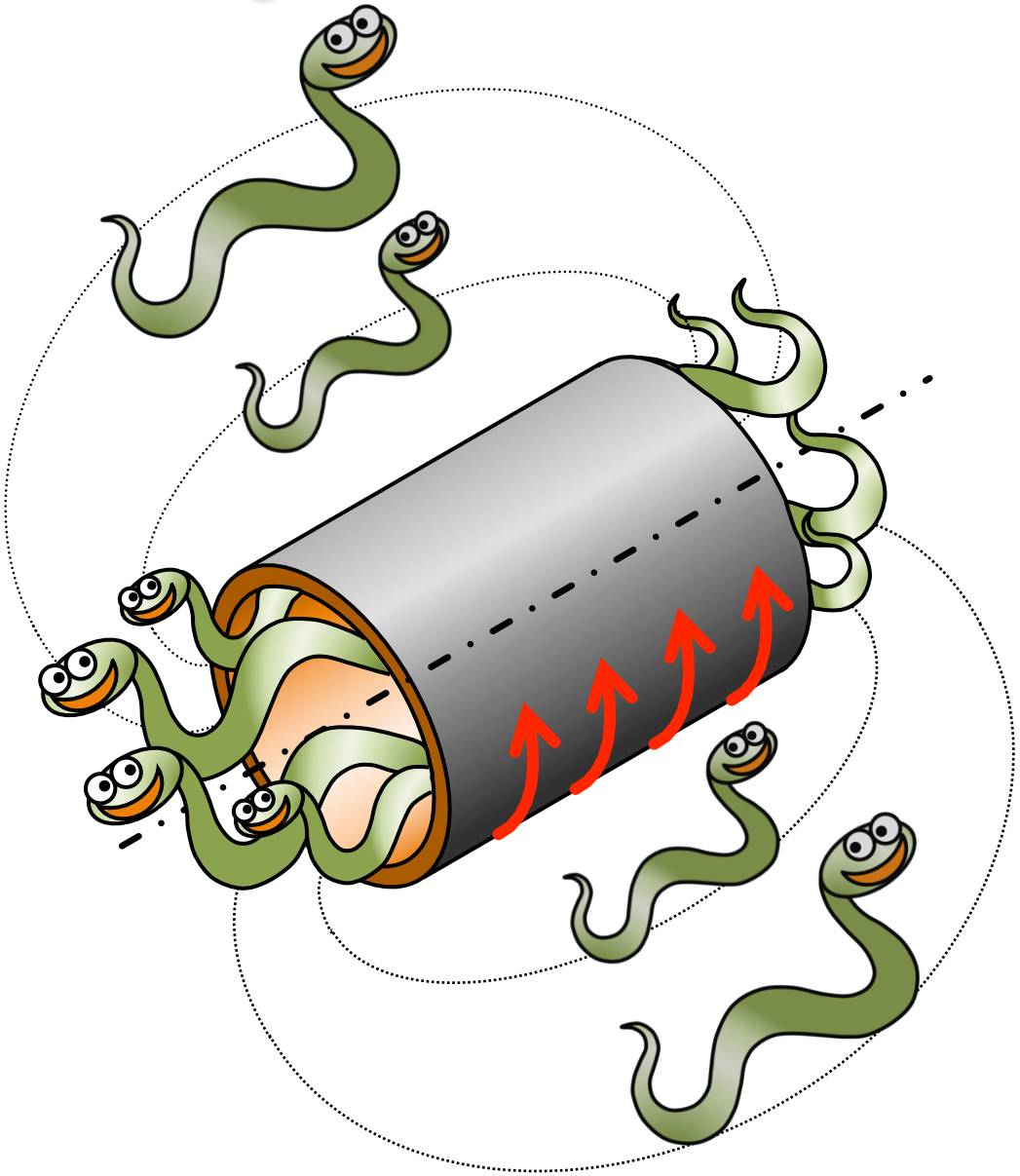

How to contain the magnetic flux?

How to invent – evolution of the methods

- **Synectics is the limit of what can be achieved, maintaining the brute force method of exhaustive search**

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How to invent – evolution of the methods

- Synectics is the limit of what can be achieved, maintaining the brute force method of exhaustive search
  - Indeed, why one would employ analogies and metaphors and irrational factors in order to come to a **natural and universal formula "the action has to happen itself"**
  - **One should aim at such formula in any invention, armed with precise identification of physical contradiction – essence of TRIZ**

Illustration by Sasha Seraia

How to invent – TRIZ

- **TRIZ – *T*eoria *R*eshenia *I*zobretatelskikh *Z*adach**

  = Theory of Inventive Problem Solving
- **Developed by Genrikh Altshuller in SU**
  - **Work in patent office in 1946**
  - **Analysed 200000 patents, discovered patterns and identified what makes a patent successful**
  - **Formulated TRIZ in 1956-1985**

Genrikh Altshuller (aka Altov)1926-1998

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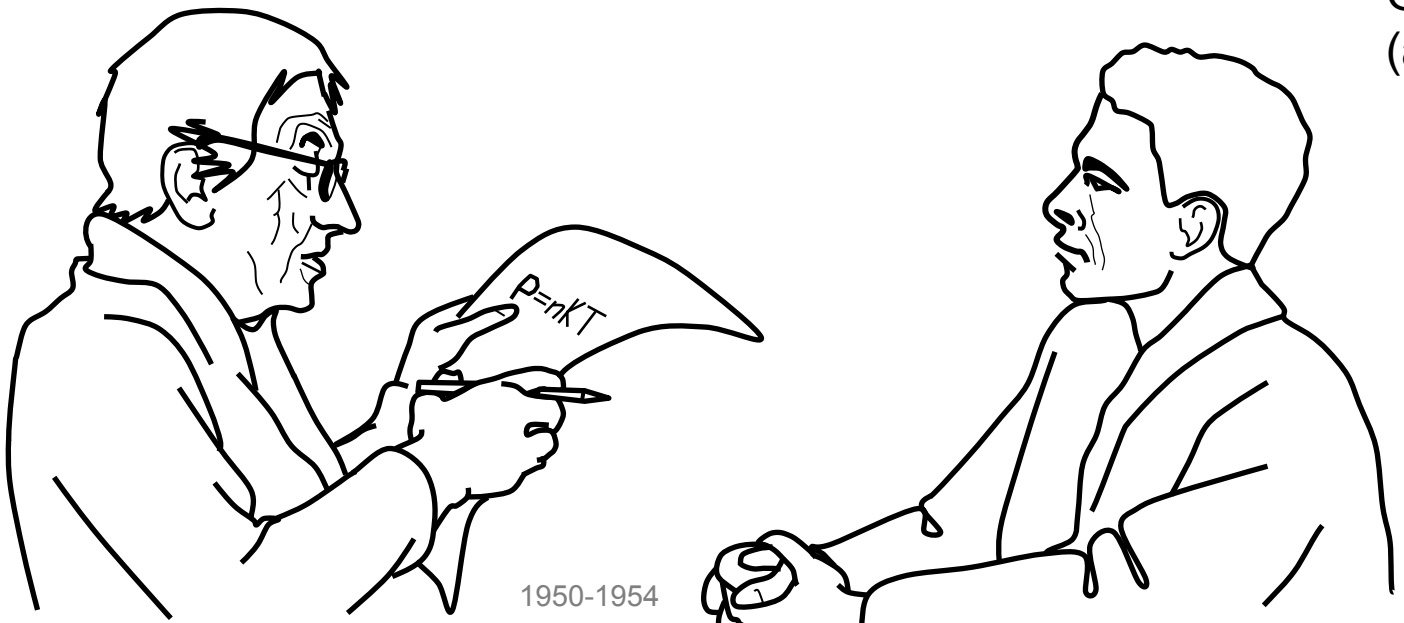

1950-1954

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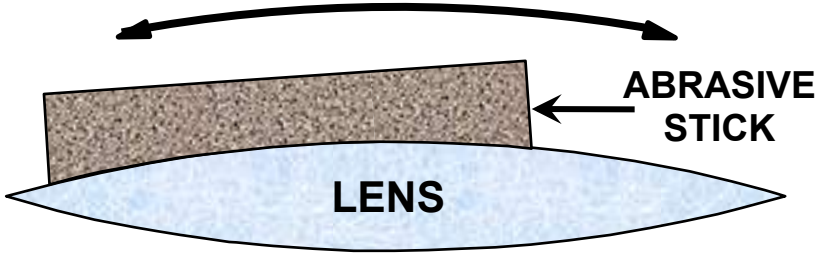
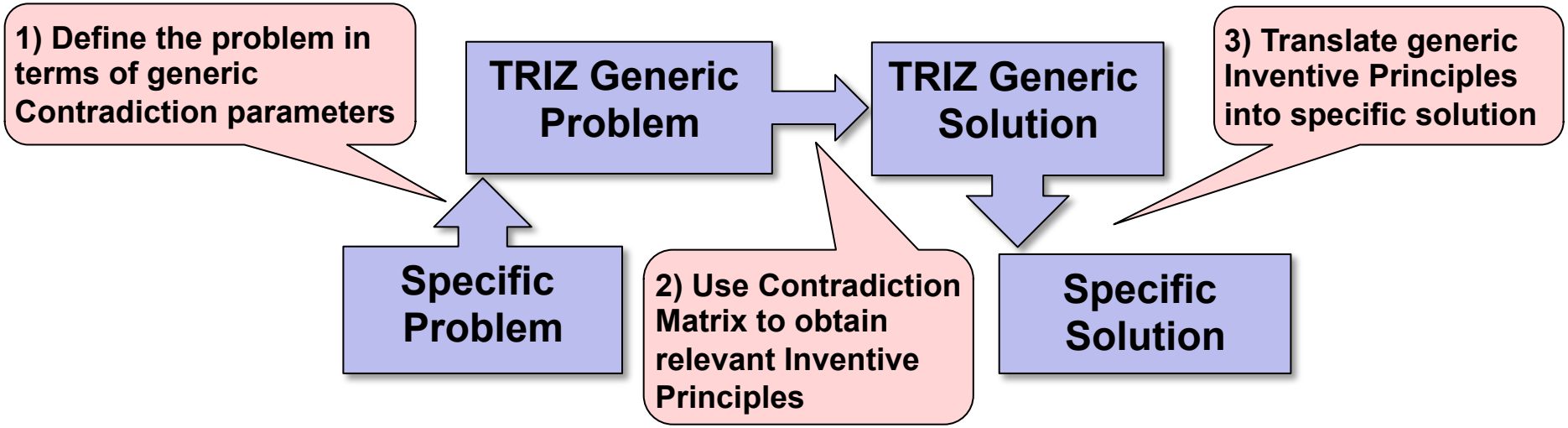
TRIZ in action - example



Problem: Lens polished – heat generated. Heat degrades optical properties. Existing cooling methods ineffective, as cannot achieve uniform cooling at each abrasive particle

To be improved: SPEED, What gets worse: TEMPERATURE

Has anyone else solved such contradiction?



Example: following J.Scanlan, School of Engineering Sciences, Univ. of Southampton

Elements of TRIZ contradiction matrix

1. Weight of moving object
2. Weight of stationary object
3. Length of moving object
4. Length of stationary object
5. Area of moving object
6. Area of stationary object
7. Volume of moving object
8. Volume of stationary object
9. Speed
10. Force (Intensity)
11. Stress or pressure
12. Shape
13. Stability of the object
14. Strength
15. Durability of moving object
16. Durability of non moving object
17. Temperature
18. Illumination intensity
19. Use of energy by moving object
20. Use of energy by stationary object
21. Power
22. Loss of Energy
23. Loss of substance
24. Loss of Information
25. Loss of Time
26. Quantity of substance/the
27. Reliability
28. Measurement accuracy
29. Manufacturing precision
30. Object-affected harmful
31. Object-generated harmful
32. Ease of manufacture
33. Ease of operation
34. Ease of repair
35. Adaptability or versatility
36. Device complexity
37. Difficulty of detecting
38. Extent of automation
39. Productivity

Only 39 Matrix parameters!!!

TRIZ Inventive Principles

1. Segmentation
2. Taking out
3. Local quality
4. Asymmetry
5. Merging
6. Universality
7. Russian dolls
8. Anti-weight
9. Preliminary anti-action
10. Preliminary action
11. Beforehand cushioning
12. Equipotentiality
13. "The other way round"
14. Spheroidality - Curvature
15. Dynamics
16. Partial or excessive actions
17. Another dimension
18. Mechanical vibration
19. Periodic action
20. Continuity of useful action
21. Skipping
22. Blessing in disguise
23. Feedback
24. Intermediary
25. Self-service
26. Copying
27. Cheap short-lived objects
28. Mechanics substitution
29. Pneumatics and hydraulics
30. Flexible shells and thin films
31. Porous materials
32. Colour changes
33. Homogeneity
34. Discarding and recovering
35. Parameter changes
36. Phase transitions
37. Thermal expansion
38. Strong oxidants
39. Inert atmosphere
40. Composite materials

Only 40 Principles !!!

TRIZ Principles and Contradiction matrix

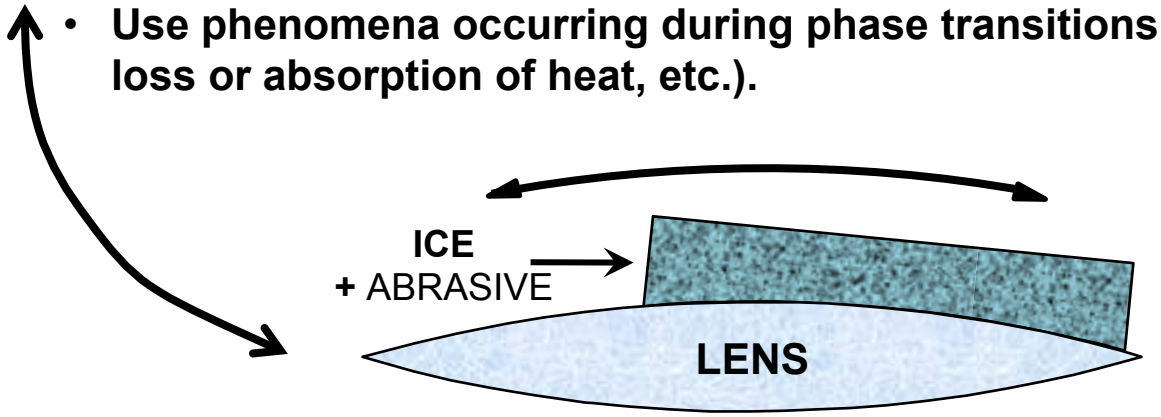
For our example with the lens:

Improving Parameter	Parameter that deteriorates					
	…	9. Speed	…	17. Temperature	…
…					
9. Speed				2, 28, 30, 36	
…					
17. Temperature					
…					

Suggested Principles that have solved similar Contradictions before

TRIZ in action - example

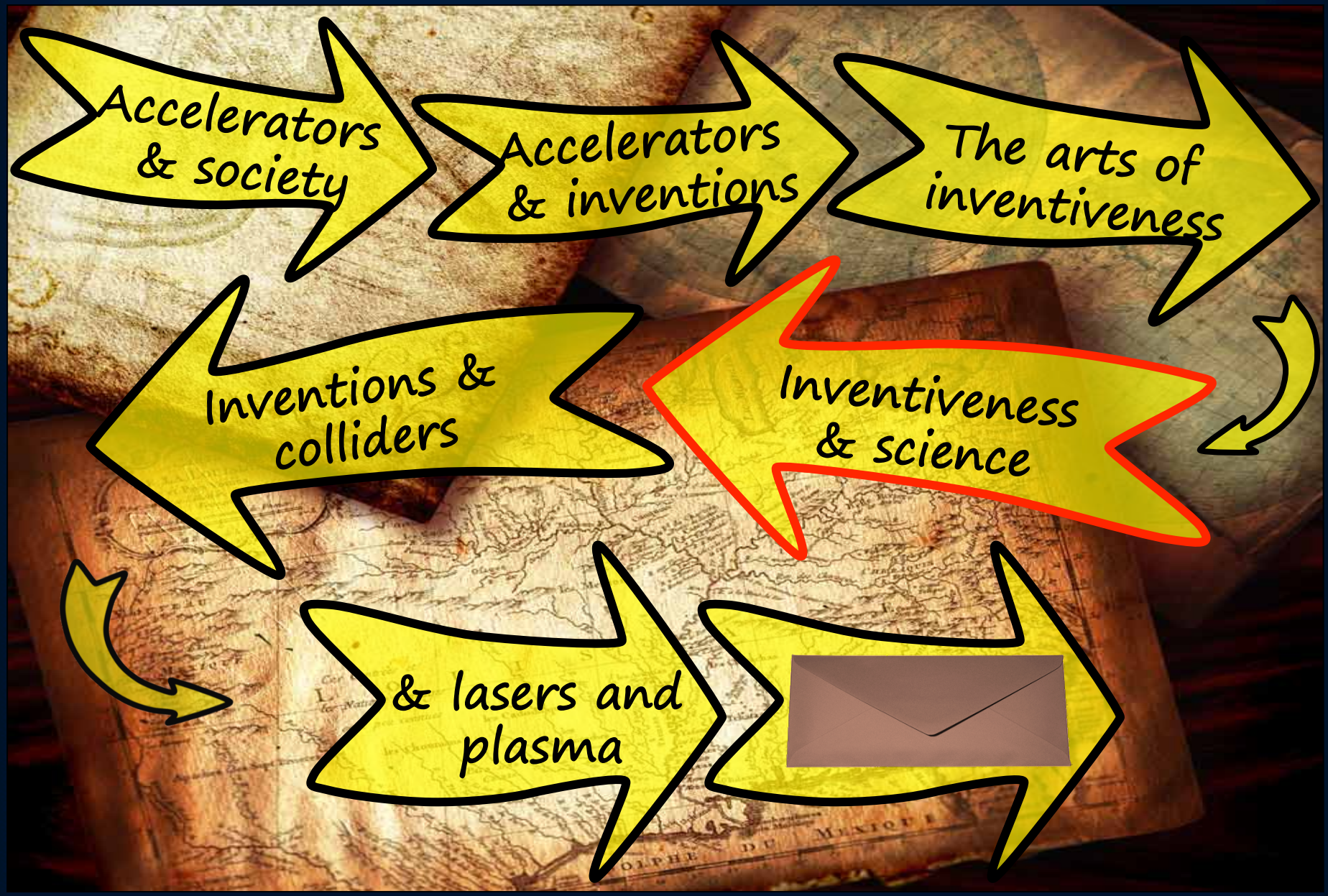
- **Perform lookup* of TRIZ Matrix for this contradiction:**
  - **Improving 9: SPEED without damaging 17: TEMPERATURE**
- **Find Principles to solve this contradiction:**
  - **2. Taking out**
  - **28. Mechanics substitution**
  - **30. Flexible shells and thin films**
  - **36. Phase transitions**
    - **Use phenomena occurring during phase transitions (e.g. volume changes, loss or absorption of heat, etc.).**



Abrasive + Ice - Inventive Principle 'Phase Transition'

*) E.g. at http://www.triz40.com/

Travel route



TRIZ => Science

- TRIZ was created for engineering
- But the method is universal and can be applied to science!
  - In particular to Accelerator Science, but not only
- Examples given in the following slides show the applicability of TRIZ principles to a variety of areas

TRIZ => Science

- **TRIZ was created for engineering**
- **But the method is universal and can be applied to science!**
  - **In particular to Accelerator Science, but not only**
- **Examples given in the following slides show the applicability of TRIZ principles to a variety of areas**

- **Looking at the world "through the prism of TRIZ" allows us to rethink the familiar things**

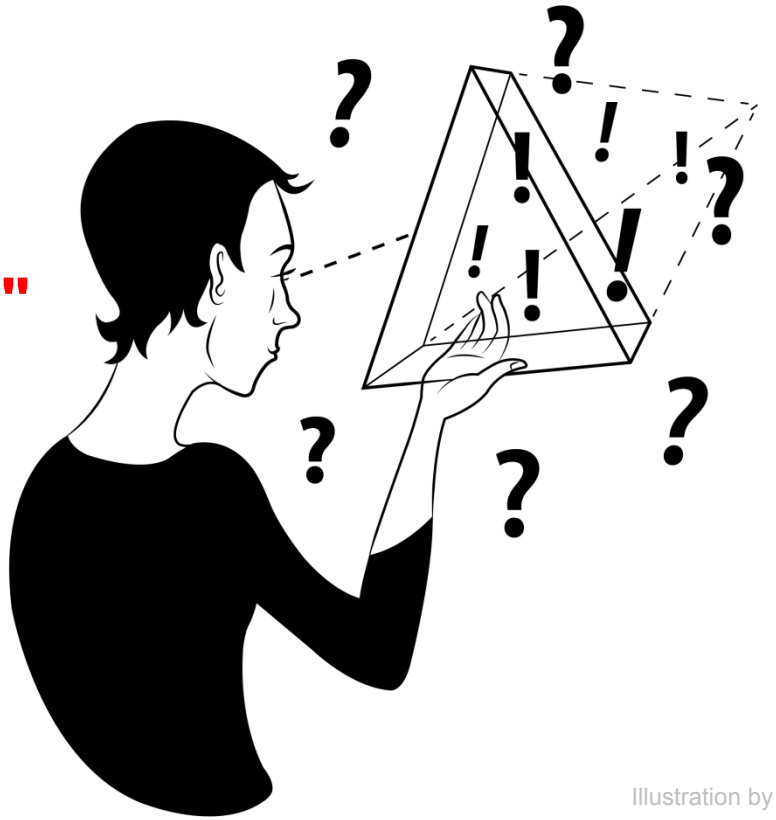


Illustration by Sasha Seraia

TRIZ Inventive Principles

1. Segm
2. Takin
3. Local
4. Asym
5. Mergi
6. Unive
7. Russian dolls
8. Anti-weight
9. Preliminary anti-action
10. Preliminary action
11. Beforehand cushion
12. Equipotentiality
13. "The other way round"
14. Spheroidality - C ature
15. Dynamics
16. Partial or excess
17. A
18. M
19. P
20. C

27. Cheap short-lived objects
28. Mechanics substitution
29. Pneumatics and hydraulics
32. Colour changes
33. Homogeneity
34. Discarding and recovering
35. Parameter changes
36. Phase transitions

Let's select a couple of principles and try to see if we can recognize them in well-known and familiar things

7. The principle of "Russian dolls"

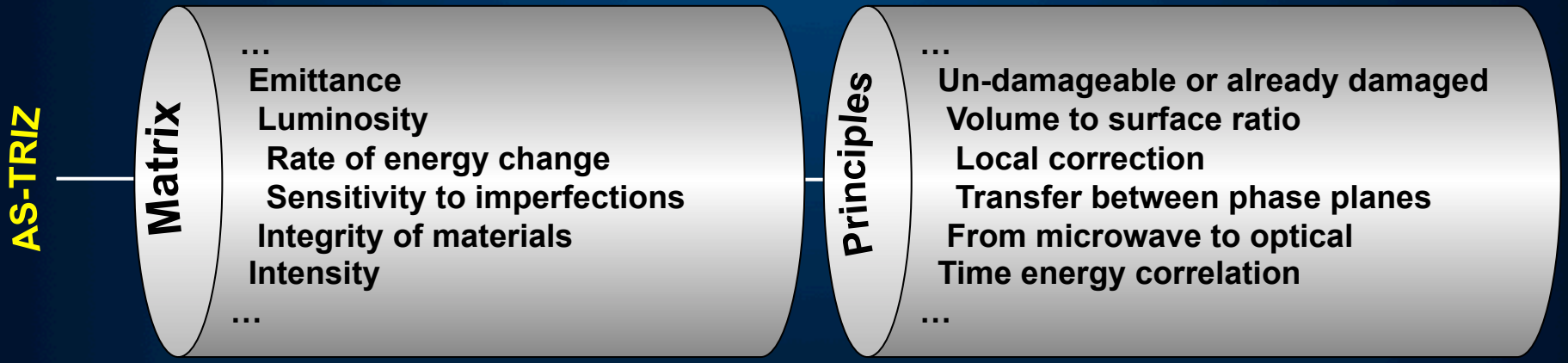
13. The principle of "The other way round" (or the principle of anti-system)

TRIZ for Accelerator Science => AS-TRIZ

- TRIZ Contradiction Matrix and Inventive Principles are suitable for engineering disciplines
- To be applicable to Accelerator Science, TRIZ may need to be re-interpreted and extended (extension called AS-TRIZ)

TRIZ for Accelerator Science => AS-TRIZ

- TRIZ Contradiction Matrix and Inventive Principles are suitable for engineering disciplines
- To be applicable to Accelerator Science, TRIZ may need to be re-interpreted and extended (extension called Accelerating Science TRIZ or AS-TRIZ)
  - AS-TRIZ Principles and Contradiction Matrix are being developed



