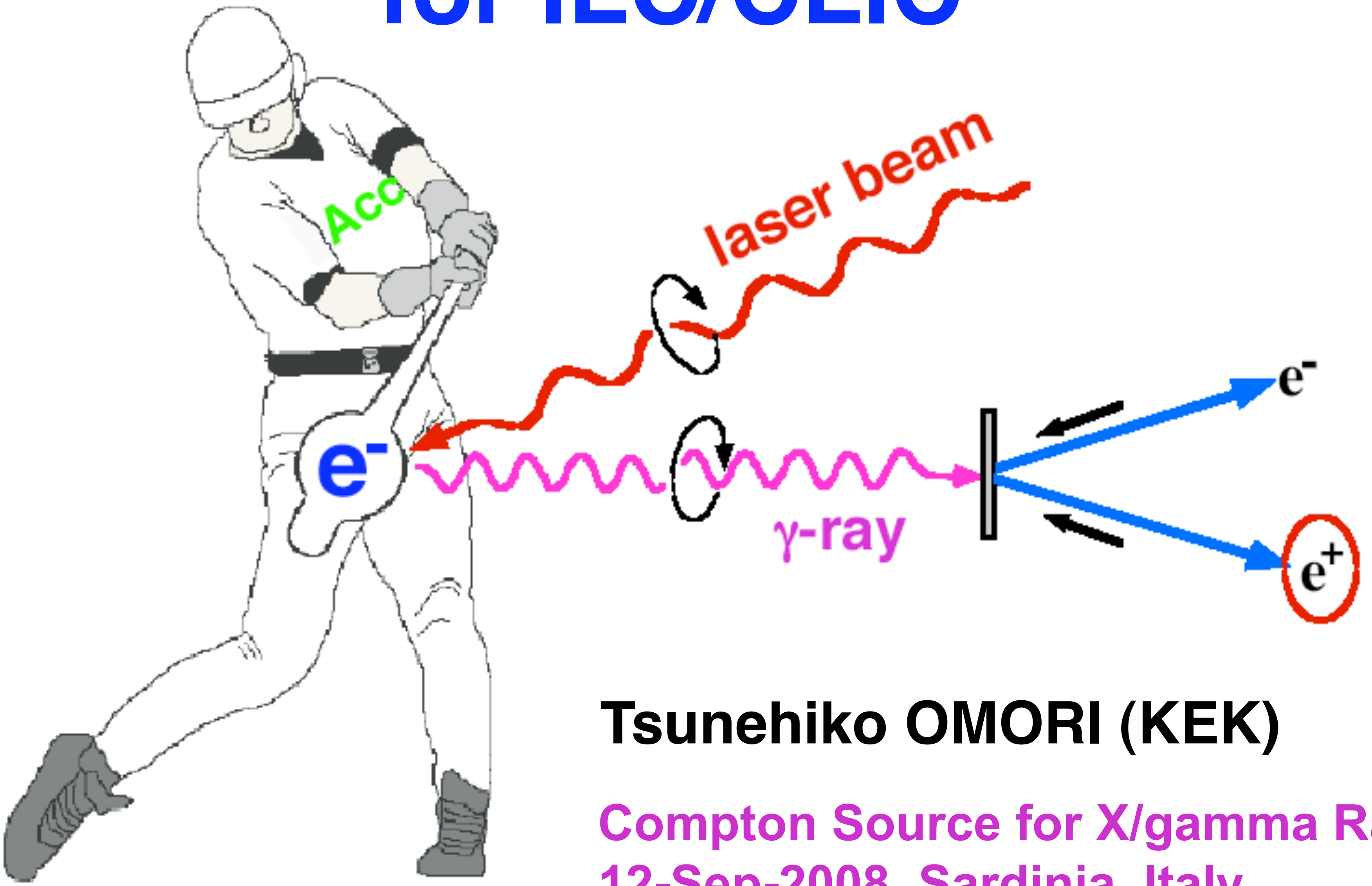
Compton Ring/ERL $\vec{e}^+$ Source for ILC/CLIC



Tsunehiko OMORI (KEK)