Another important reason for creating AS-TRIZ – this will take us through the process of analysing TRIZ, thus helping us to study it proactively

AS-TRIZ

Matrix

- Luminosity
- Rate of energy change
- Sensitivity to imperfections
- Integrity of materials
- Intensity
- …

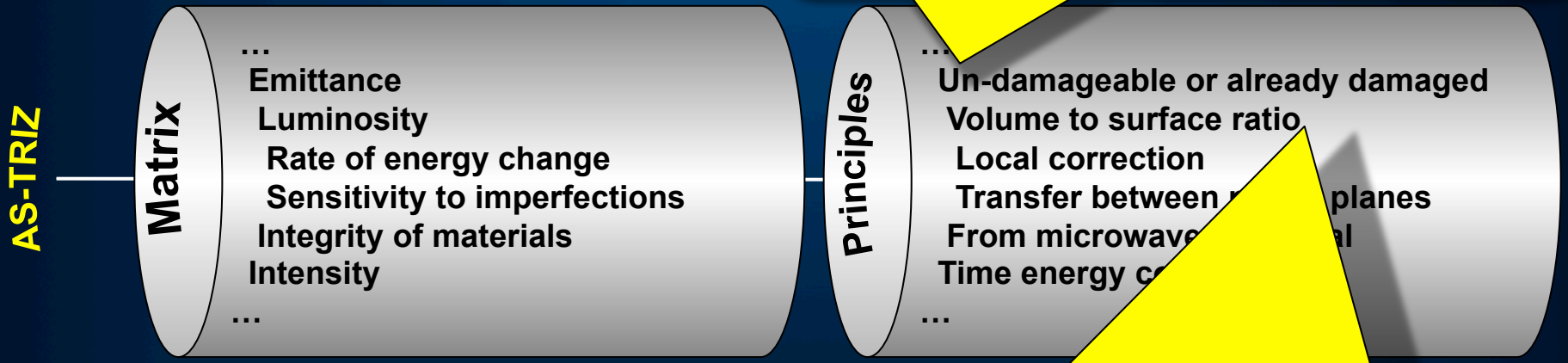
Principles

- Volume to surface ratio
- Local correction
- Transfer between phase planes
- From microwave to optical
- Time energy correlation
- …

And from the list of the AS-TRIZ principles we shall consider here this pair

- suitable for engineering disciplines
- To be applicable to Accelerator Science, TRIZ may need to be re-interpreted and extend
  Accelerating Science TRIZ c
  - AS-TRIZ Principles and Contra

3. Using un-damageable or already damaged materials



4. Changing of volume to surface ratio

The principle of changing the volume to surface ratio

The same volume,
but different surface area

The principle of changing the volume to surface ratio

The same volume,
but different surface area

The principle of changing the volume to surface ratio

The same volume,
but different surface area

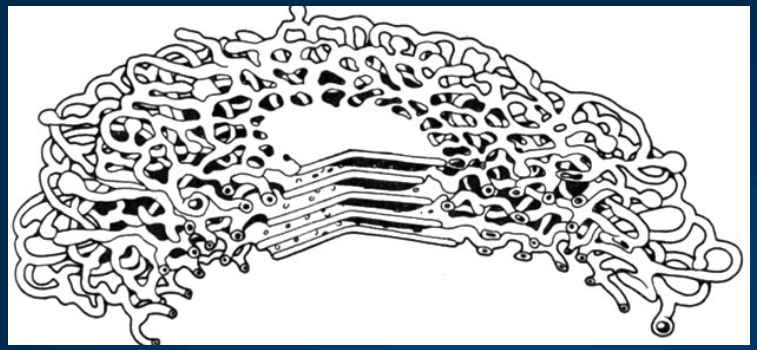
The same principle is used in linear colliders, where "pancakes" are collided instead of "buns"

The principle of changing the volume to surface ratio – an example

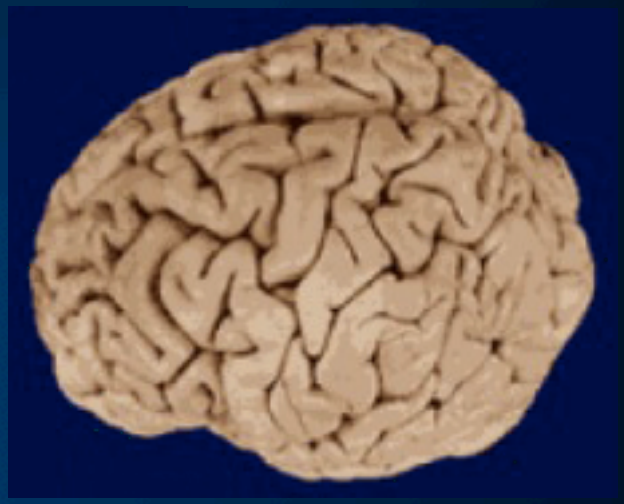
The same volume, but different surface area and the different amount of information ☺

And could we suggest an example illustrating this principle, for instance, in biology?

The principle of changing the volume to surface ratio – examples

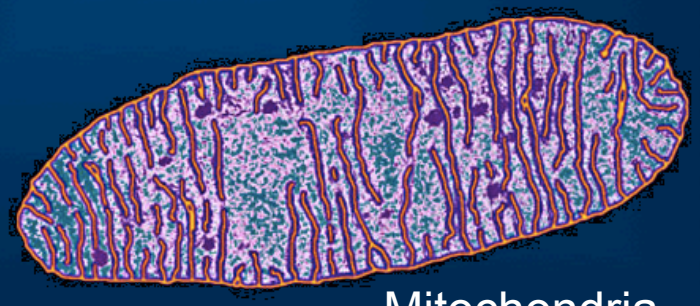


Golgi Apparatus



Brain

Algae



Mitochondria

Keeping the same volume but increasing the surface area to enhance the functionality

The principle of “Russian dolls”

Could you give an example of using the principle of “Russian dolls” in everyday life?

The principle of “Russian dolls”

The principle of “Russian dolls”

And what about an example of the application of the principle of “Russian dolls”, for instance ... in philology?

The principle of “Russian dolls”

“This is the house that Jack built”

This is the house that Jack built.

This is the malt
That lay in the house that Jack built.

This is the rat,
That ate the malt
That lay in the house that Jack built.

This is the cat,
That killed the rat,
That ate the malt
That lay in the house that Jack built.

This is the dog,
That worried the cat,
That killed the rat,
That ate the malt
That lay in the house that Jack built.

This is the cow with the crumpled horn,
That tossed the dog,
That worried the cat,
That killed the rat,
That ate the malt
That lay in the house that Jack built.

Illustration by Olga Rubtsova (Atroshenko)

This is the maiden all forlorn,
That milked the cow with the crumpled horn,
That tossed the dog,
That worried the cat,
That killed the rat,
That ate the malt
That lay in the house that Jack built.

This is the man all tattered and torn,
That kissed the maiden all forlorn,
That milked the cow with the crumpled horn,
That tossed the dog,
That worried the cat,
That killed the rat,
That ate the malt
That lay in the house that Jack built.

This is the priest all shaven and shorn,
That married the man all tattered and torn,
That kissed the maiden all forlorn,
That milked the cow with the crumpled horn,
That tossed the dog,
That worried the cat,
That killed the rat,
That ate the malt
That lay in the house that Jack built.

This is the cock that crowed in the morn,
That waked the priest all shaven and shorn,
That married the man all tattered and torn,
That kissed the maiden all forlorn,
That milked the cow with the crumpled horn,
That tossed the dog,
That worried the cat,
That killed the rat,
That ate the malt
That lay in the house that Jack built.

This is the farmer sowing his corn,
That kept the cock that crowed in the morn,
That waked the priest all shaven and shorn,
That married the man all tattered and torn,
That kissed the maiden all forlorn,
That milked the cow with the crumpled horn,
That tossed the dog,
That worried the cat,
That killed the rat,
That ate the malt
That lay in the house that Jack built.

Mother Goose Rhymes

The principle of “Russian dolls”

“This is the house that Jack built”

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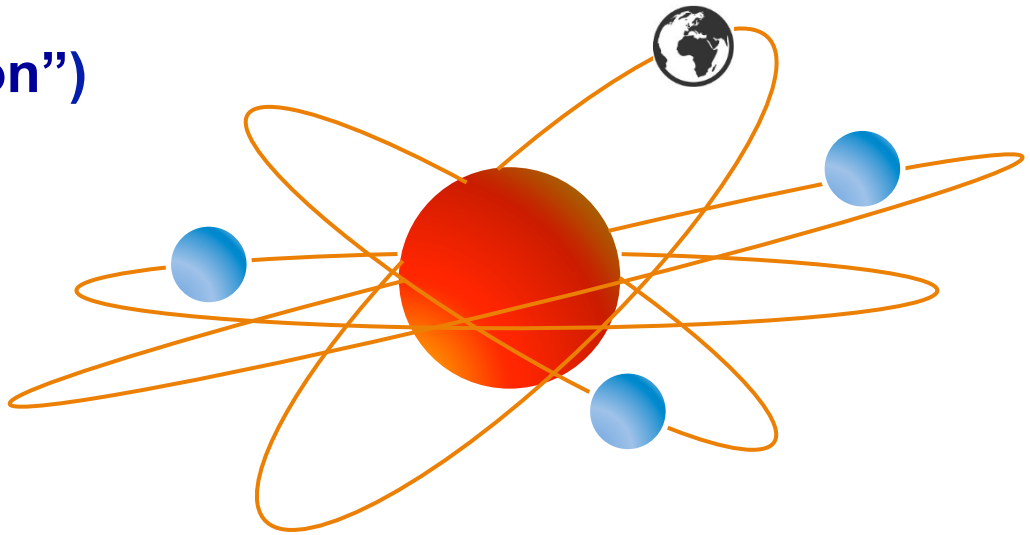
Mother Goose Rhymes

Is there any example of this principle in science fiction?

The principle of “Russian dolls”

Valery Bryusov – 1920 poem
“Atom” (“The World of Electron”)



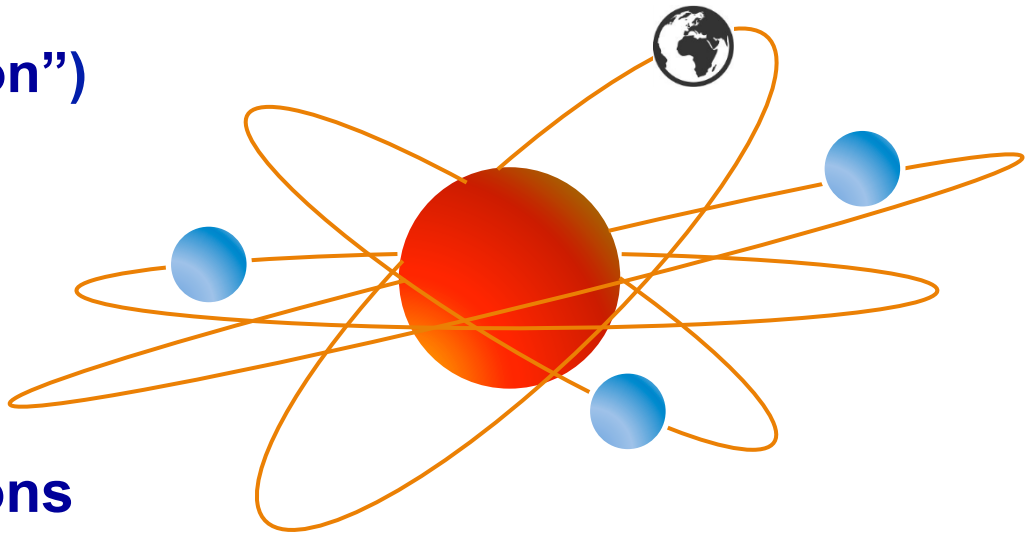
Быть может, эти электроны
Миры, где пять материков,
Искусства, знанья, войны, троны
И память сорока веков!

Ещё, быть может, каждый атом —
Вселенная, где сто планет;
Там — всё, что здесь, в объёме сжатом,
Но также то, чего здесь нет.

…

The principle of “Russian dolls”

Valery Bryusov – 1920 poem
“Atom” (“The World of Electron”)



Can you imagine that electrons
Are planets circling their Suns?
Space exploration, wars, elections
And hundreds of computer tongues

…

Remake-translation by A.Seryi

Быть может, эти электроны
Миры, где пять материков,
Искусства, знанья, войны, троны
И память сорока веков!

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Вселенная, где сто планет;
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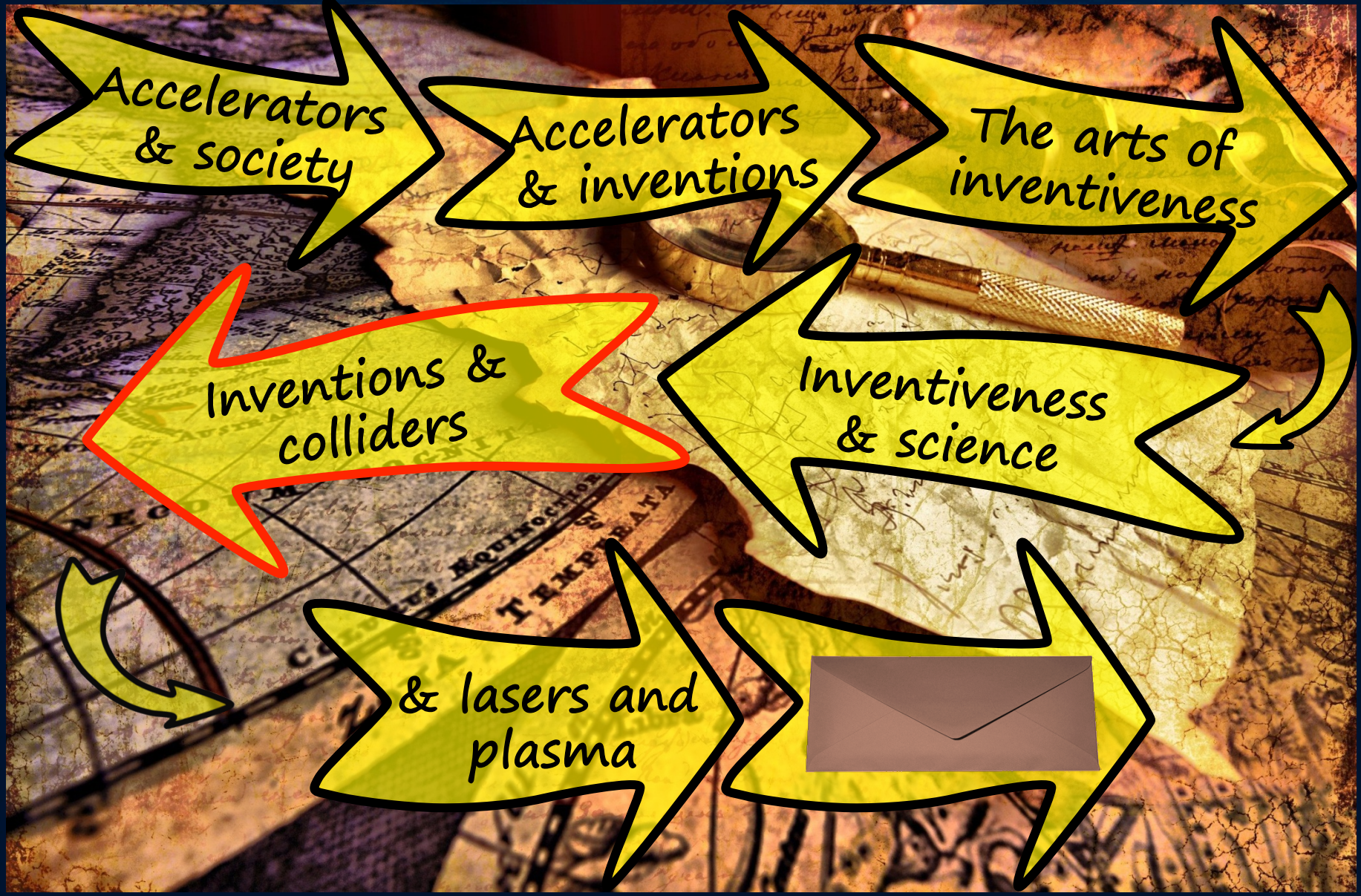
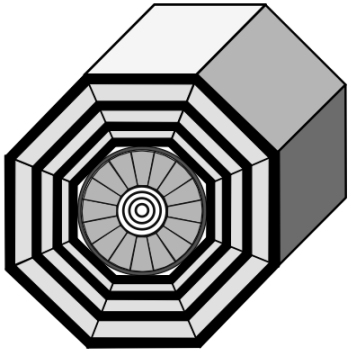
Но также то, чего здесь нет.

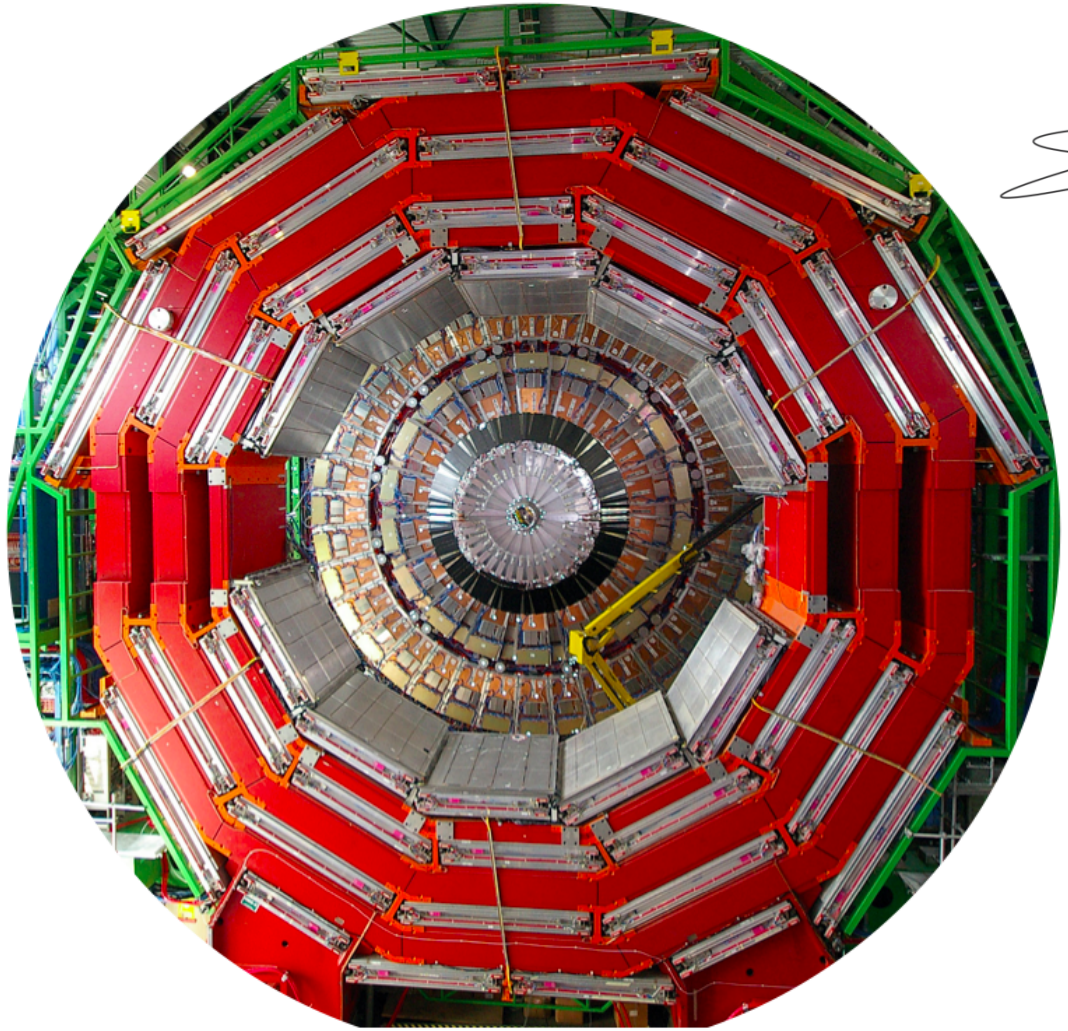
…

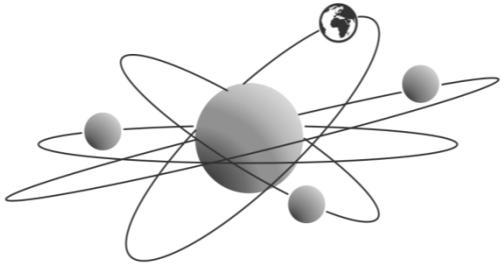
Travel route



Is there world inside of an electron?

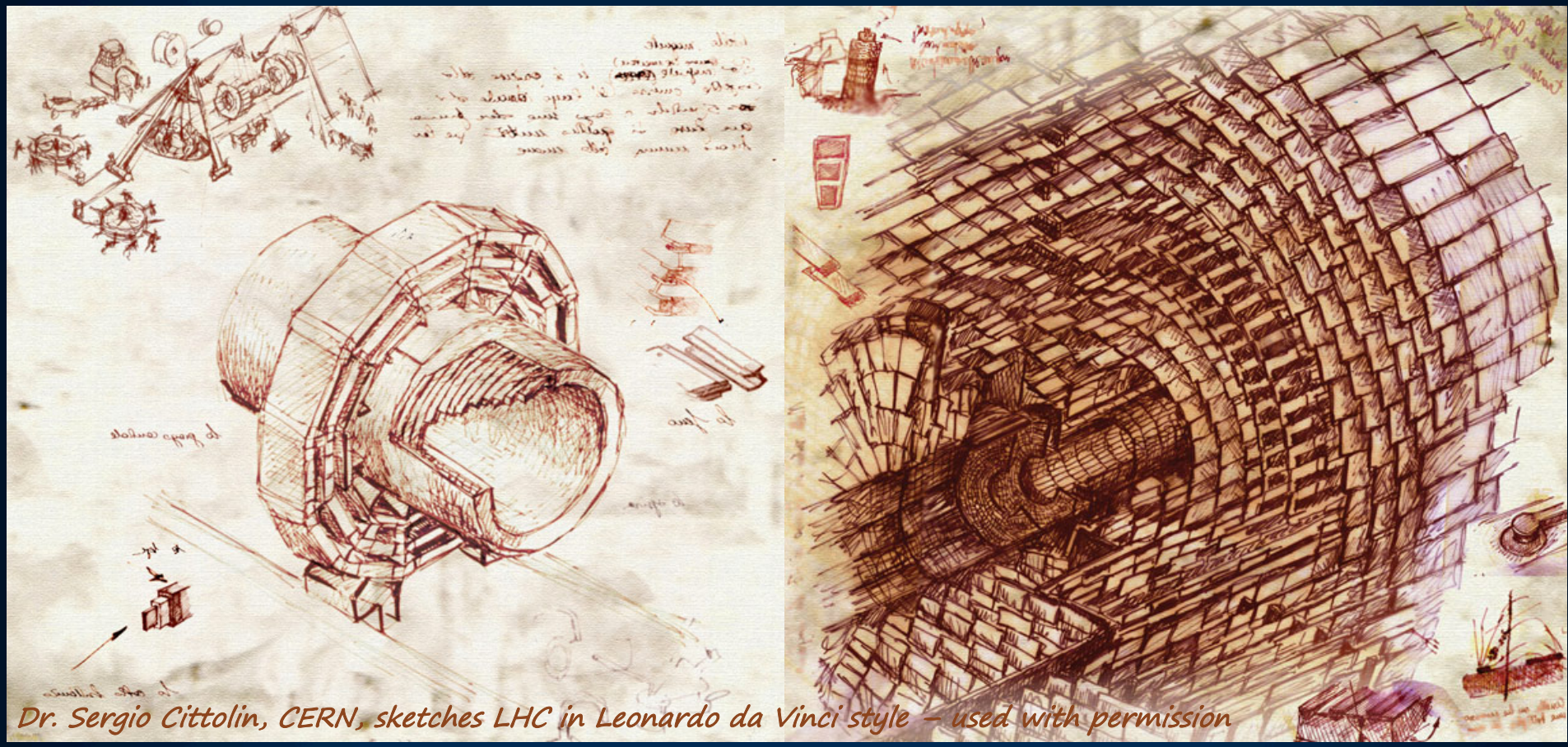






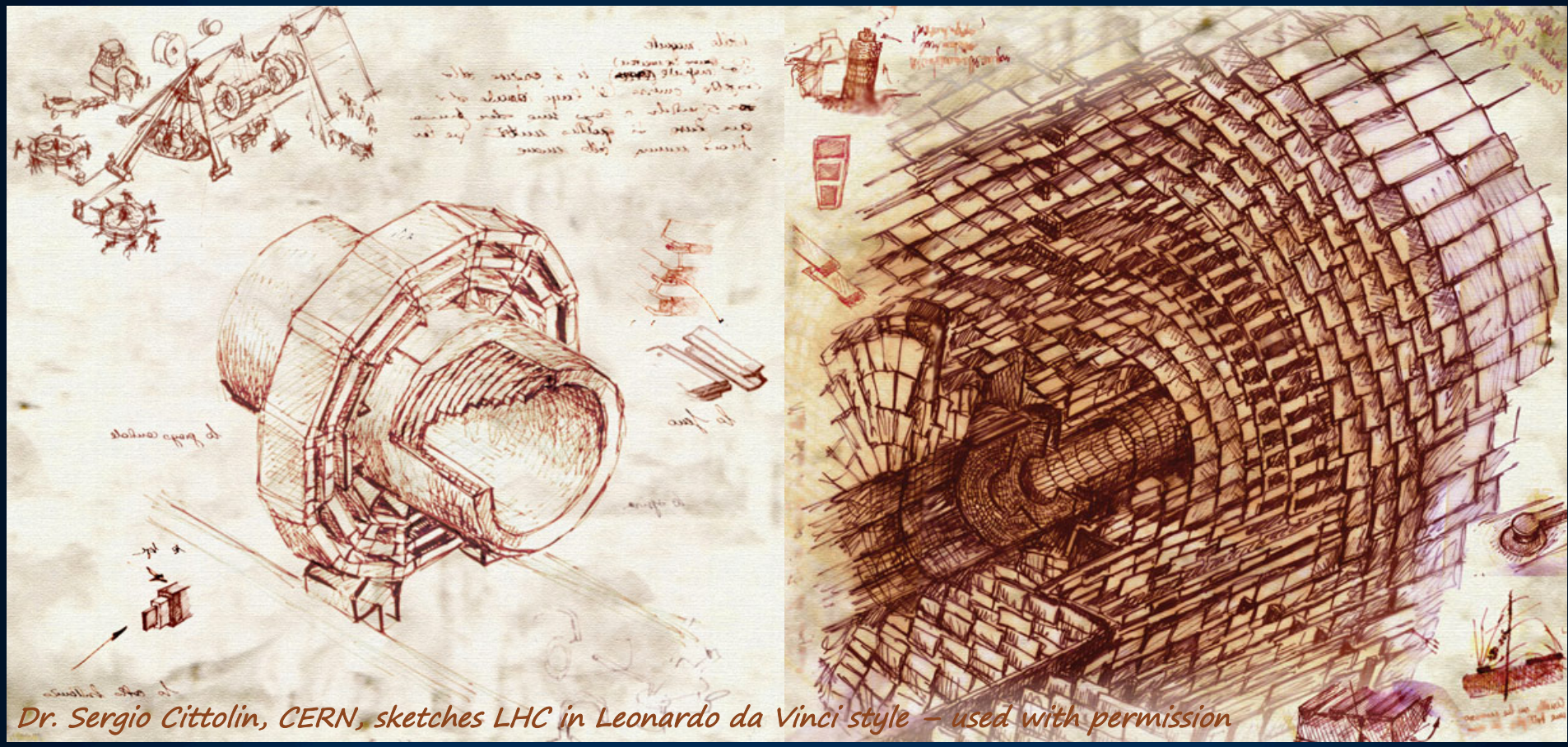
Accelerators and detectors can help to understand whether there is a world inside of an electron

The detectors are arranged just as “Russian dolls”



Dr. Sergio Cittolin, CERN, sketches LHC in Leonardo da Vinci style – used with permission

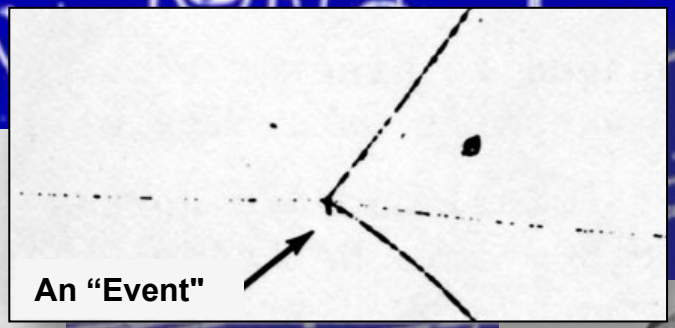
The detectors are arranged just as “Russian dolls”

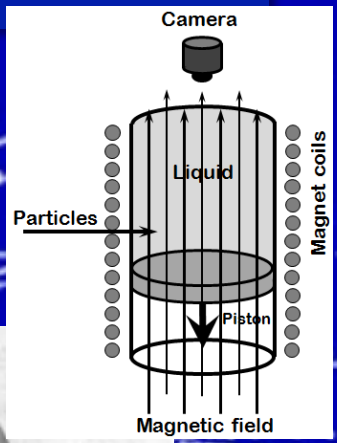


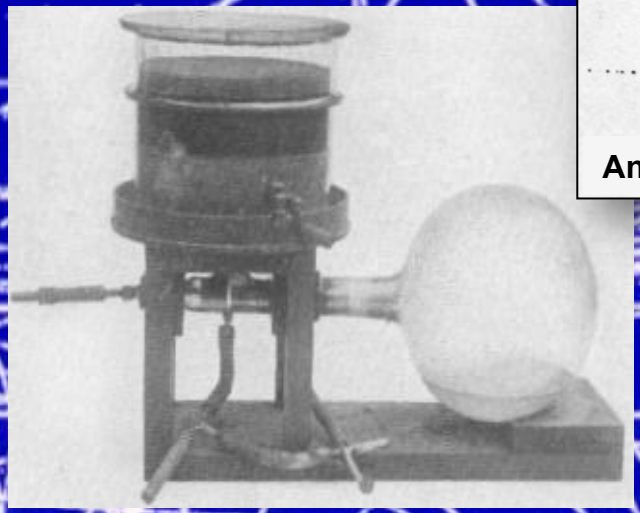
Dr. Sergio Cittolin, CERN, sketches LHC in Leonardo da Vinci style – used with permission

And what were the ones of the first particle detectors?

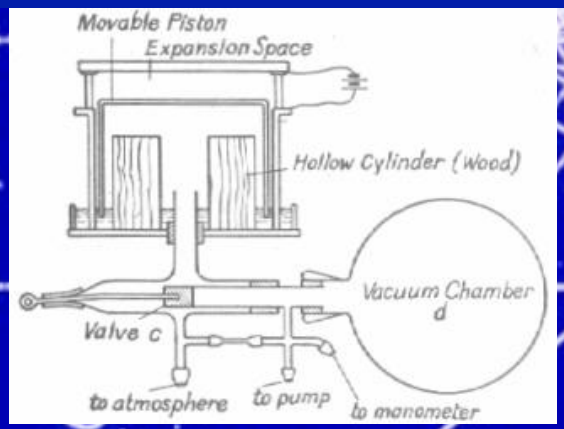
Cloud and bubble chambers







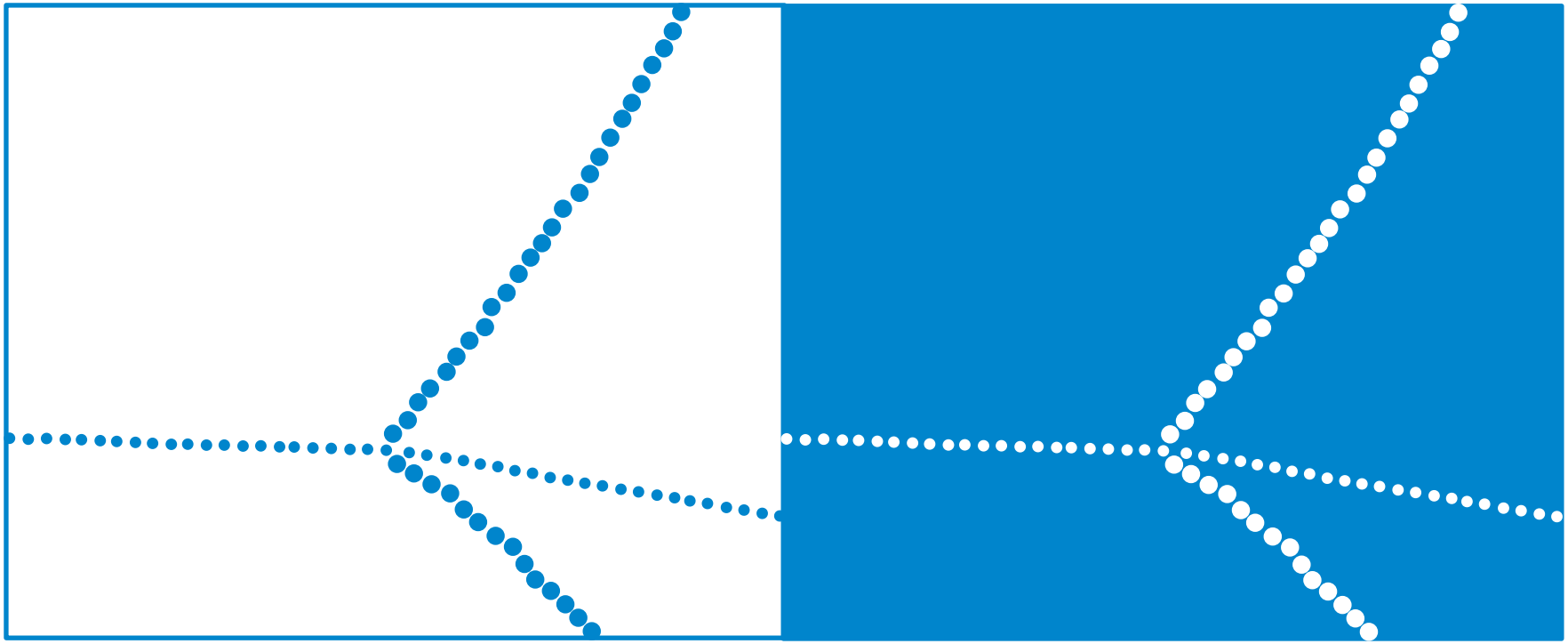
Wilson’s Cloud chamber
(invented in 1911)



Bubble Chamber
(invented in 1952 by D. Glaser –
Nobel prize 1960)

On the photo Bubble chamber
being installed near Fermilab

Cloud and bubble chambers



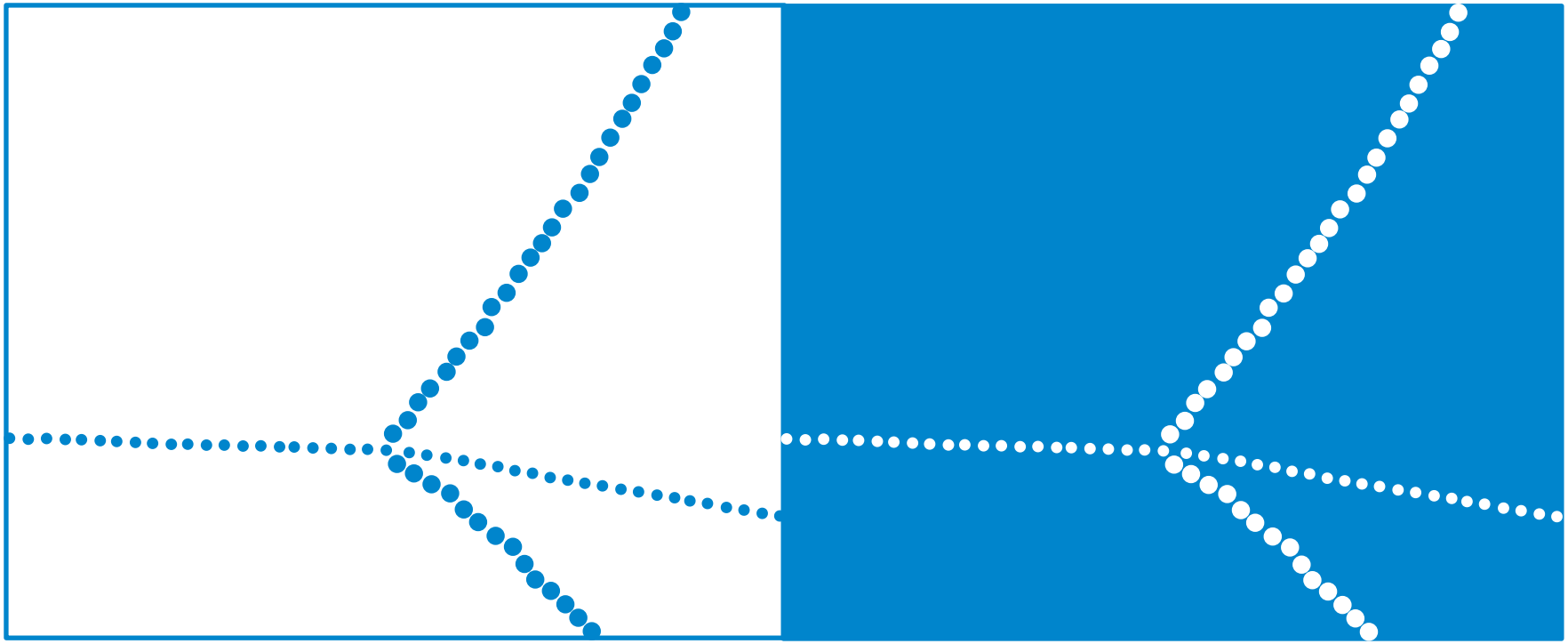
Wilson's Cloud chamber invented in 1911

Glaser's Bubble chamber, invented in 1952

Bubbles of liquid in gas

Bubbles of gas in liquid

Cloud and bubble chambers

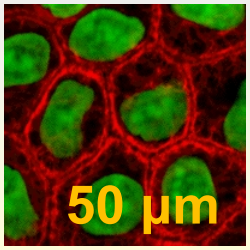


Wilson's Cloud chamber, invented in 1911

Glaser's Bubble chamber, invented in 1952

Cloud chamber and bubble chamber are often mentioned in the TRIZ books with the question - would the invention of the bubble chamber take almost half-a-century if the principle of anti-system had been used?

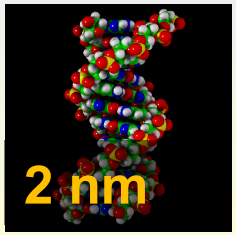
The structure of matter…



Extra magnification?

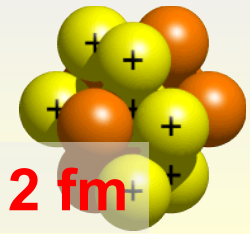
CELLS
Twenty per mm

Microscope



x 25 thousand

DNA
Five hundred thousand per mm



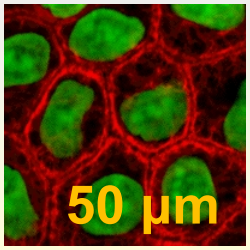
x 1 million

Nucleus
Five hundred billion per mm

x 2 thousand

Quarks
More than one million billion per mm

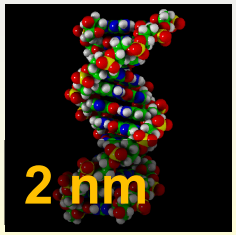
…use particles



Extra magnification?

CELLS
Twenty per mm

Microscope



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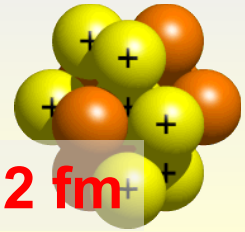


x 1 million

Nucleus
Five hundred billion per mm

x 2 thousand

Quarks
More than one million billion per mm

Particles & their wave properties

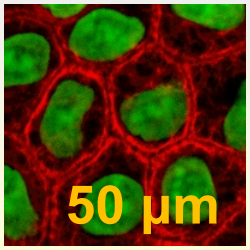
Wavelength corresponding to the particle:

$$\lambda = h / p$$

De Broglie Wavelength — Planck Constant — Momentum

See small? Use particles and increase their energy

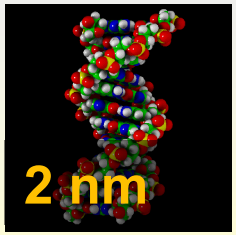
…use particle accelerators



Extra magnification?

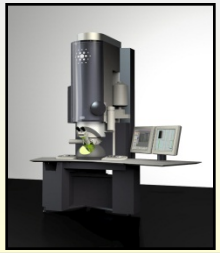
CELLS
Twenty per mm

Microscope

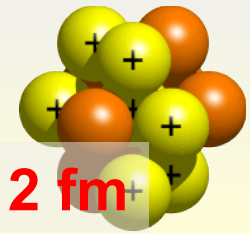


x 25 thousand

DNA
Five hundred thousand per mm



Electron microscope



x 1 million

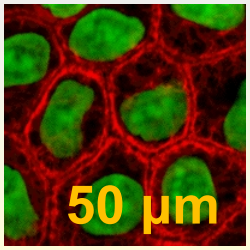
Nucleus
Five hundred billion per mm

Particle Accelerators

x 2 thousand

Quarks
More than one million billion per mm

Chemistry Nobel 2014 & inventive principles?



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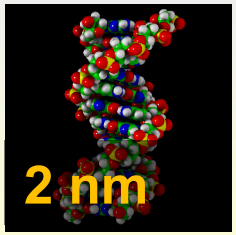

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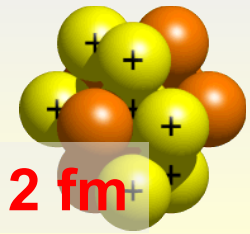

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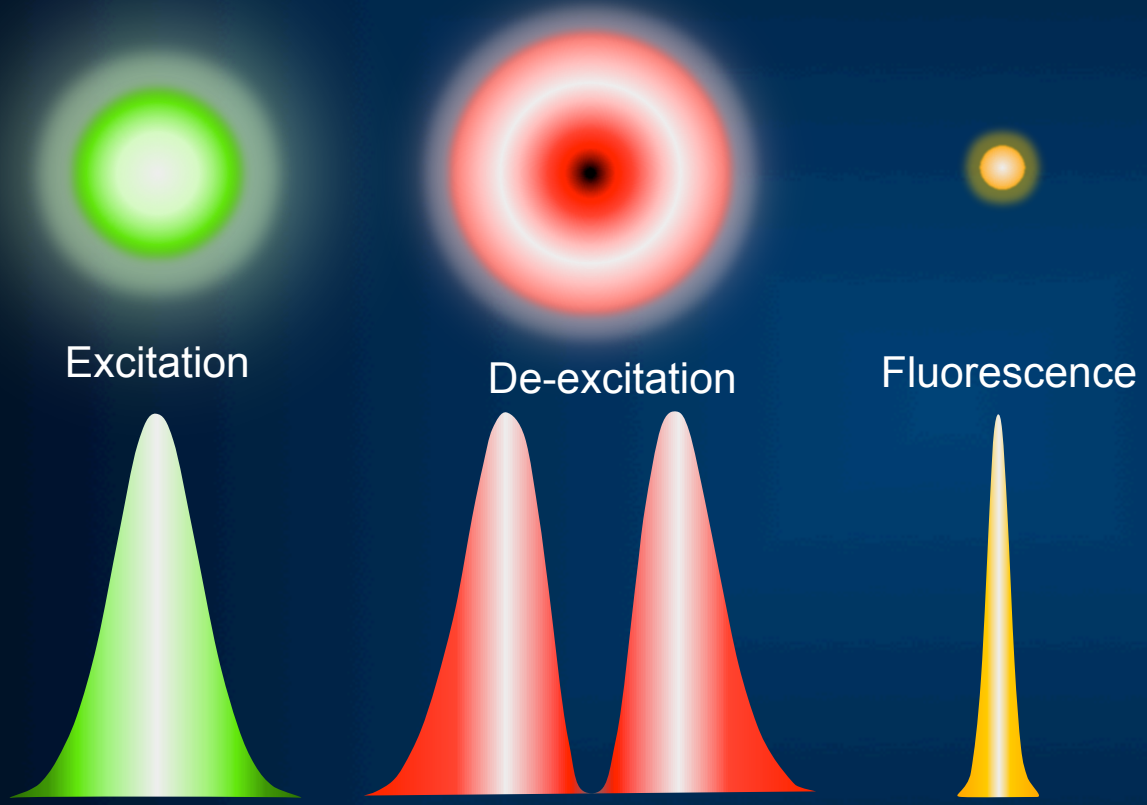
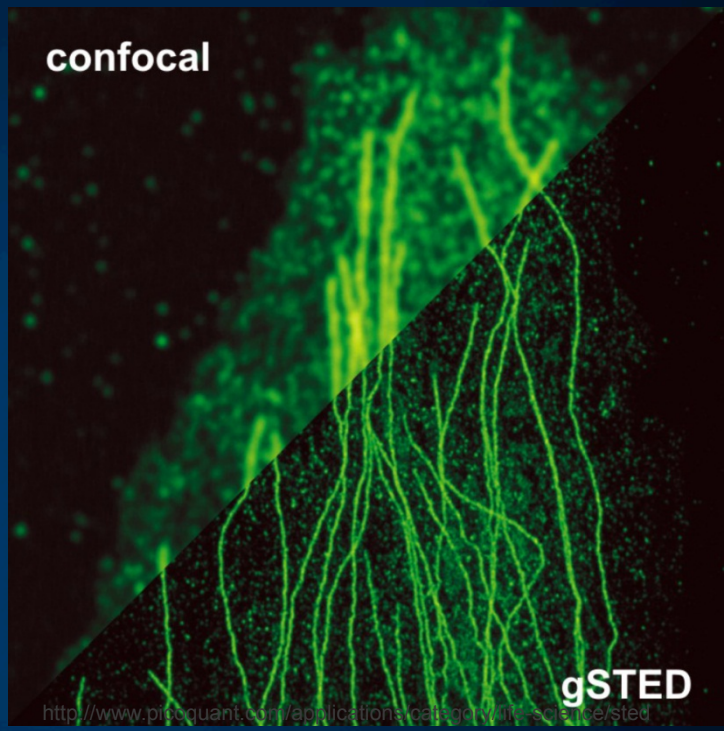
Chemistry Nobel 2014 …

Stimulated Emission Depletion microscopy (STED)
Stefan W. Hell





(gated) STED image of Tubulin vs standard confocal image

Chemistry Nobel 2014 & inventive principles

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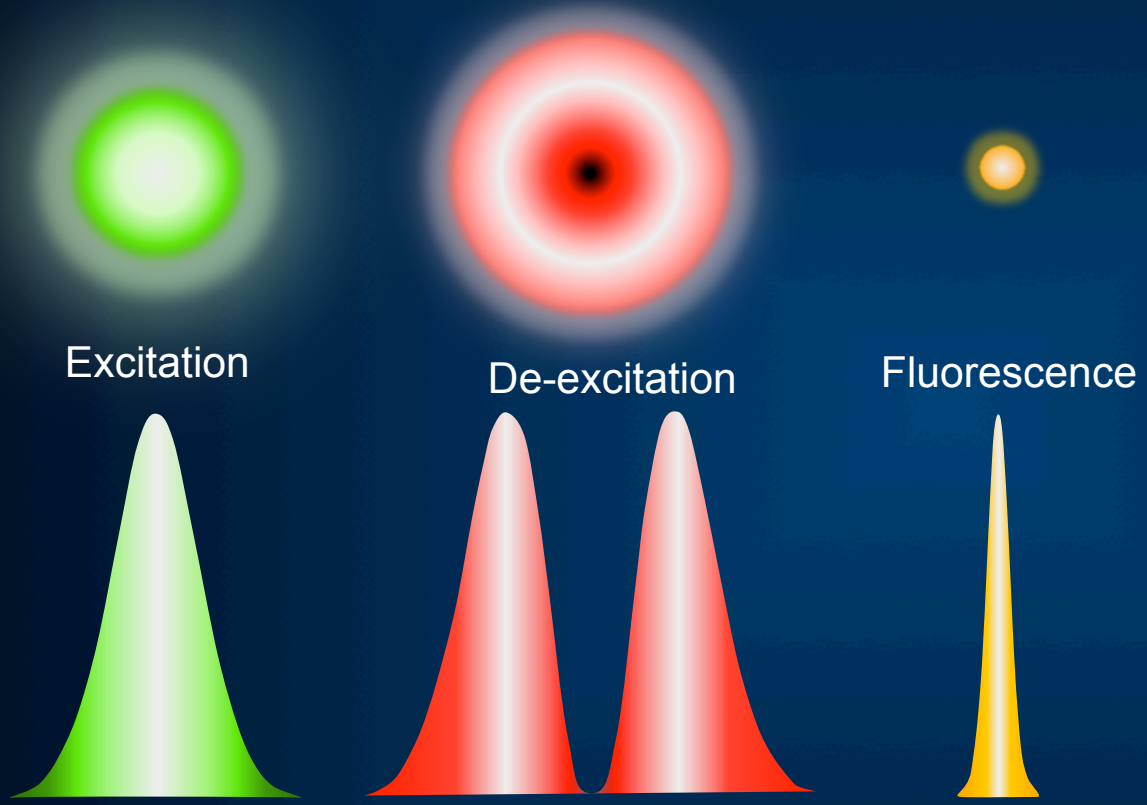