Compton Source for X/gamma Rays
12-Sep-2008 Sardinia, Italy

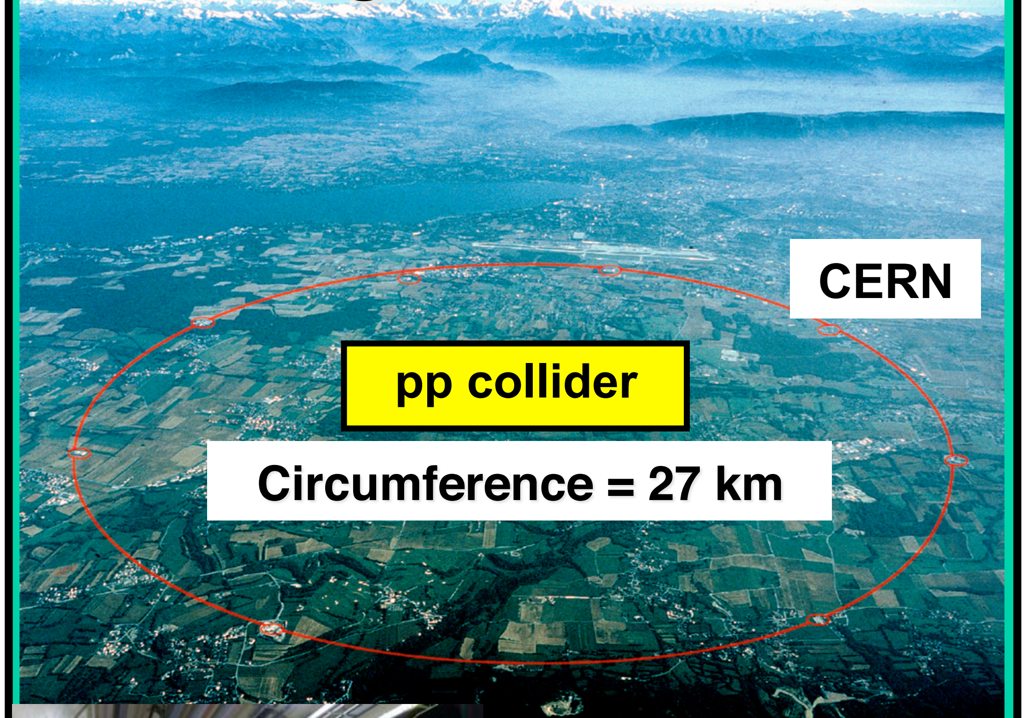
Today's Talk

1. Two Energy Frontier Machines
   LHC and a Linear Collider
2. Why Liner Collider
3. Why Beam Polarization
4. Why Laser-Compton for ILC/CLIC e^+ Source
5. Ring/ERL Compton e^+ Source
6. R/Ds and PosiPol Collaboration
7. Summary