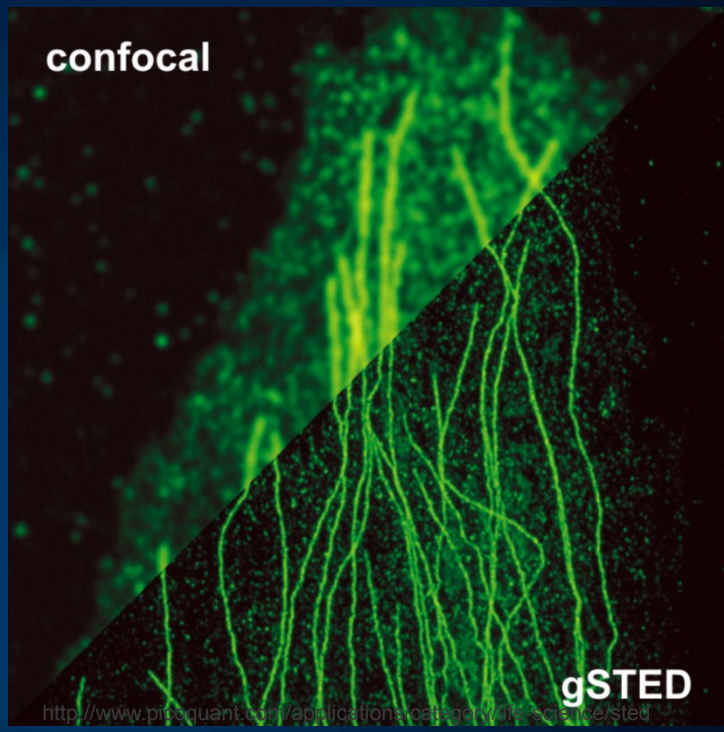

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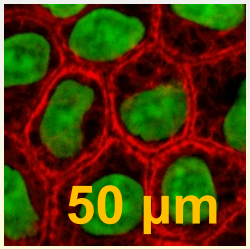
From the perspective of TRIZ this is an illustration of the use of the principles of system and anti-system and nested dolls

Colliders & principles of TRIZ



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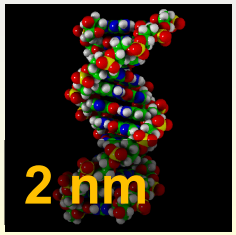

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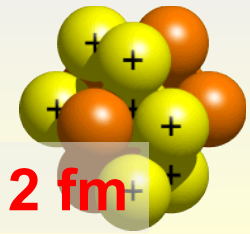

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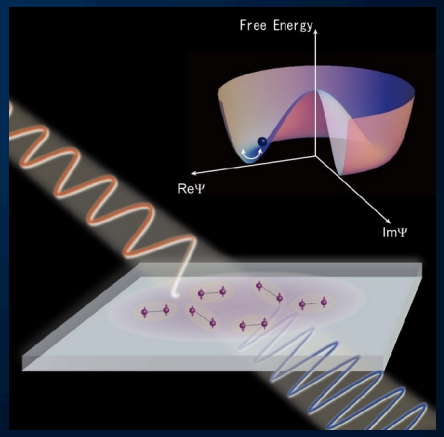
Discovery 2012, Nobel Prize in Physics 2013

The Nobel Prize in Physics 2013 was awarded jointly to François Englert and Peter W. Higgs *"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider".*

Higgs and Superconductivity

"The recent discovery of the Higgs boson has created a lot of excitement … the theoretical proposal of the Higgs mechanism was actually inspired by ideas from condensed matter physics … In 1958, Anderson discussed the appearance of a coherent excited state in superconducting condensates with spontaneously broken symmetry... *On page 1145 of this issue, Matsunaga et al. report direct observation of the Higgs mode in the conventional superconductor niobium nitride (NbN) excited by intense electric field transients*."

Particle physics in a superconductor, A Pashkin & A Leitenstorfer Science 345, 1121 (2014)



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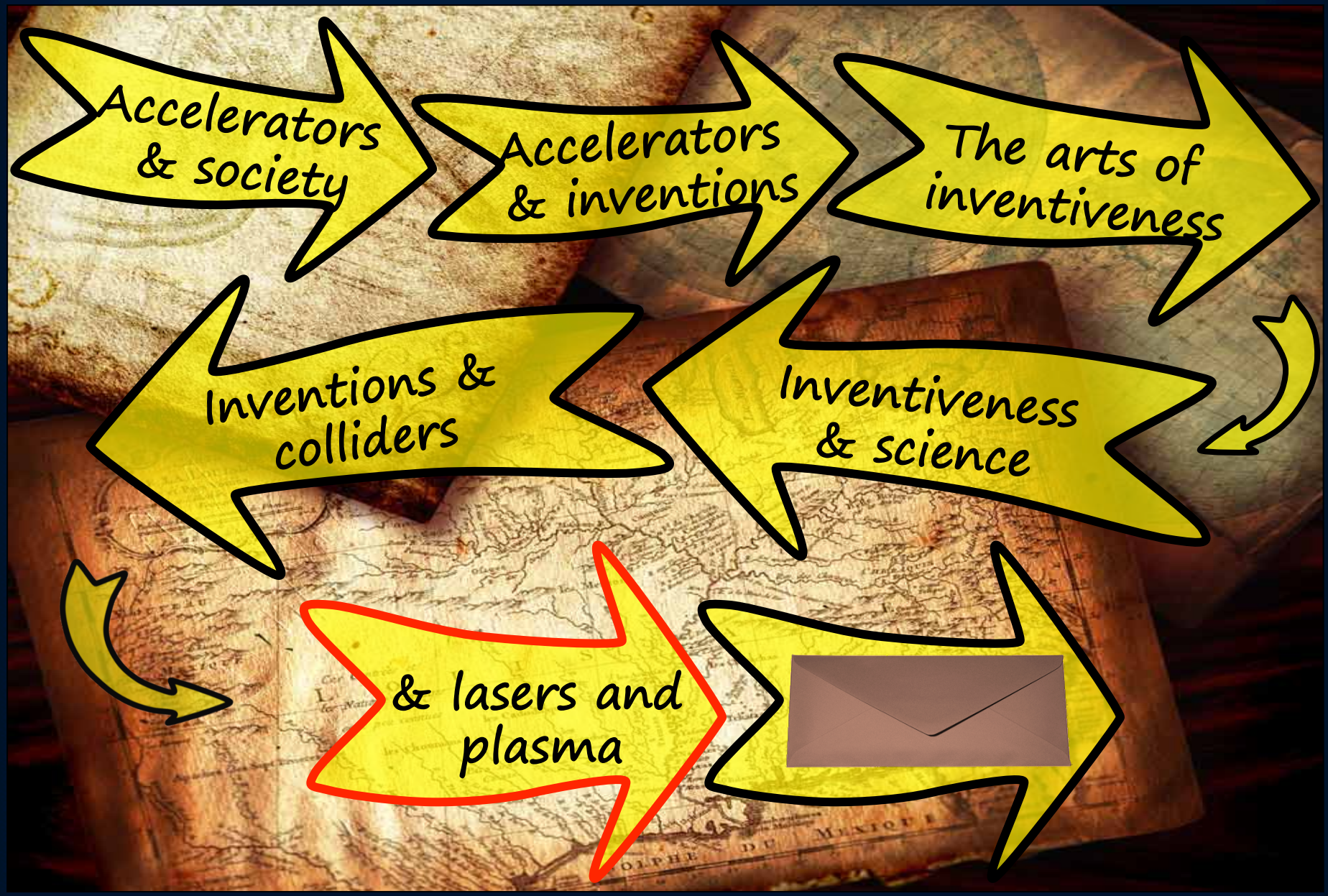
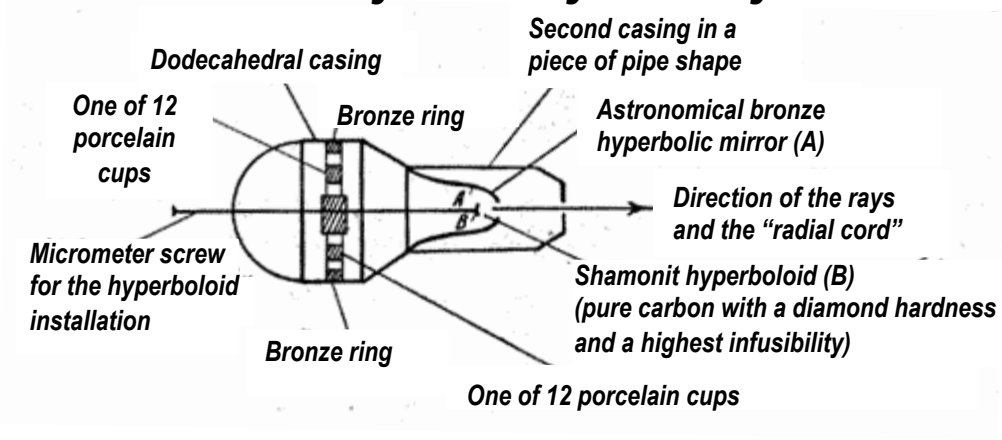
- This shows us that a general conclusion of TRIZ
  - ***"The same Problems and Solutions appear again and again but in different disciplines"***
- is applicable to science too

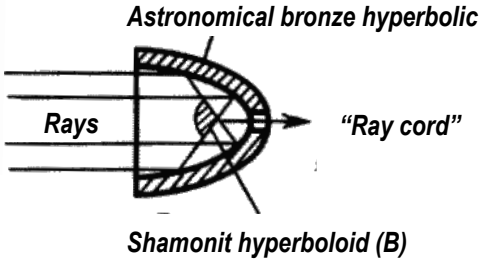
Travel route



“The Hyperboloid of Engineer Garin”

1926 novel by Aleksey Tolstoy





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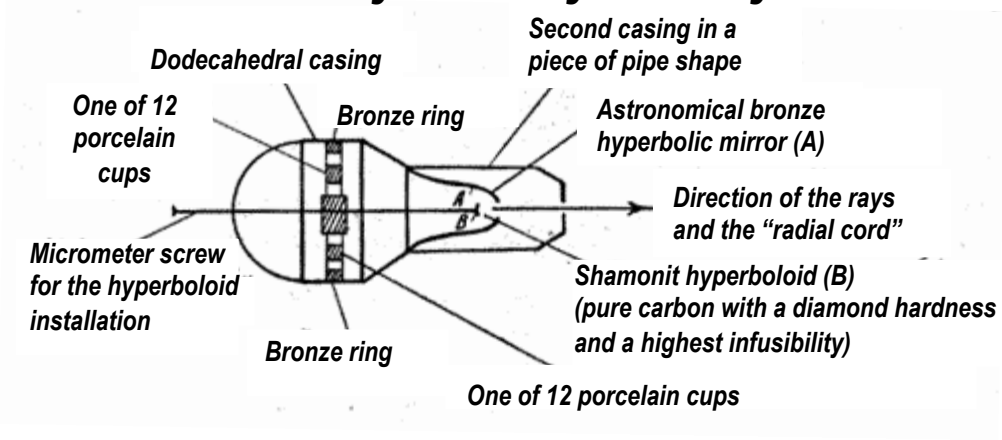

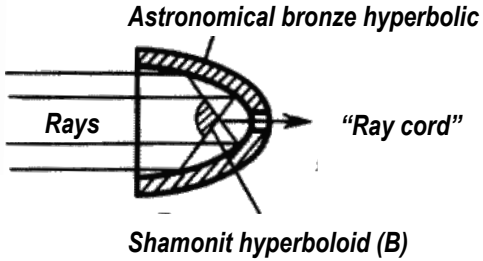

Aleksey Tolstoy

From Tolstoy’s novel:

“…Can you imagine what opportunities are opening now? Nothing in the nature can withstand the power of the ray cord - buildings, forts, dreadnoughts, airships, rocks, mountains, the earth's crust - everything could be penetrated, destroyed, cleaved with my beam.”

Garin suddenly broke off and lifted his head, listening ...

”Three cars and eight people,” he said in a whisper, “they came after us”…

"The Hyperboloid of Engineer Garin"

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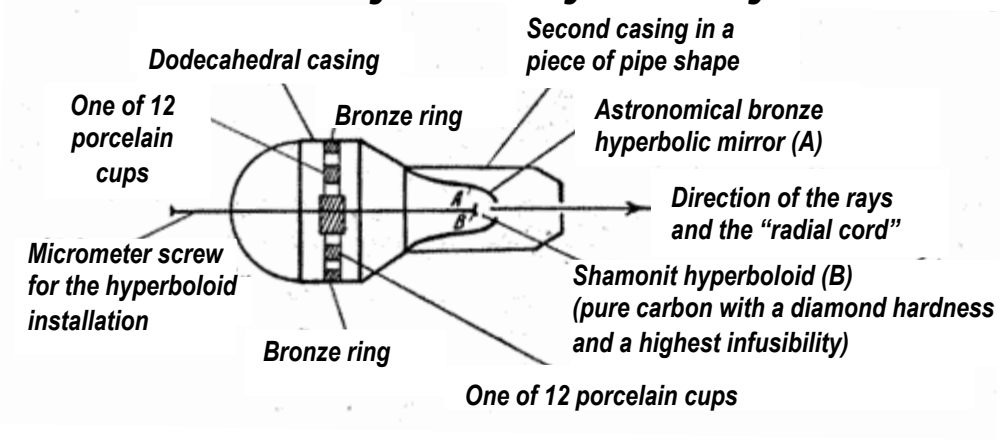
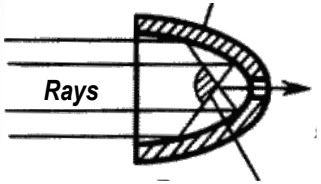
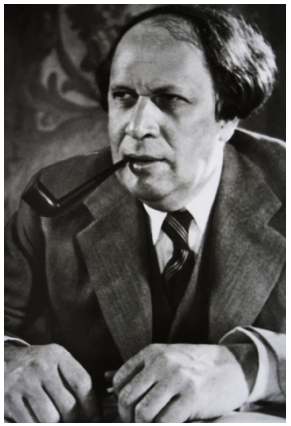
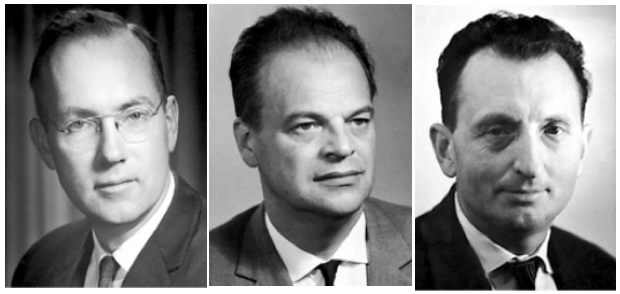






Aleksey Tolstoy

… and laser



C.Townes N.Basov A. Prokhorov

Nobel Prize in 1964 for the research that led to the development of lasers

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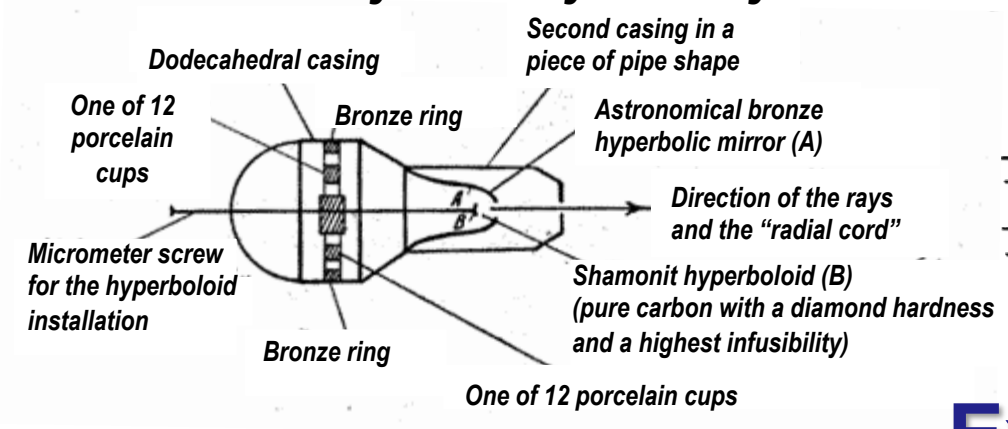
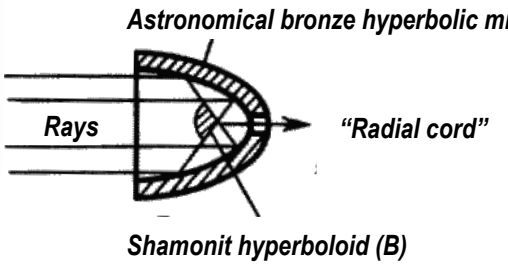
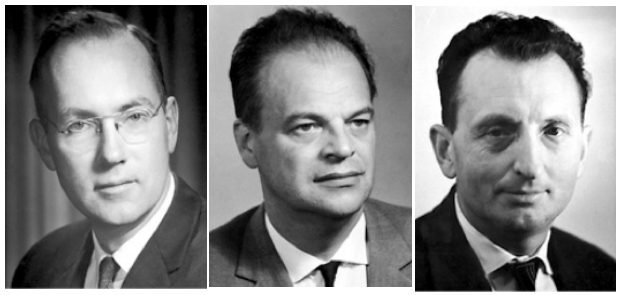




Aleksey Tolstoy

Example: Ruby laser



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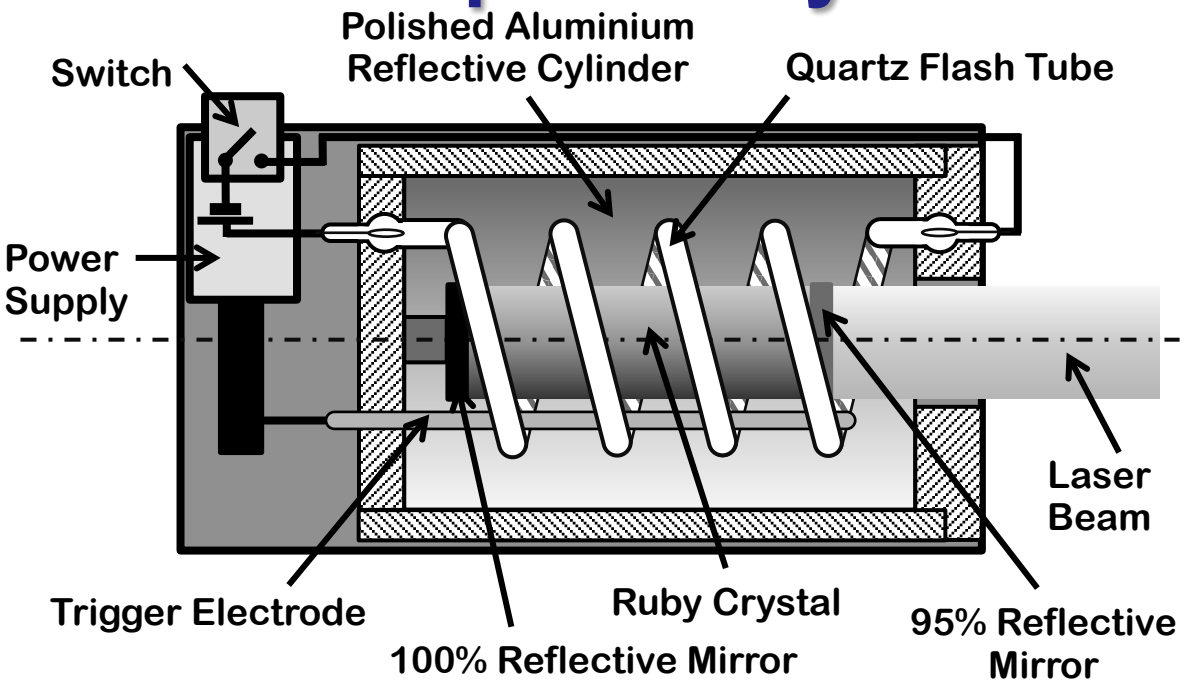

Problem of high-power lasers - active medium T°

Problem:

As intensity of the laser light increase, it takes much more time for active medium to cool down and be ready for next use

Contradiction:

To be improved: INTENSITY

What gets worse: REP RATE

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- **A general principle which can solve this can be taken from nature or AS-TRIZ:**
  - **4: Volume to surface ratio – change it to alter the characteristics such as cooling rate, fields of the object, etc**

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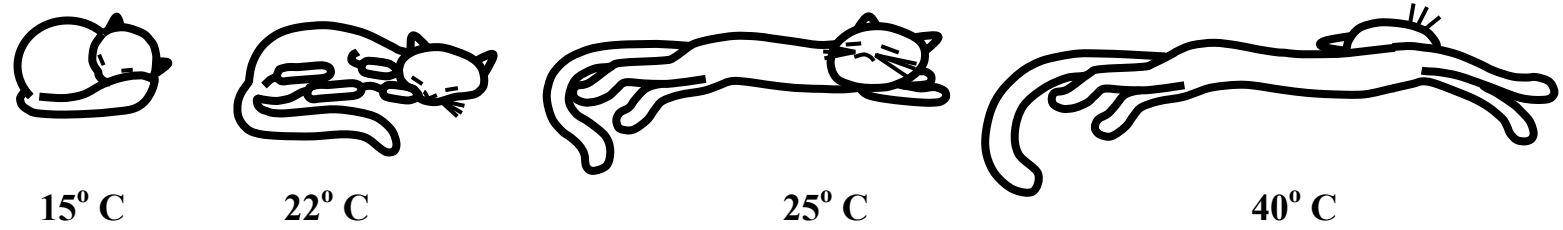

The cat intuitively knows the inventive principle of surface to volume ratio

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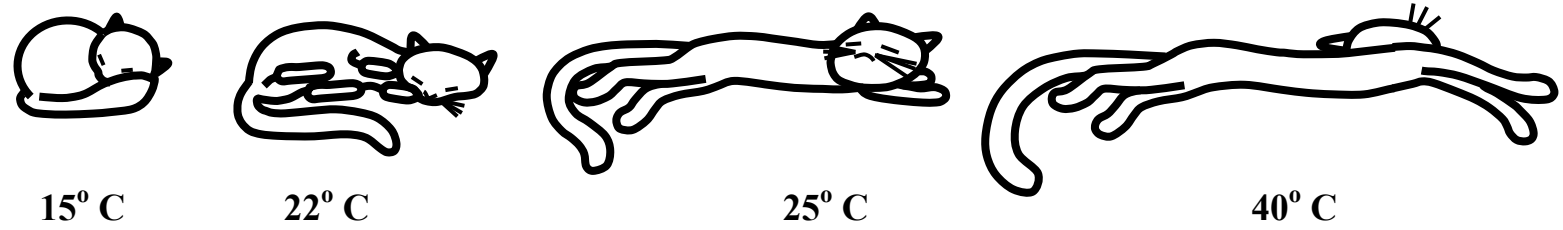
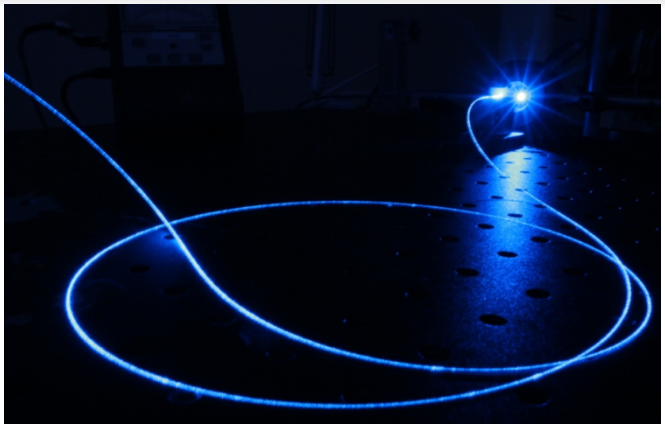


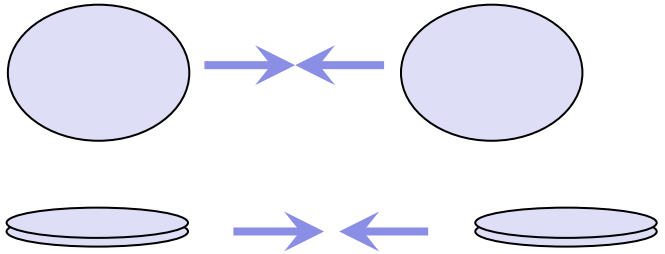
The cat intuitively knows the inventive principle of surface to volume ratio

- **Fiber lasers use the principle of a large surface to volume ratio**
  - **The possibility of high power, high repetition rate, high efficiency**

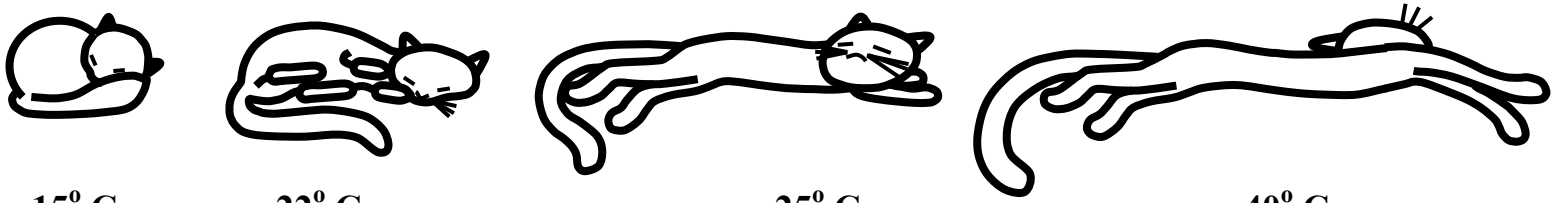


So, you just saw that

colliding beams…



cats…



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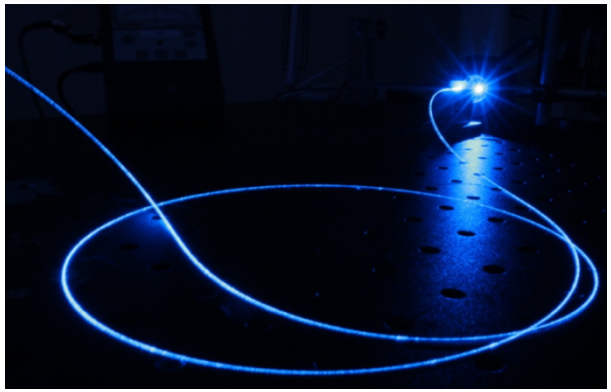


and fibre lasers…

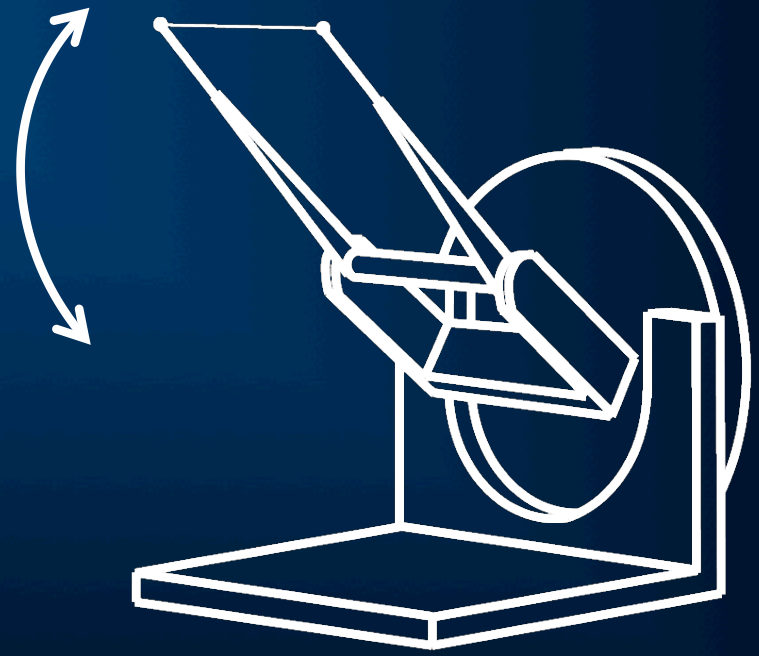
…are <u>connected via TRIZ inventive principles!</u>

Lasers and beam diagnostics

Lasers are often used to measure parameters of the beams in accelerators

But traditionally "simple" mechanical devices have been used

beam bunches



Wires for the beam profile monitor should be very thin ...

Romantic methods in physics

Sometimes thin wires for beam diagnostics were made ...

*"... With a romantic crossbow shooting method * ..."*

beam bunches

*) from PhD dissertation of V.V.Parkhomchuk (Budker Inst. of Nuclear Physics) - my Scientific Mentor in 1982 - 1986

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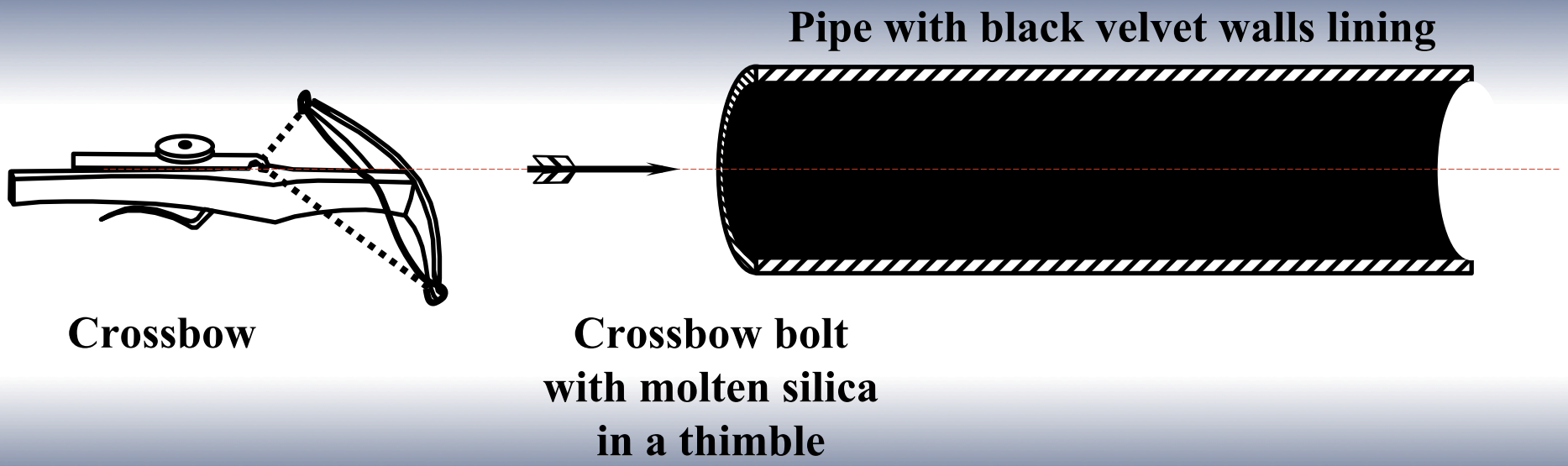

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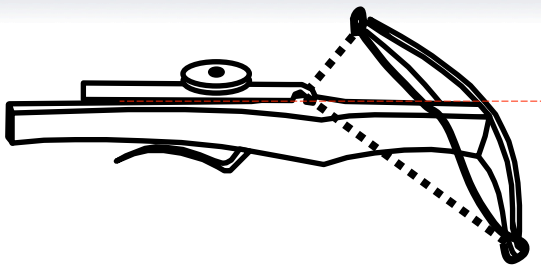
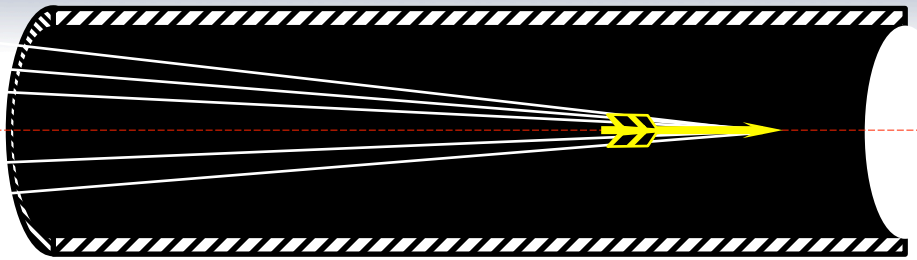


Crossbow

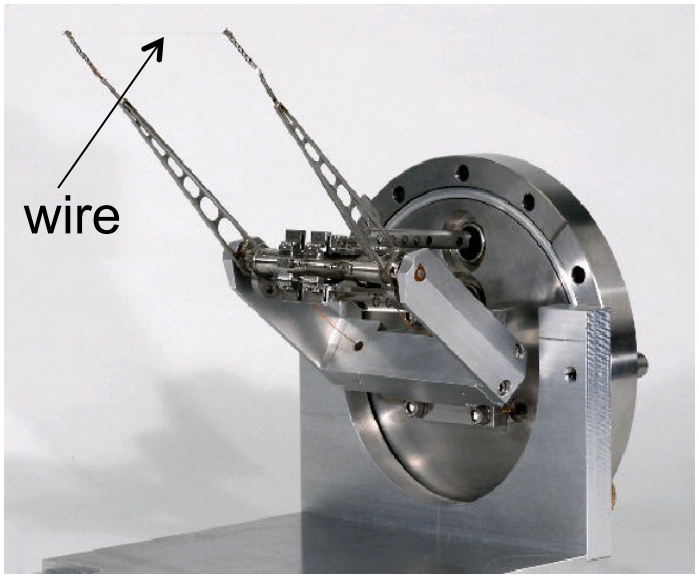
Pipe with black velvet walls lining



Finer silica threads

Crossbow bolt with molten silica in a thimble

And yet, how laser can help here?



Beam profile monitor with tungsten or carbon wire

Problem:

As intensity of the beam increase, the wire get damaged after a single use

Contradiction:

To be improved: INTENSITY

What gets worse: INTEGRITY

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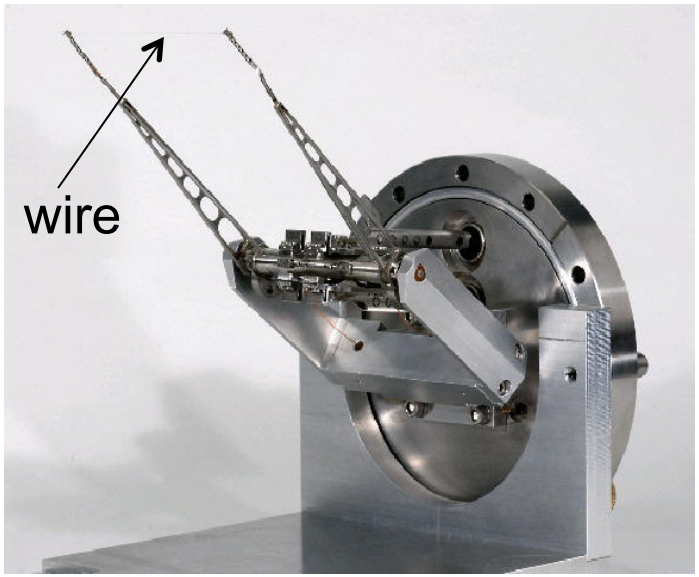

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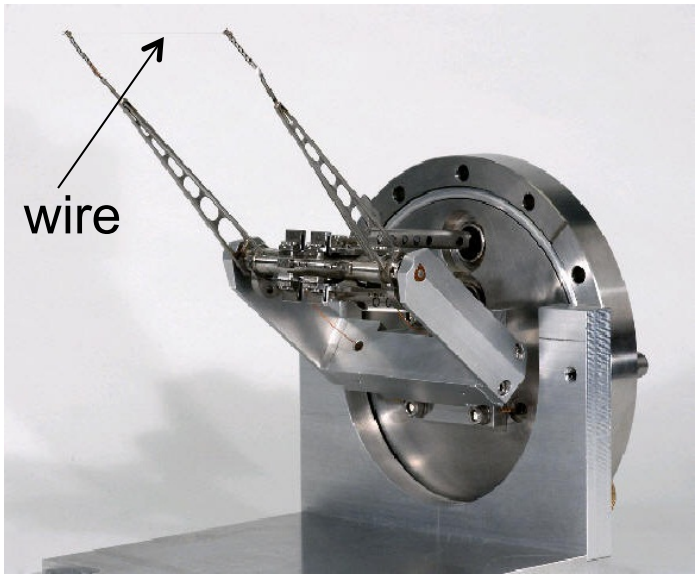
We look at the AS-TRIZ matrix:

Improving Parameter		…	…	Parameter that deteriorates: 9. Integrity	…
	…				
	6. Intensity			3, …	
	…				

And yet, how laser can help here?



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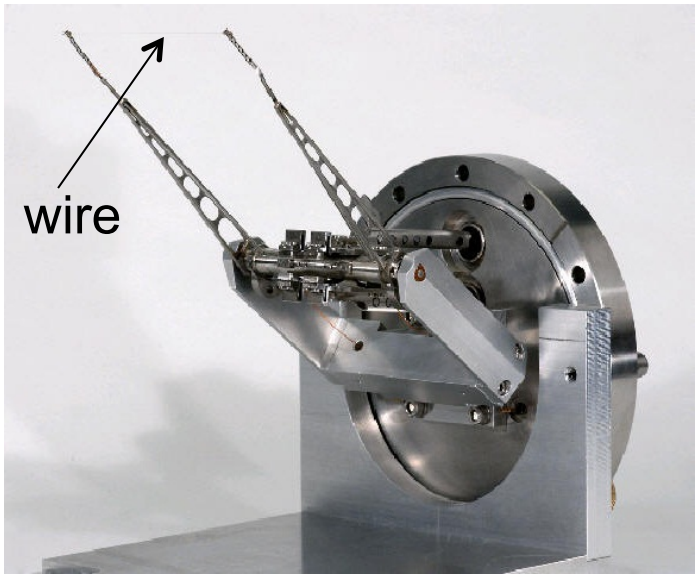
And select one of the inventive principles of emerging AS-TRIZ:

- **3: Replace material that can be damaged with other media, which either cannot be damaged (light) or already "damaged" (e.g. plasma)**

Indestructible laser wire!



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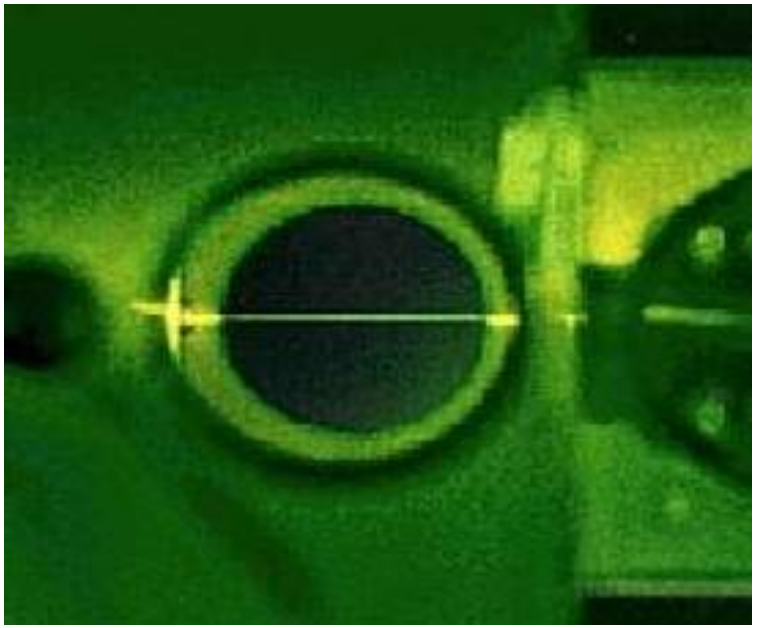

Beam profile monitor with laser beam as the “wire”

Solution:

Then we apply this AS-TRIZ inventive principle:

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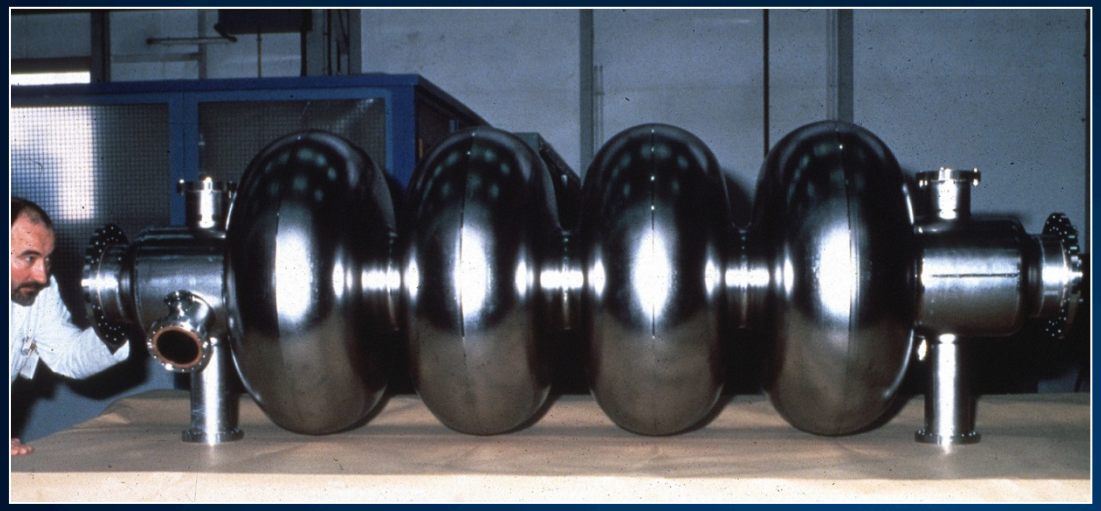
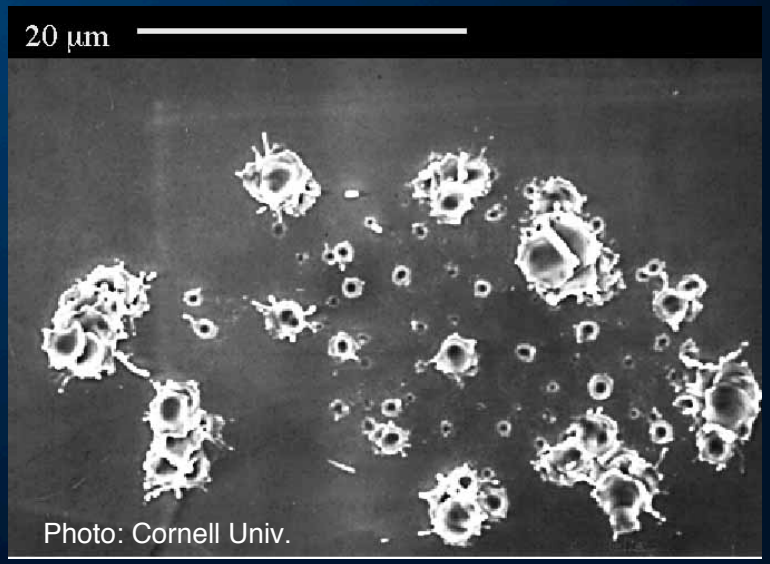
Limits of resonators for acceleration



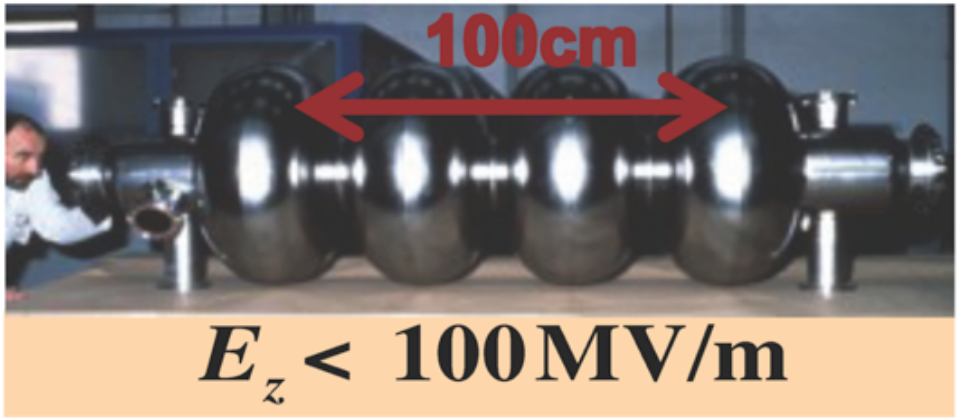
Superconducting Nb accelerating structures

Conventional, Cu

Problem:
As rate of E change (accelerating gradient) increases, the surface of cavities get damaged by occasional breakdowns



Lasers and particle acceleration



Accelerating structure, metal (normal conductive or super-conductive)

Problem:

As rate of E change (accelerating gradient) increase, the surface of cavities get damaged by occasional breakdowns

Contradiction:

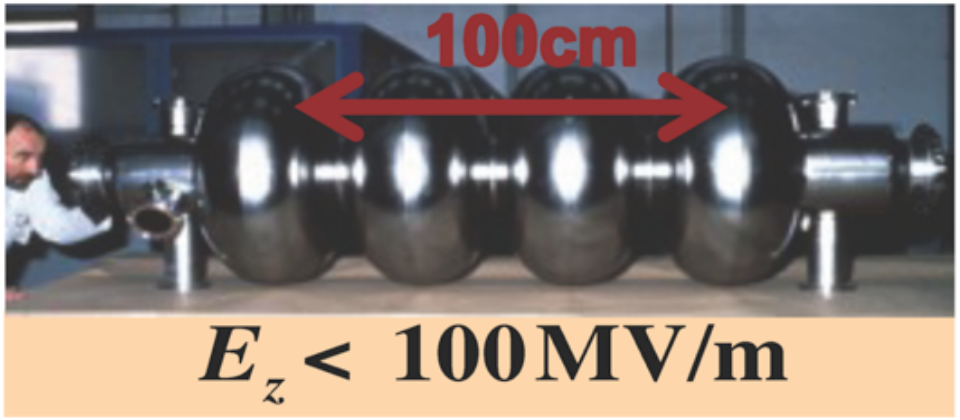
To be improved: Rate of E change

What gets worse: INTEGRITY

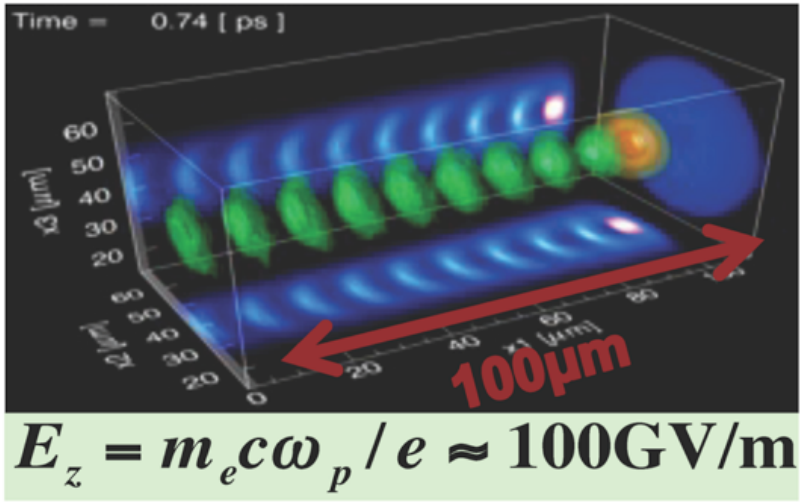
Select one of the inventive principles of emerging AS-TRIZ:

- **3: Replace material that can be damaged with other media, which either cannot be damaged (light) or already "damaged" (e.g. plasma)**

Lasers and particle acceleration



Accelerating structure, metal (normal conductive or super-conductive)