Two
Energy Frontier Machines

Energy Frontier Machines

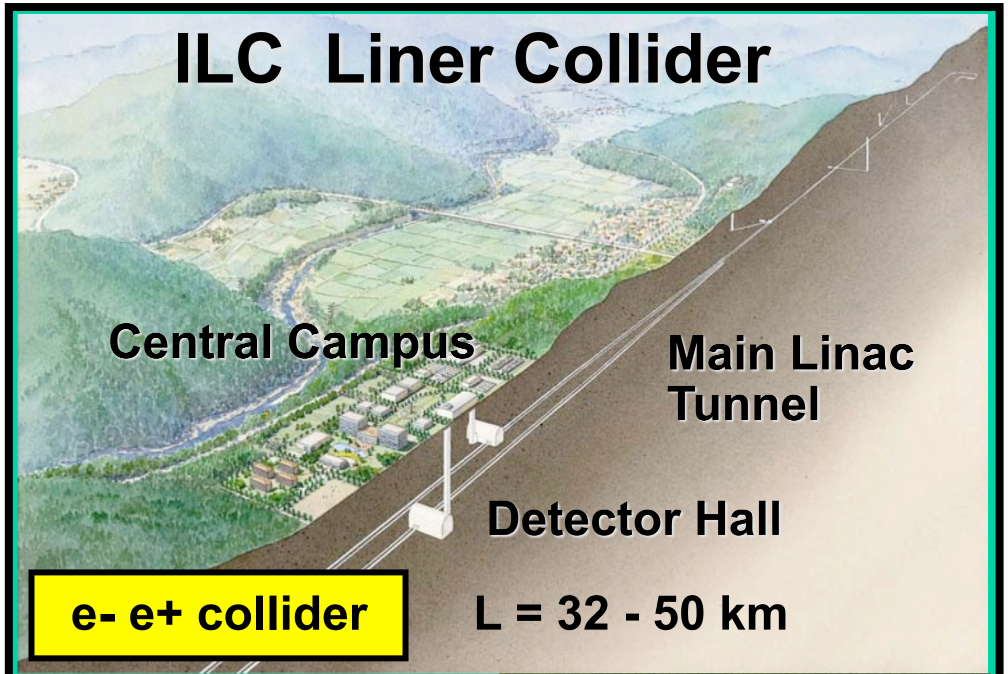
LHC Large Hadron Collider



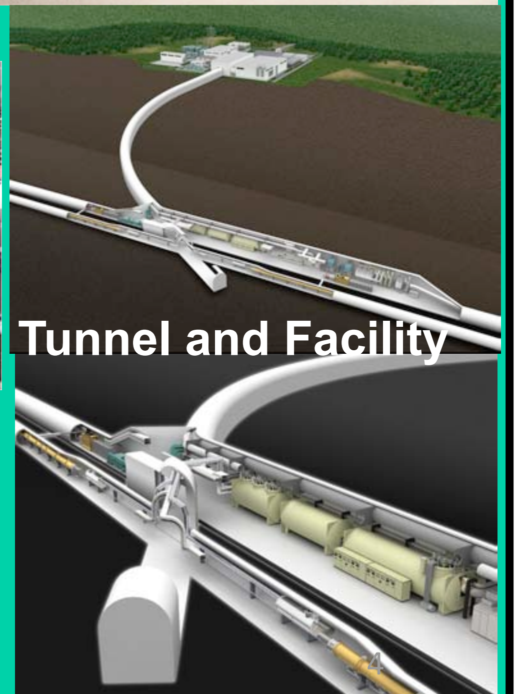
Superconducting Magnets