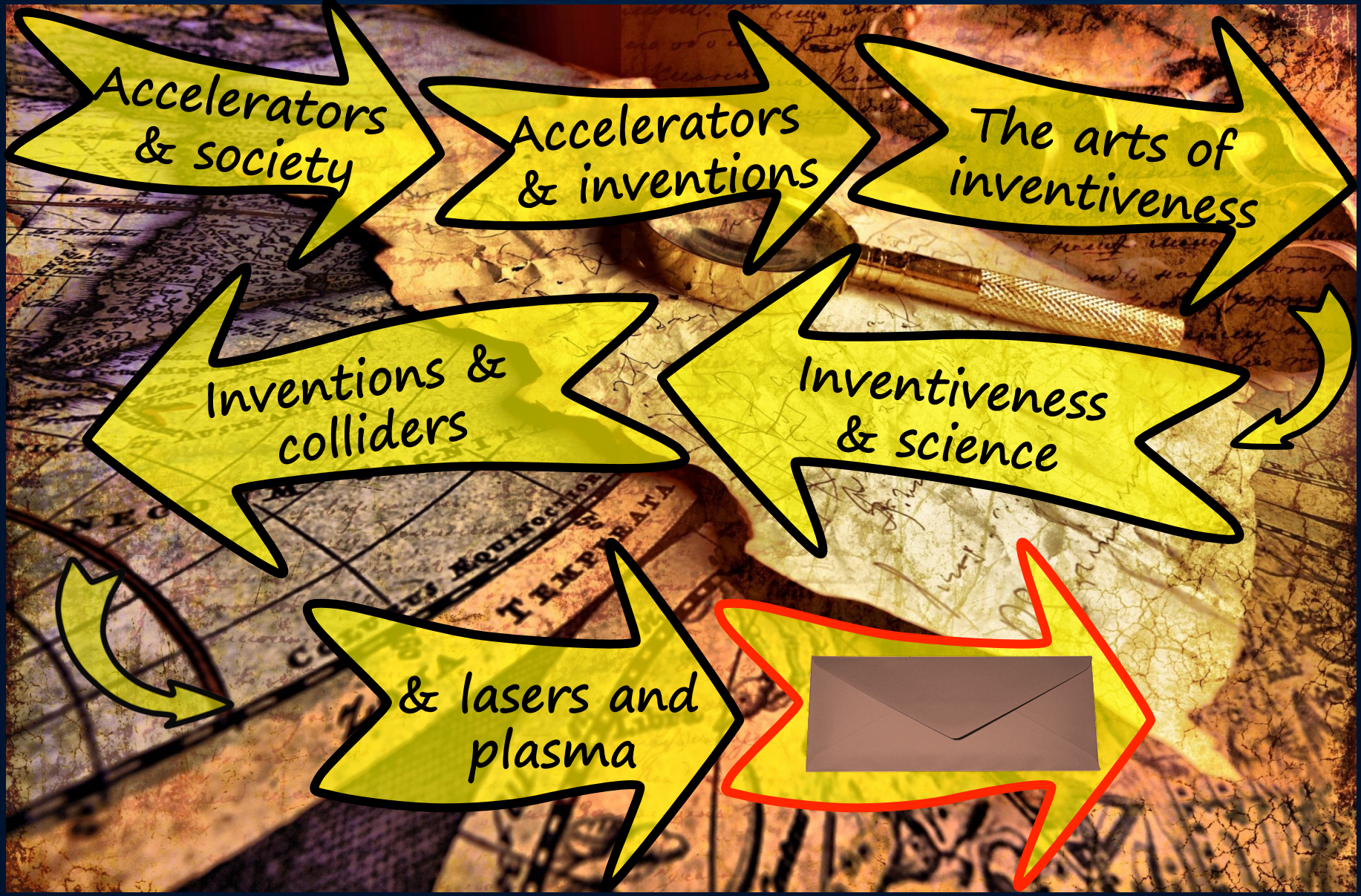
"Accelerating structure" produced on-the-fly in plasma by laser pulse

Solution:

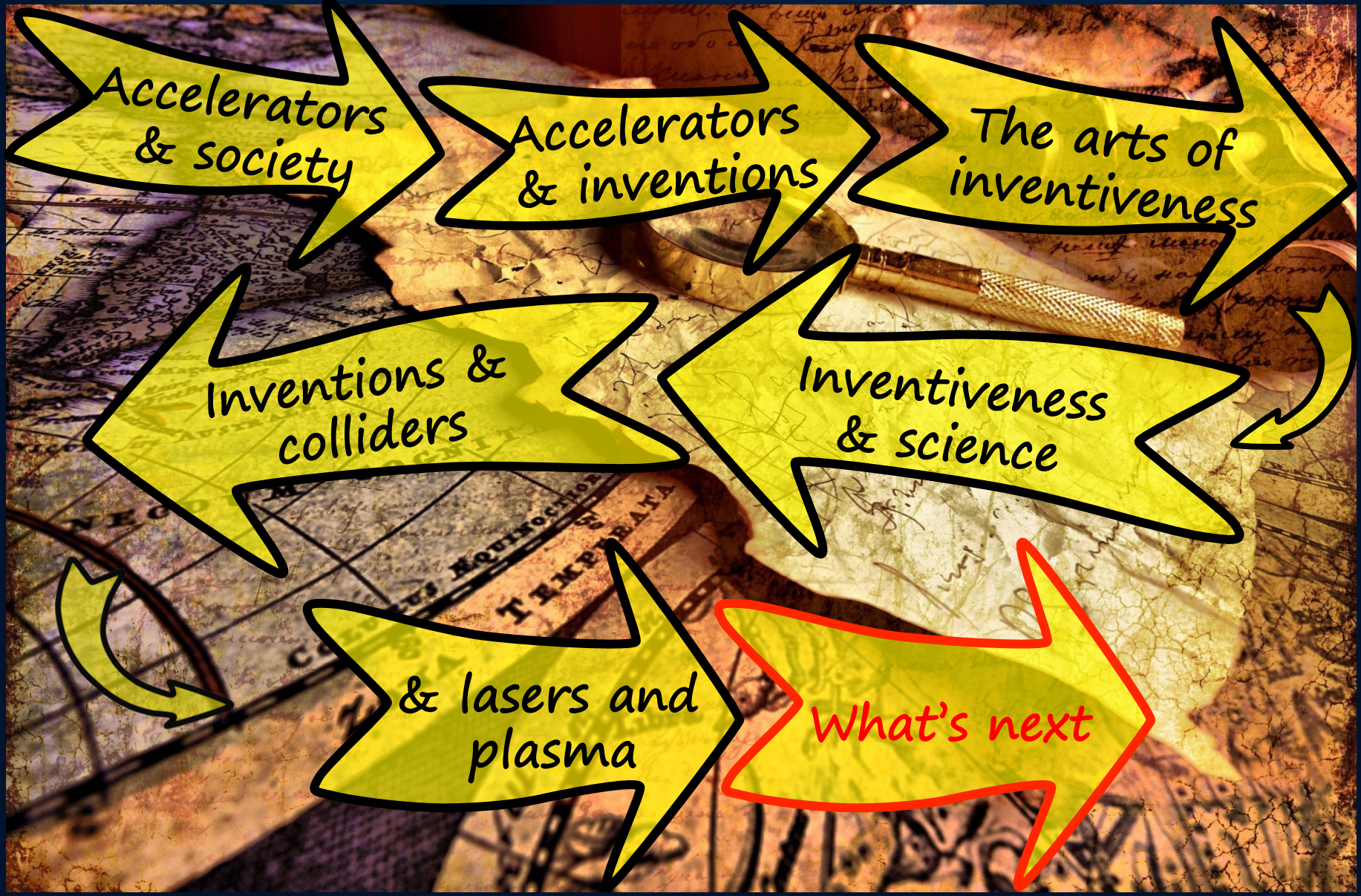
Then apply this inventive AS-TRIZ principle:

- **3: Replace material that can be damaged with other media, which either cannot be damaged (light) or already "damaged" (e.g. plasma)**

Travel route



Travel route

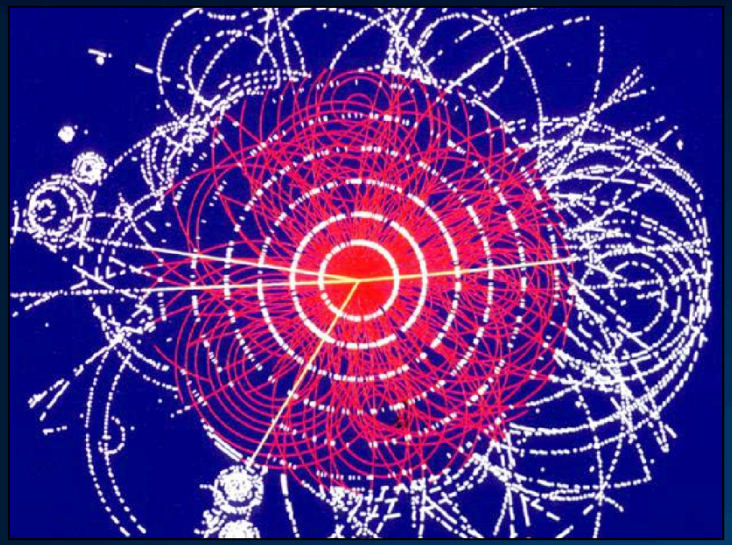


Higgs boson discovered – what's next?

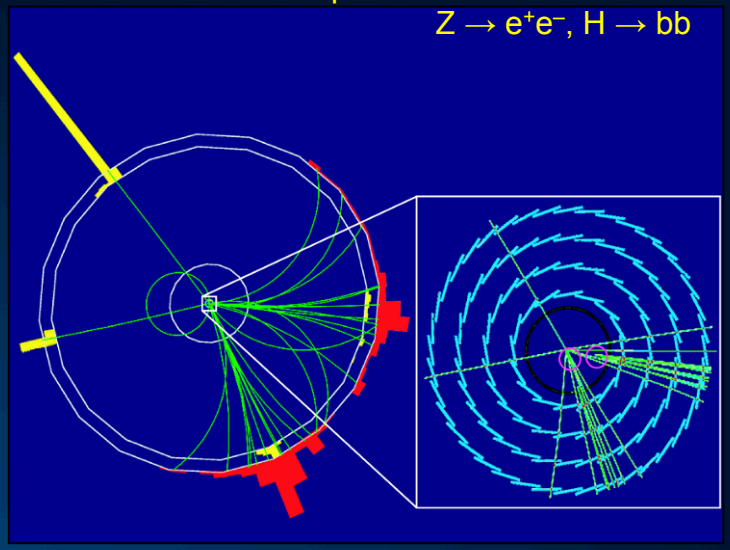
detailed studies…

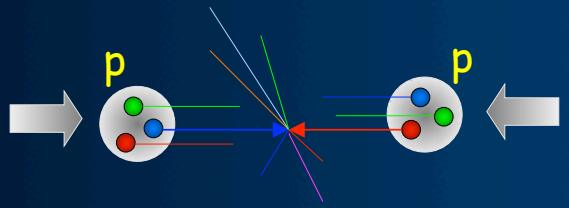
…in the years to come.

Simulation of HIGGS in LHC



Simulation of HIGGS production $e^+e^- \rightarrow Z\,H$
$Z \rightarrow e^+e^-$, $H \rightarrow bb$

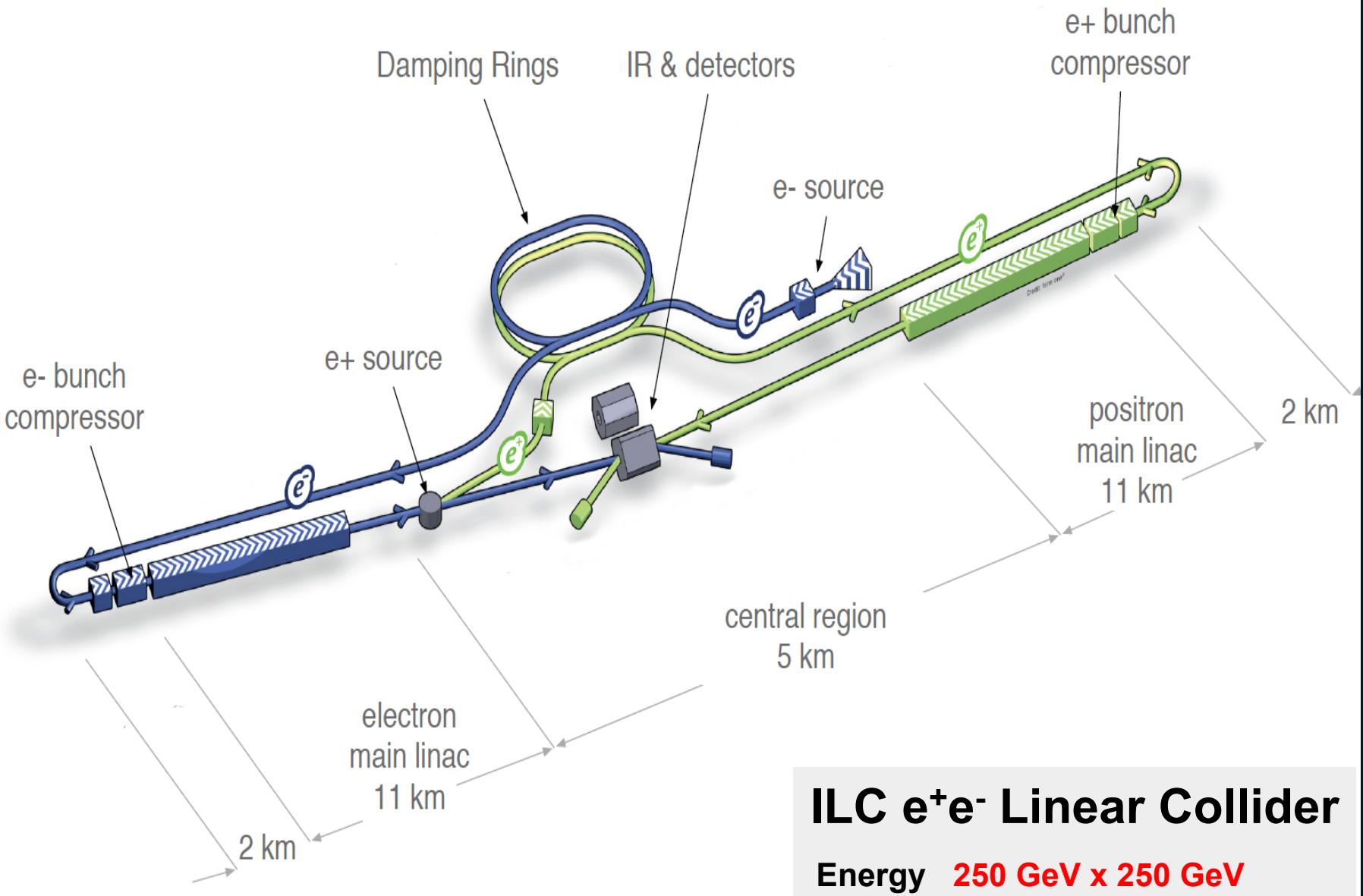




- Hadron collider: frontier of physics
  - Large QCD background
  - not all nucleon energy available in collision
- Lepton collider: precision physics
  - Colliding point like particles
  - well defined initial energy for reaction

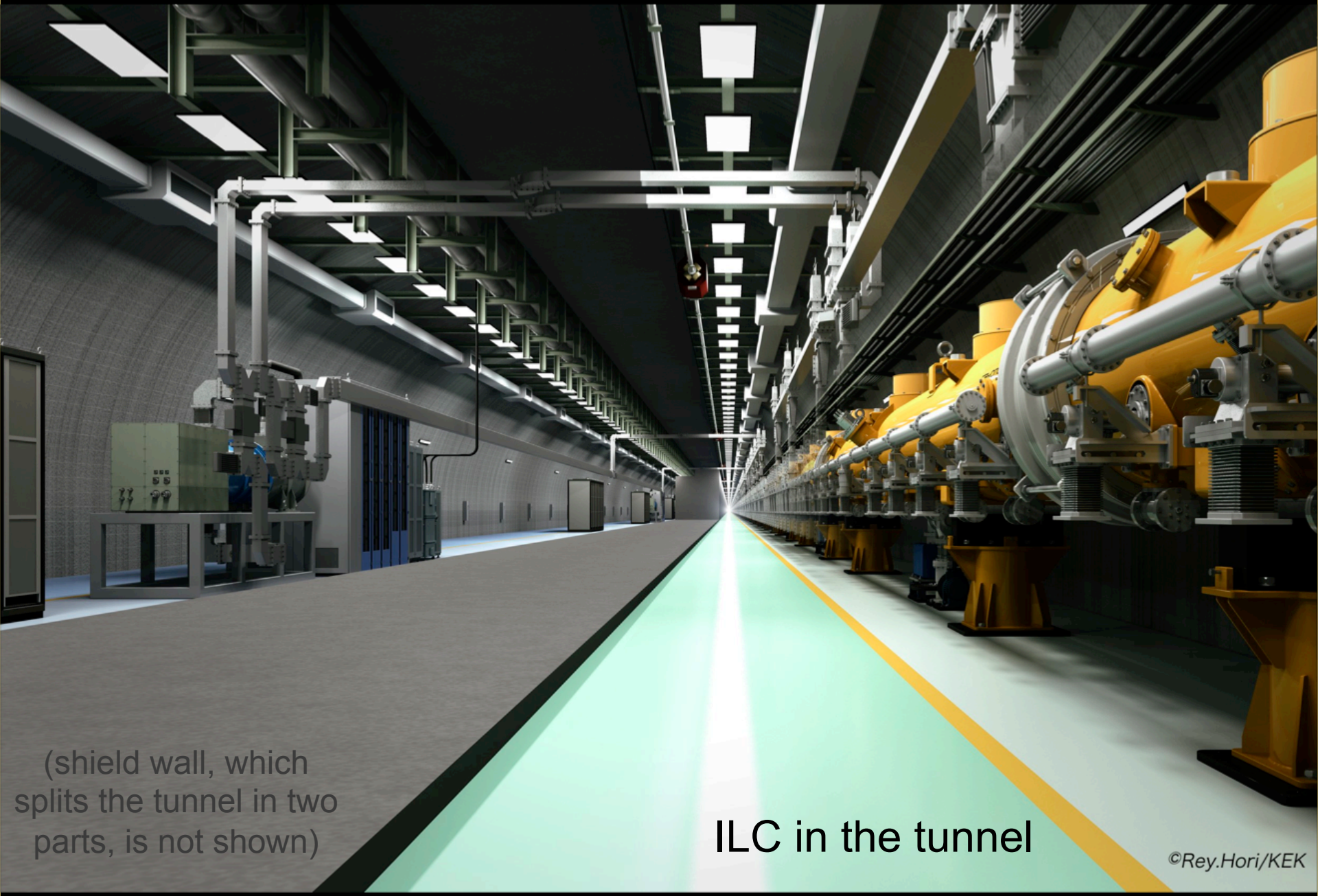
Candidate next machine after LHC can be e+e- collider, with energy determined by the Higgs boson mass, aimed at studies of the new physics

International Linear Collider ILC



ILC e^+e^- Linear Collider

Energy **250 GeV x 250 GeV**


(shield wall, which splits the tunnel in two parts, is not shown)
ILC in the tunnel
©Rey.Hori/KEK

ILC - possibly in Japan

The final decision will be made by the Government of Japan in the coming years

TeV upgrade of ILC with proton plasma acc?

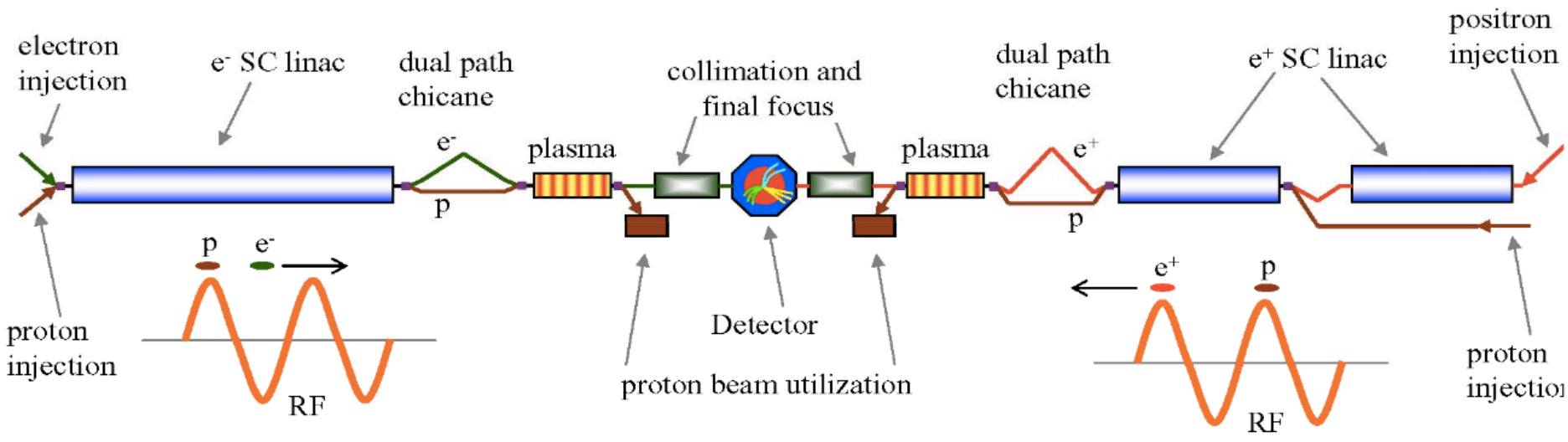


Figure 1: Concept for a multi-TeV upgrade of the International Linear Collider based on proton-driven plasma acceleration. The phase slippage controlling chicanes within the linacs are not shown. Not to scale.

Energy per beam, e- or e+, before plasma acceleration	250 GeV
Bunch population, e- or e+	1×10^{10}
Train format, number of bunches and rep rate	2000, 5Hz
Proton beam on e- side, charge, energy, bunch length	3×10^{10}, 250 GeV, 0.05mm
Proton beam on e+ side, charge, energy, bunch length	3×10^{10}, ~200 GeV, 0.05mm
Plasma density, accelerating gradient and plasma cell length	2.4×10^{15}cm^{-3}, 3 GV/m, 200 m
Energy per beam, e- or e+, after plasma acceleration	500 GeV
Main beam emittances, e- or e+, x, y	2, 0.05 mm-mrad
Main beam sizes at Interaction Point, x, y, z	0.14, 0.0032, 10 μm
Energy of e+e- collisions	1 TeV CM
Luminosity	3.0×10^{34} cm^{-2}s^{-1}
Luminosity in 1% of energy	1.0×10^{34} cm^{-2}s^{-1}

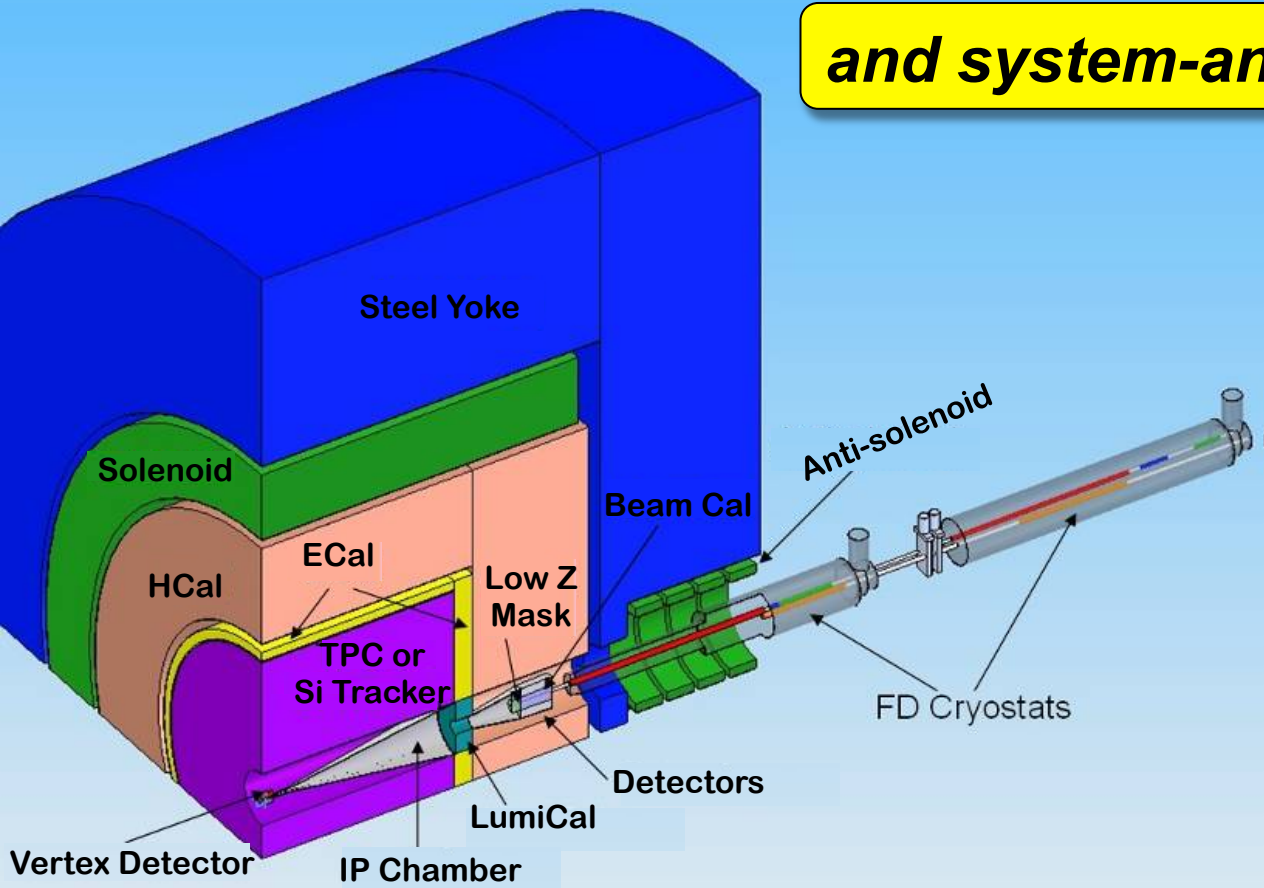
ILC-Note-2010-052, A. Seryi

ILC Interaction Region…

has many examples of TRIZ-like inventions ..

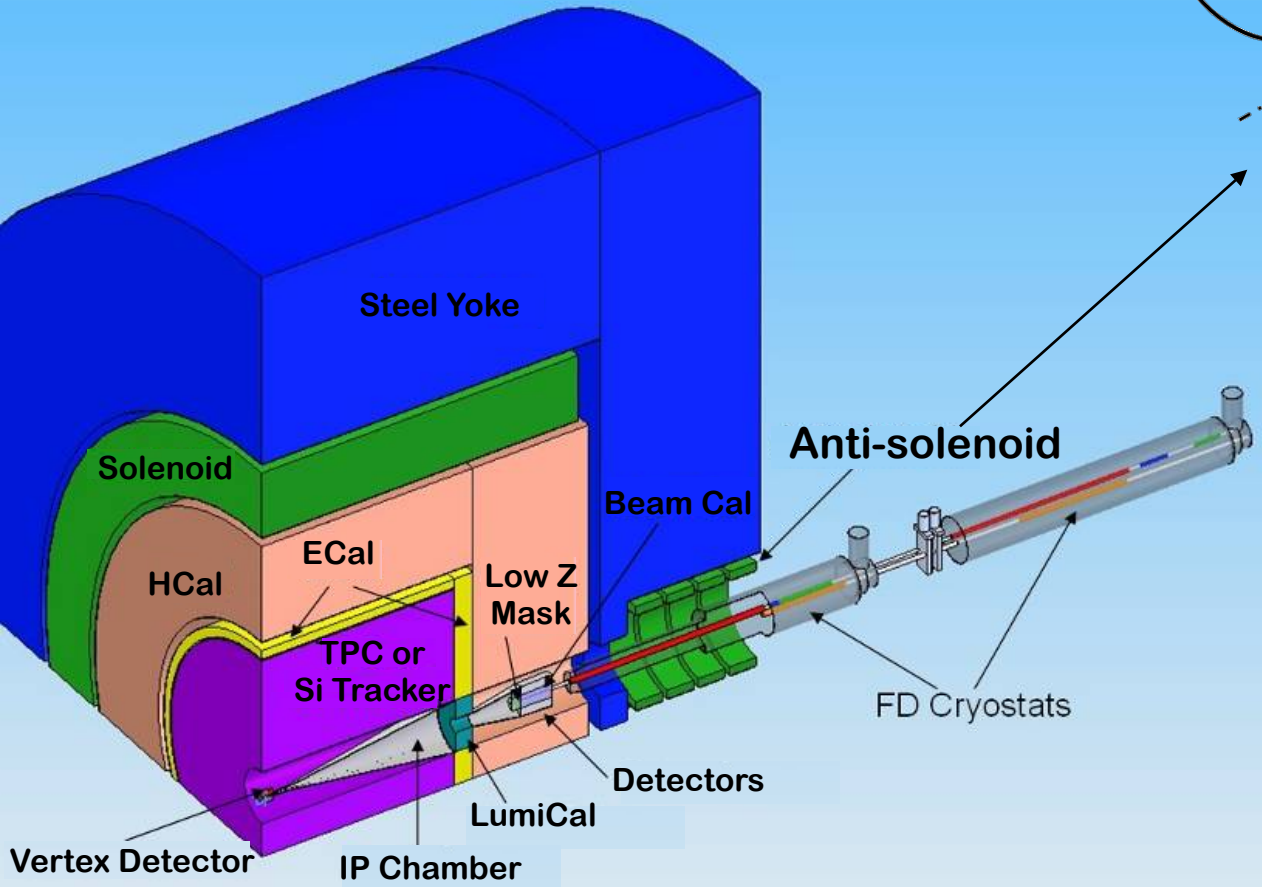
with Russian dolls…

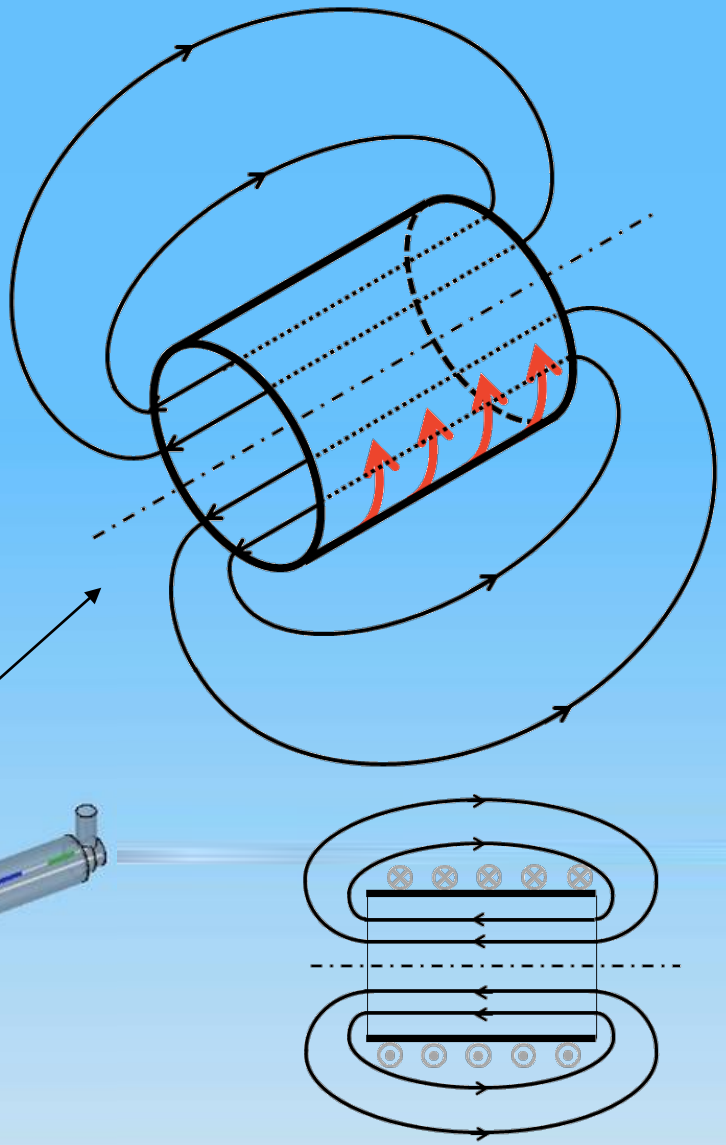
and system-antisystem principles



ILC Interaction Region…

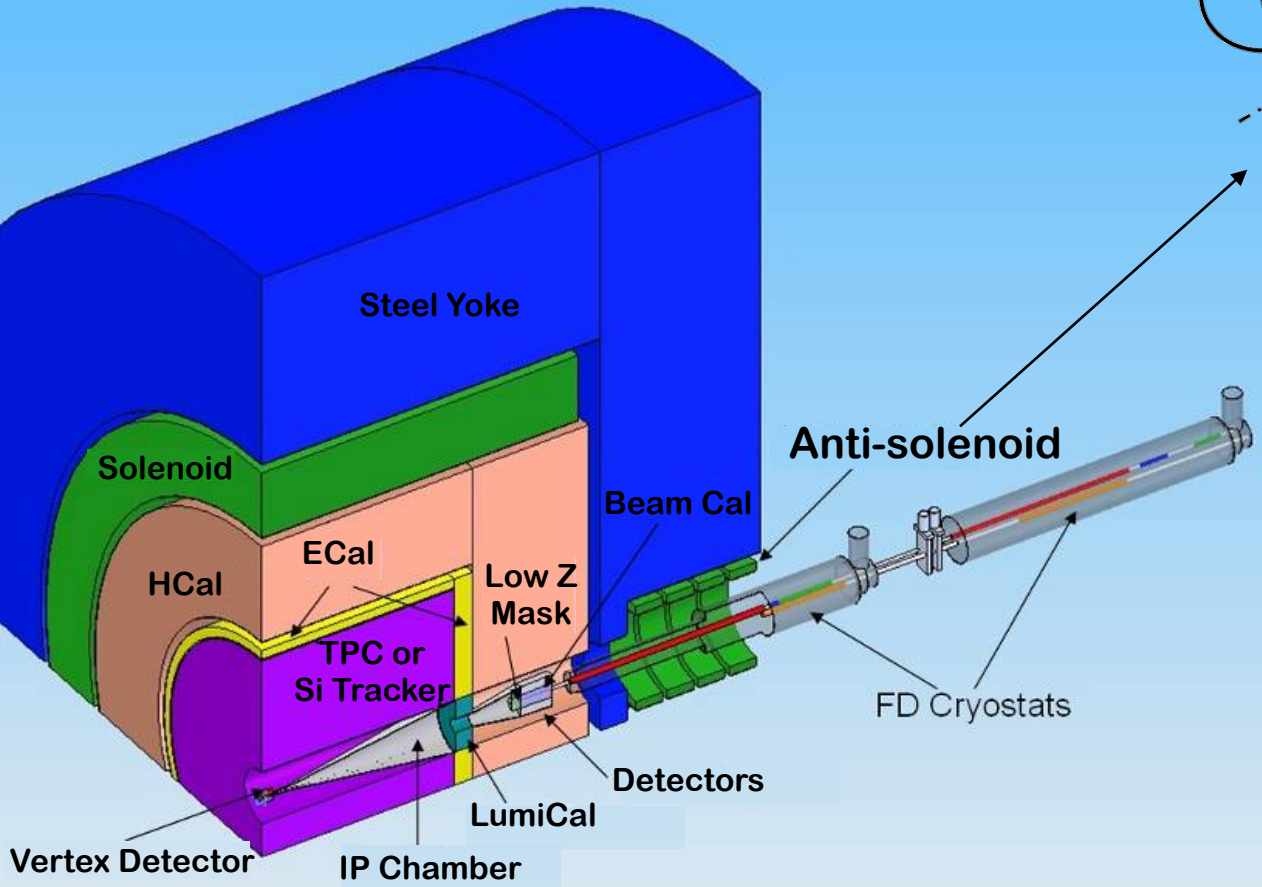
Anti-solenoid is needed, but it would be pulled into the main solenoid with humongous force

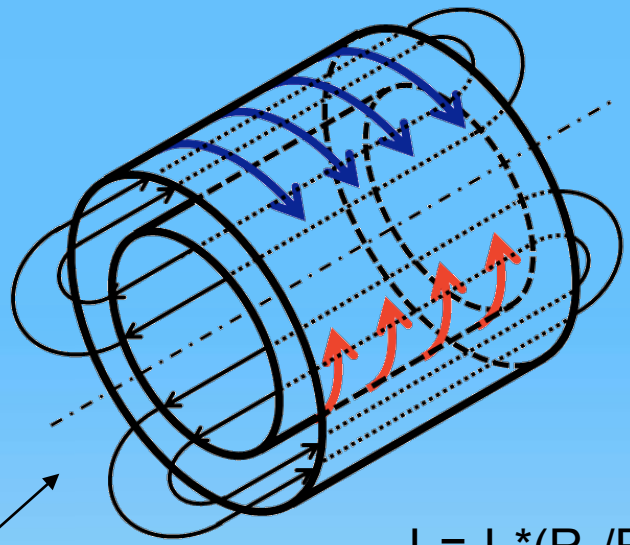




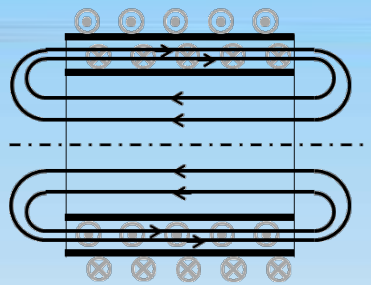
ILC Interaction Region…

Dual anti-solenoid is used, to cancel its external field – this makes it force-neutral





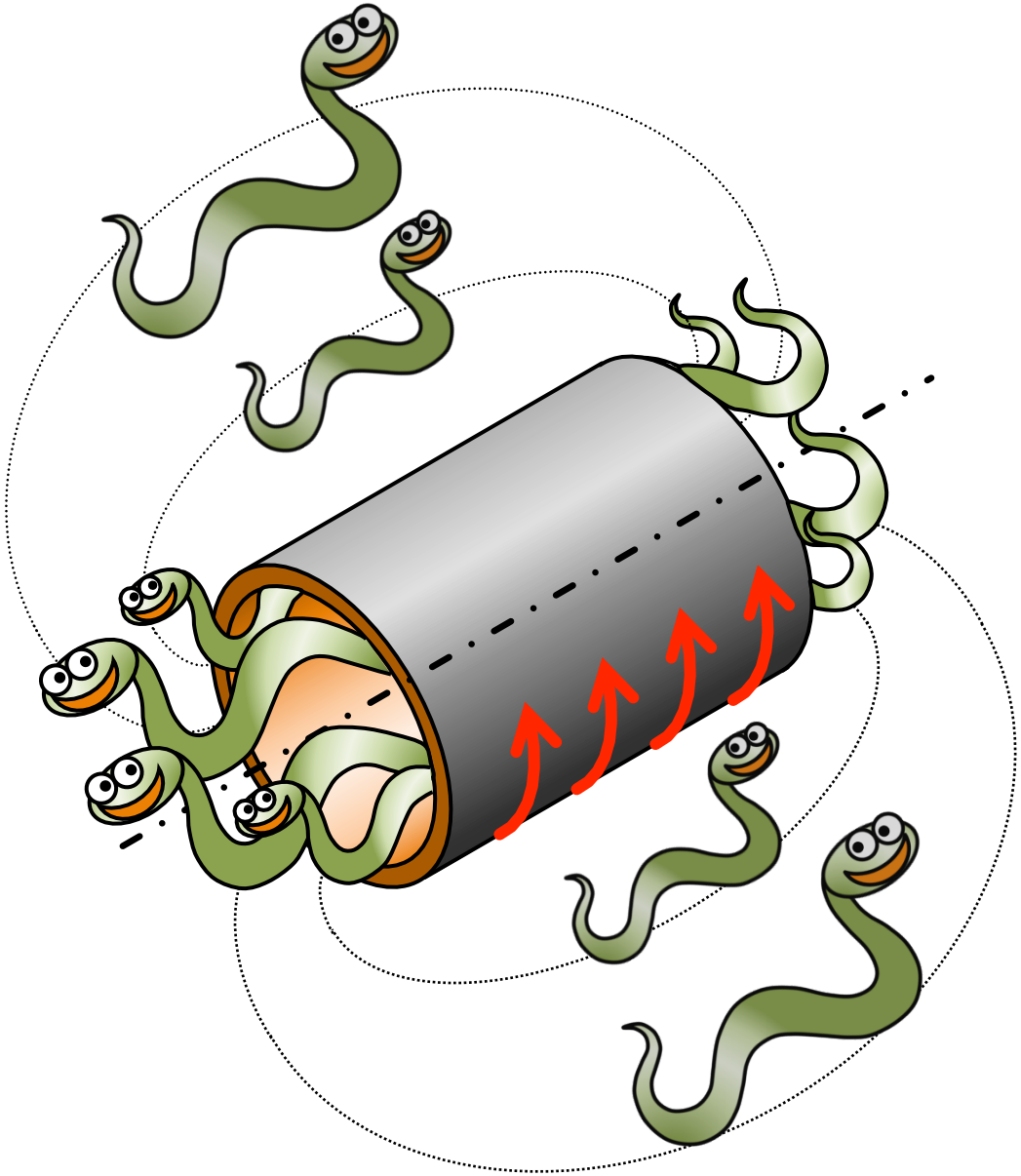
$I_2 = -I_1 * (R_1/R_2)^2$



This is Russian doll & system – anti-system!

Recall synectics and use of analogies

- Use of analogies to generate fresh view
  - …
  - empathic (attempting to look at the problem identifying yourself with the object);
  - …
  - metaphorical (describing the problem in terms of fairy-tales and legends);



Recall synectics and use of analogies

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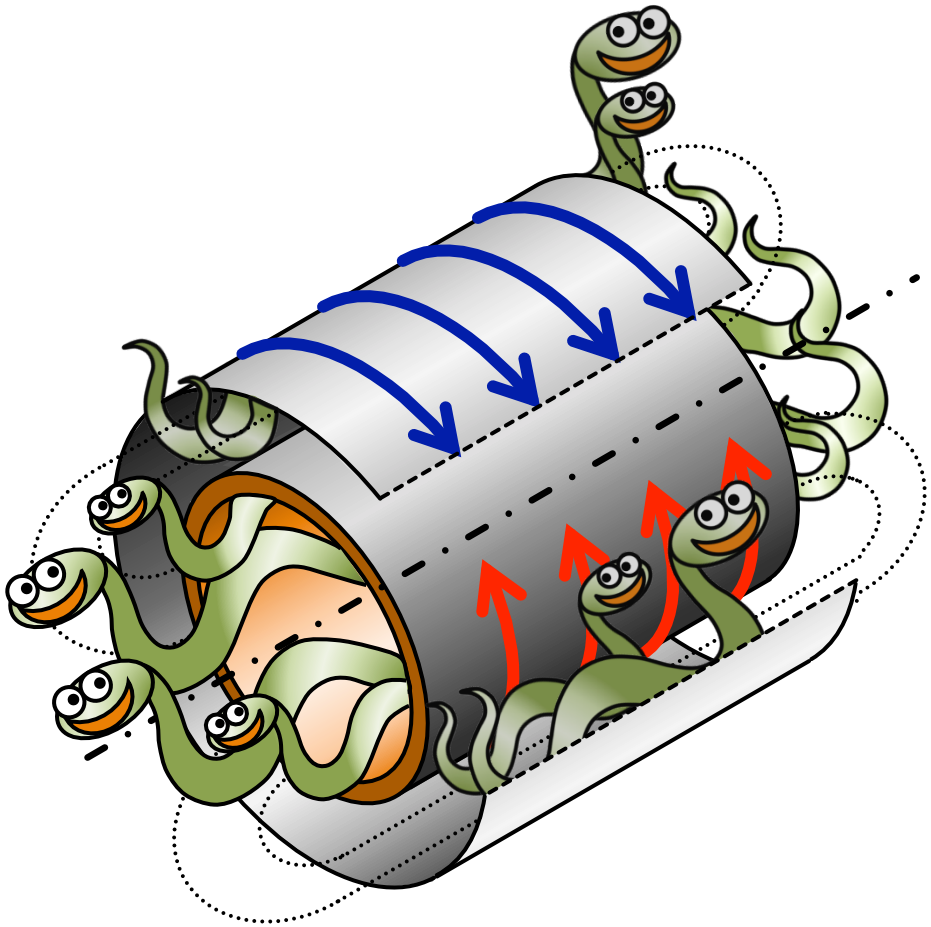
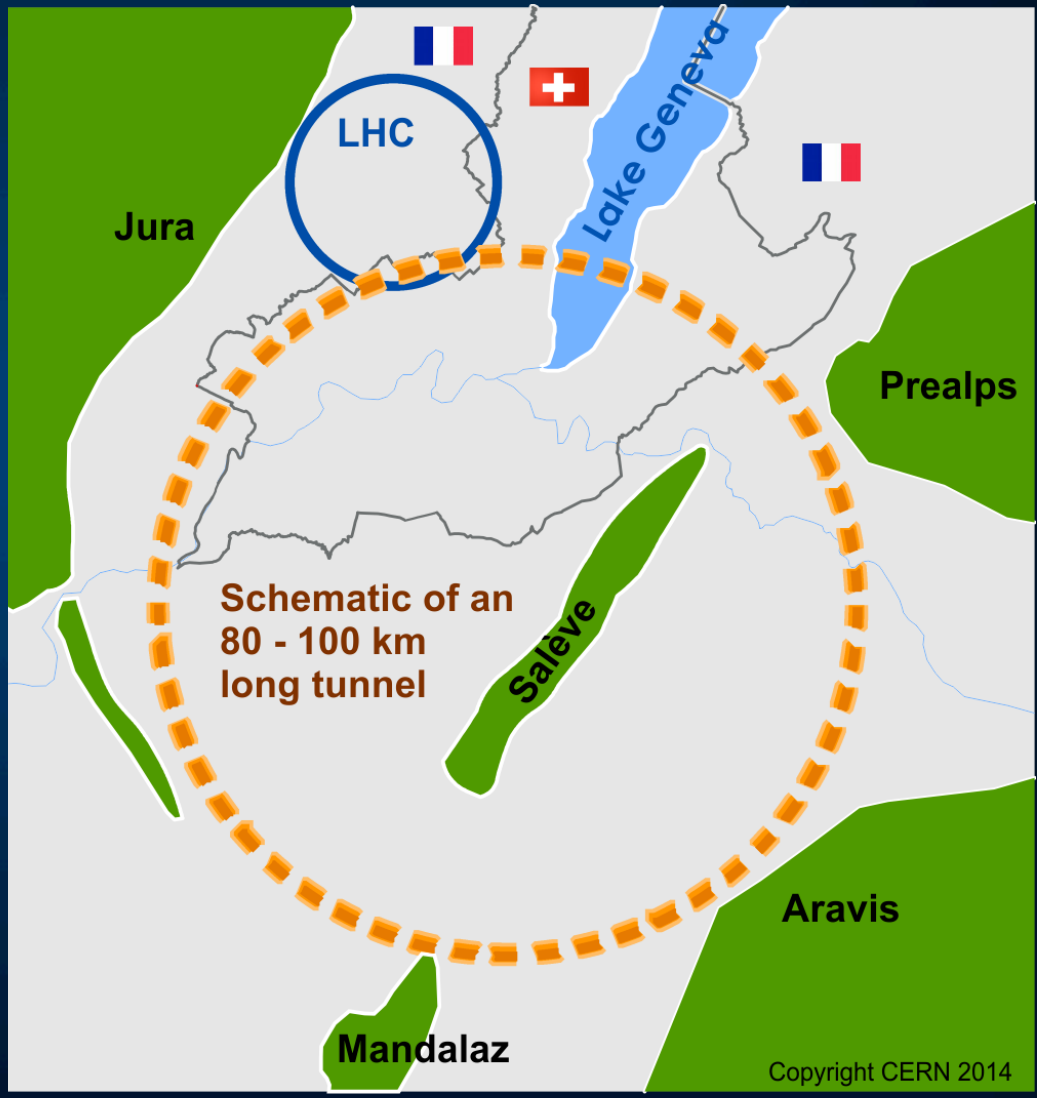


Circular Collider after LHC – FCC (CERN)

FCC = Future Circular Collider

100 km tunnel infrastructure in Geneva area – design driven by pp-collider requirements *with possibility of e+-e- and p-e*



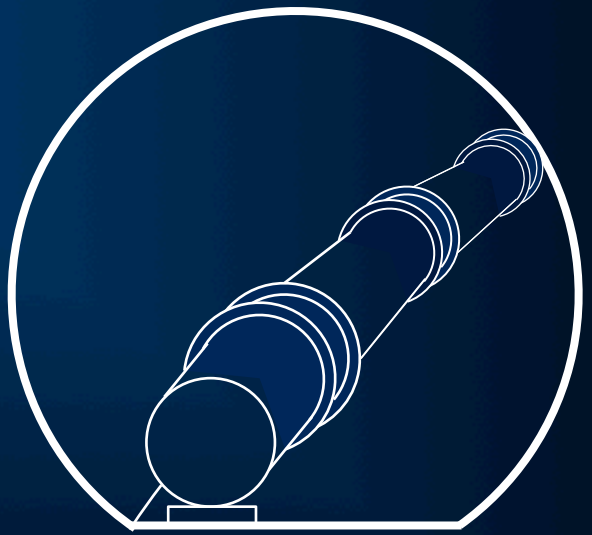
Preliminary parameters (FCC-hh):

CM energy	**100 TeV**
Circumference	**100 km**
Dipole field	**16 Tesla**
Peak Lumi	**5E34 $cm^{-2}s^{-1}$**

TRIZ and challenges of the future colliders

Can TRIZ methodology be applied to a new project with a lot of new challenges such as FCC?

- Many interesting challenges!
- Total energy in the beam 8GJ!



FCC: Energy of each circulating beam above 8GJ (= 1 Airbus 380 at 720km/h)

TRIZ and challenges of the future colliders

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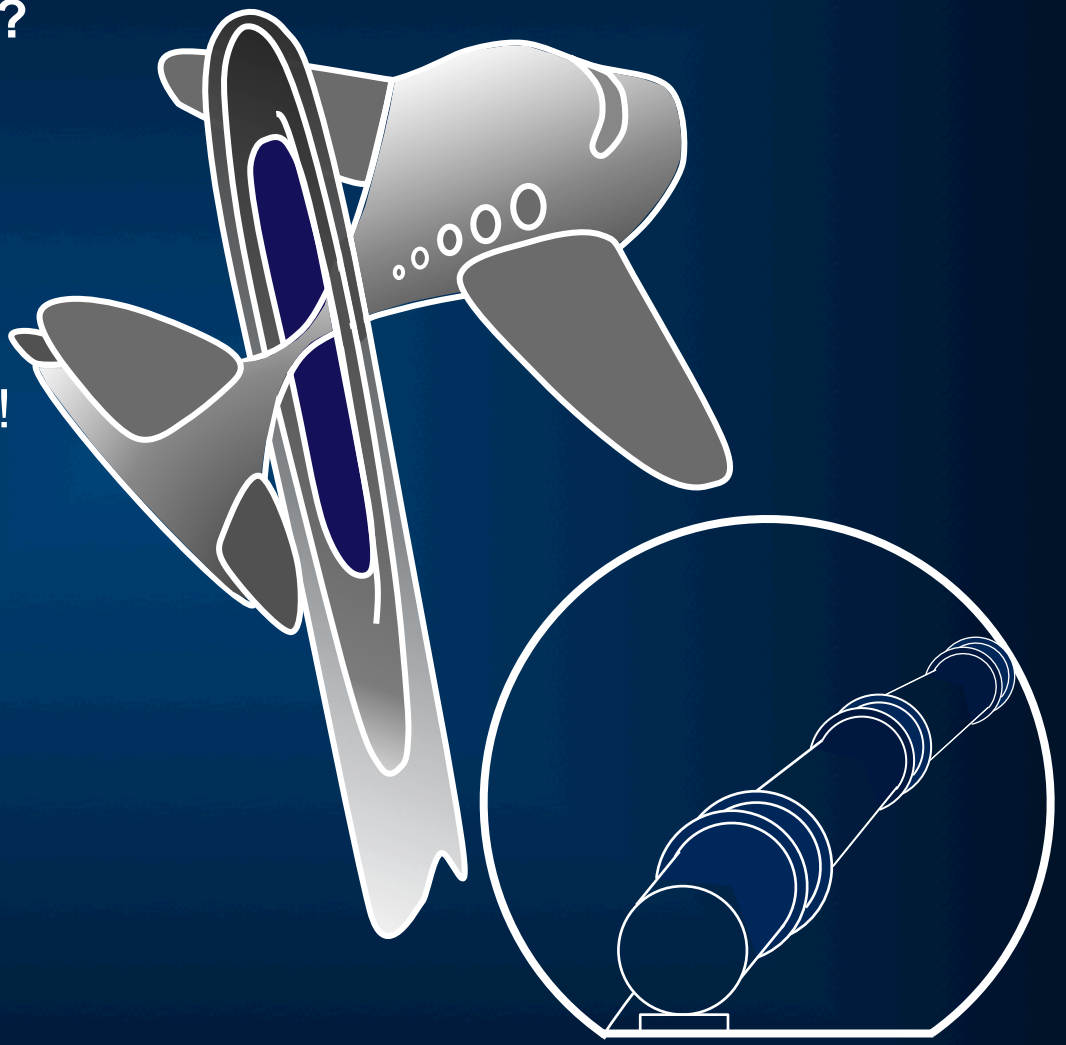

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TRIZ and challenges of the future colliders

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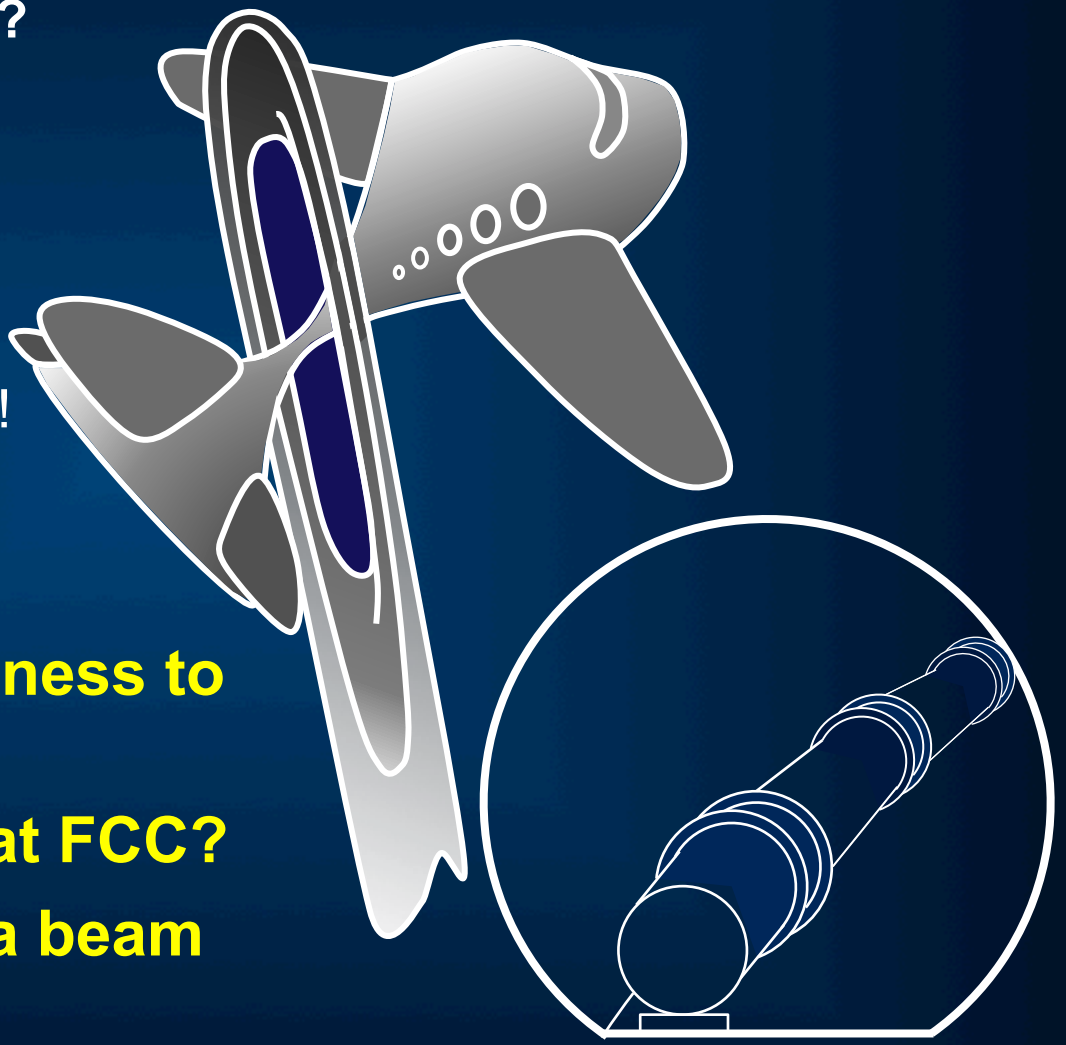


FCC: Energy of each circulating beam above 8GJ (= 1 Airbus 380 at 720km/h)

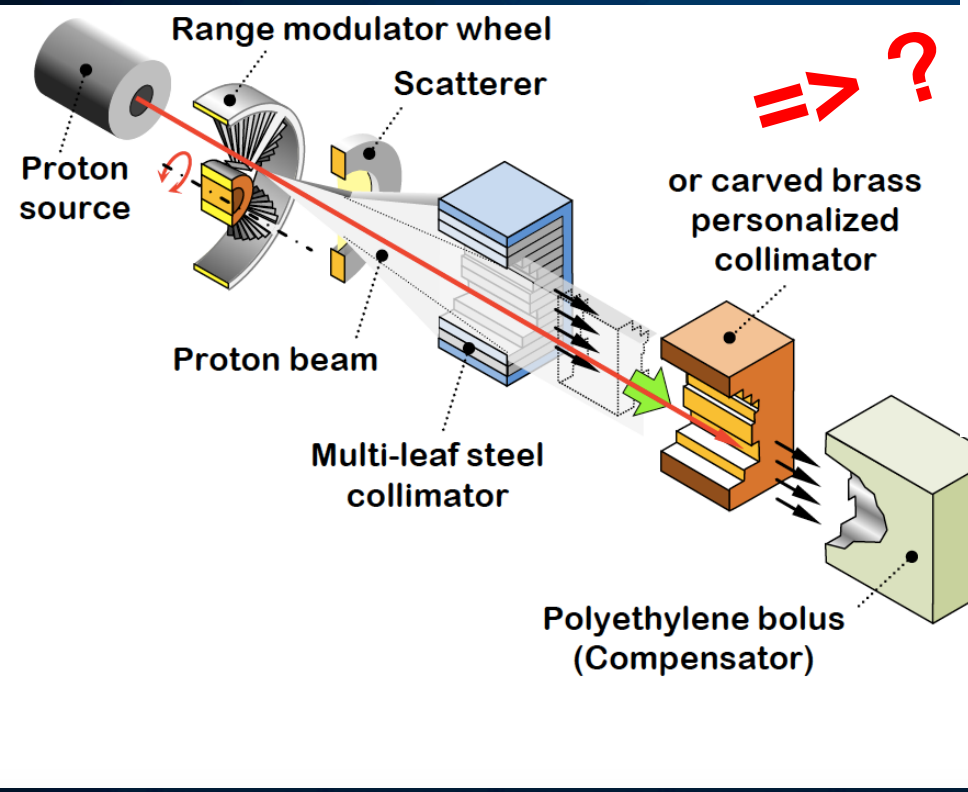
Can we apply our inventiveness to figure out…

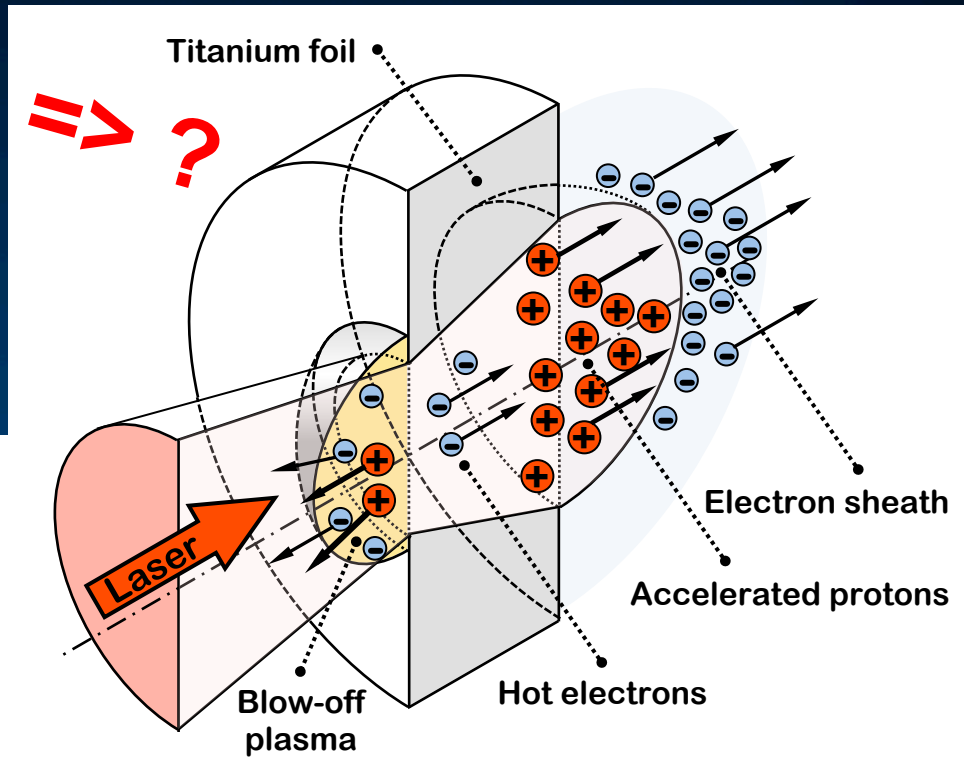
How AWAKE will look like at FCC?

Can we make active plasma beam dump for FCC?

What about e-p plasma collider?

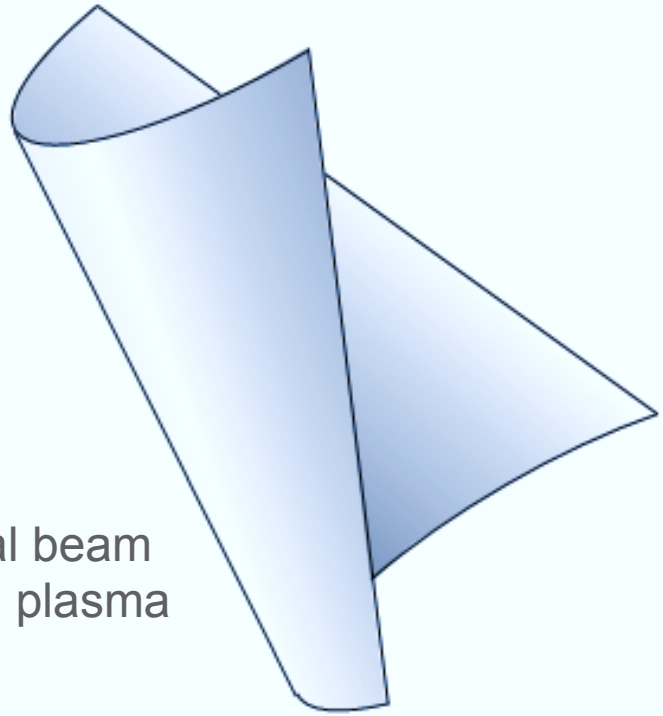
Future p-therapy



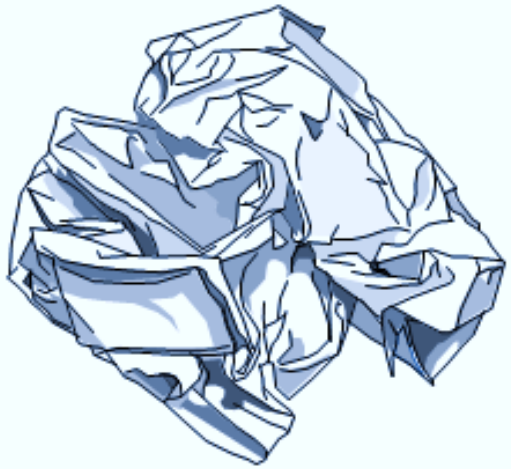


TNSA (RPA, light sail, etc.)

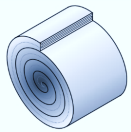
Can TRIZ methodology be applied to help solving the challenges of plasma acceleration driven proton therapy?



Initial beam from plasma acc.



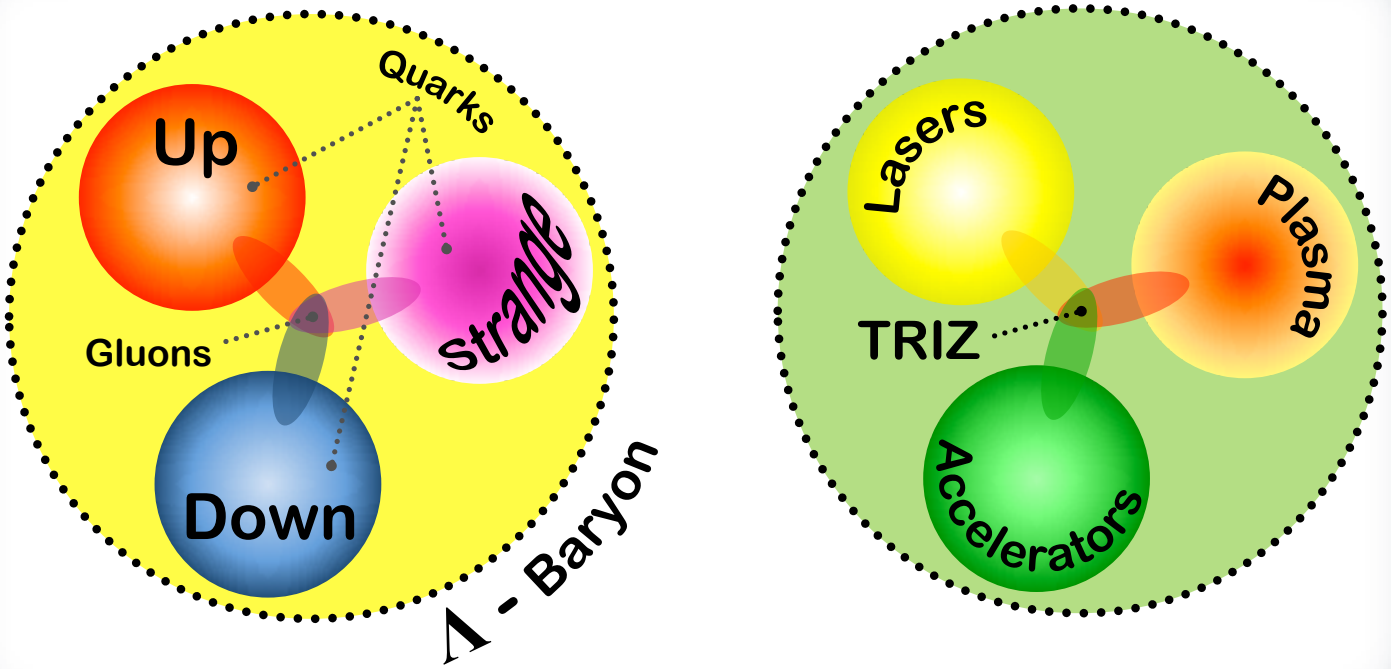
Filamentation – poorly matched beam



Well matched beam

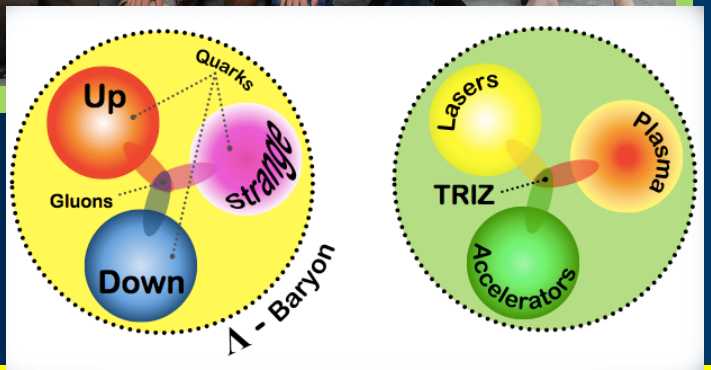
Can we apply our inventiveness to figure out how to capture, match and use the plasma-accelerated beam?

… and the final slides …


Quarks
Up
Strange
Gluons
Down
Λ - Baryon
Lasers
Plasma
TRIZ
Accelerators

http://www.crcpress.com/product/isbn/9781482240580

USPAS 2014
Unifying Physics of Accelerators, Lasers & Plasma

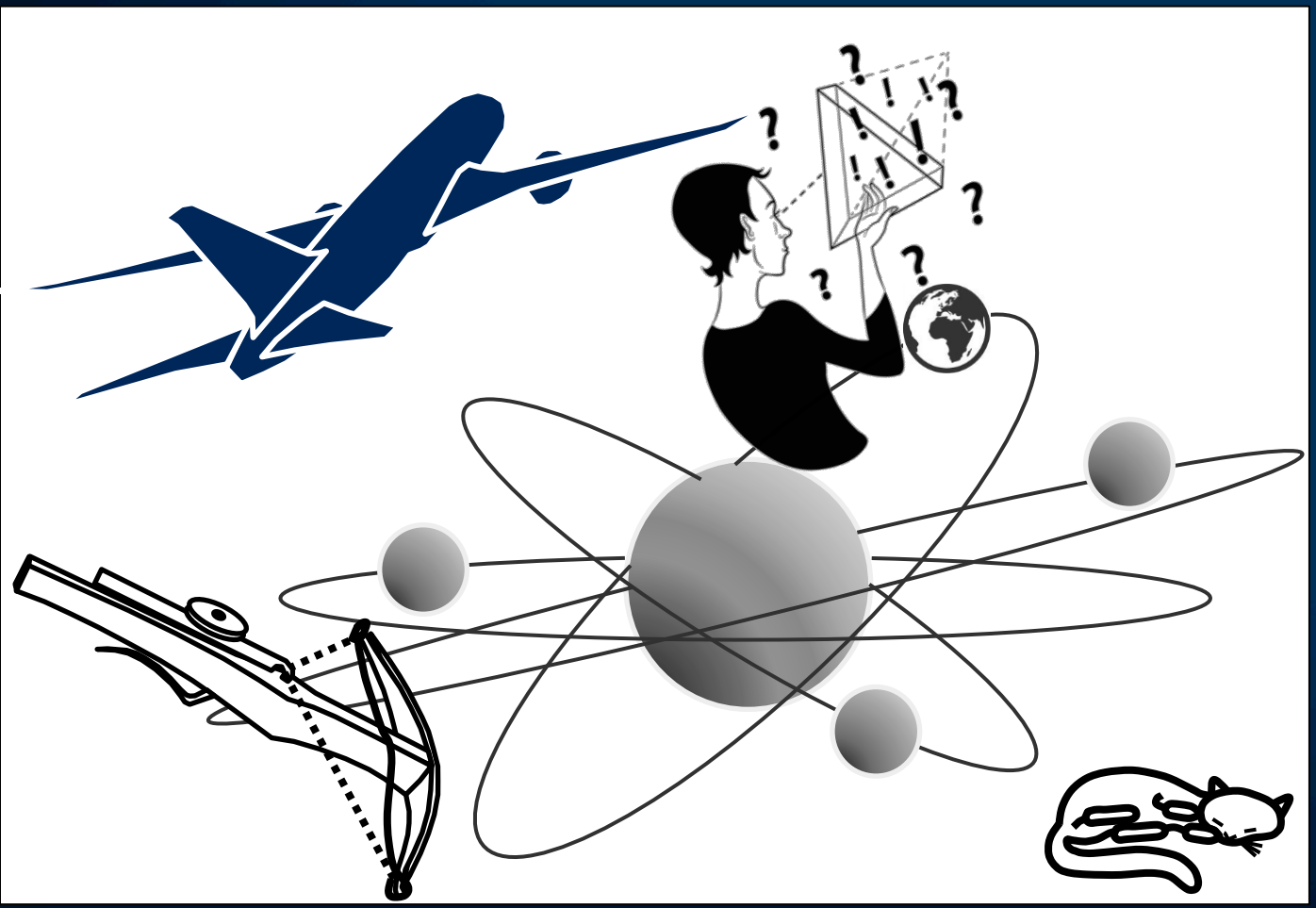


USPAS July 2016
Unifying Physics of Accelerators, Lasers & Plasma

The course will be suitable those who are interested exploring the exciting science arising from synergy of three areas – accelerators, lasers and plasma. We will explore novel laser-plasma acceleration methods comparing them with traditional accelerators. We will study design of national scale as well as compact Free Electron Lasers. We will study what would it take to make a next generation particle therapy facility based on plasma acceleration, studying in meanwhile the effect of radiation on DNA and as well as elements of medical imaging. We will explore the designs of colliders which could be built after LHC. We will highlight similarities and differences of terminology and mathematical apparatus used for description of similar phenomena in these areas of physics, building bridges of understanding between accelerators, lasers and plasma. We will discuss these three areas of physics in tandem with the industrial methodology of inventiveness to connect the areas further, and to stimulate our students for taking on the challenges of scientific and technological innovation.

Thanks to my creative family team!

For many illustrations created for this presentation and for the book



Sasha Seraia

www.sashaseraia.com

Elena Seraia

University of Oxford, Target Discovery Institute

Thank you for your attention!