ATLAS detector
40m x 40 m x 40 m

ILC Liner Collider

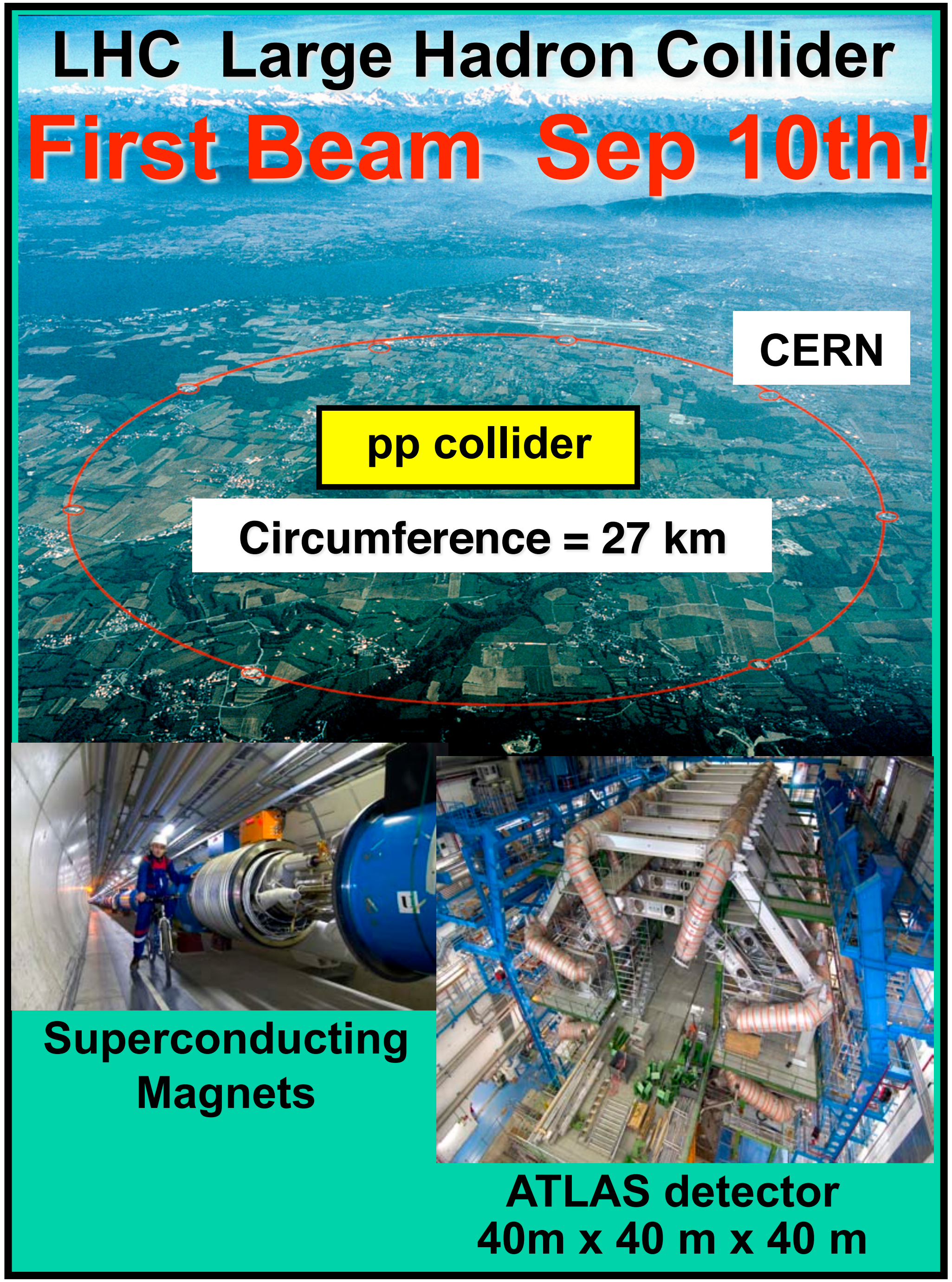


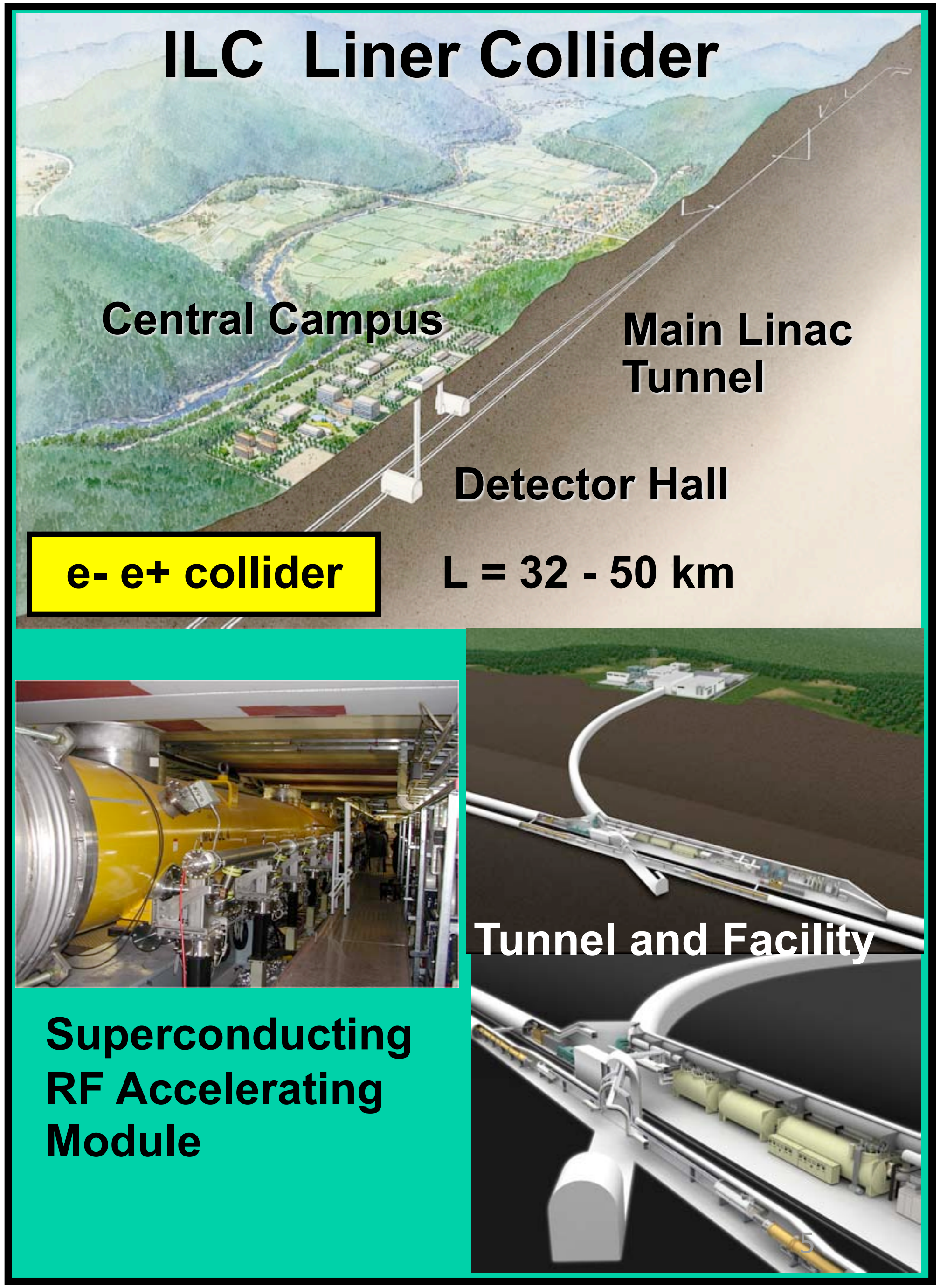
Superconducting RF Accelerating Module



Tunnel and Facility

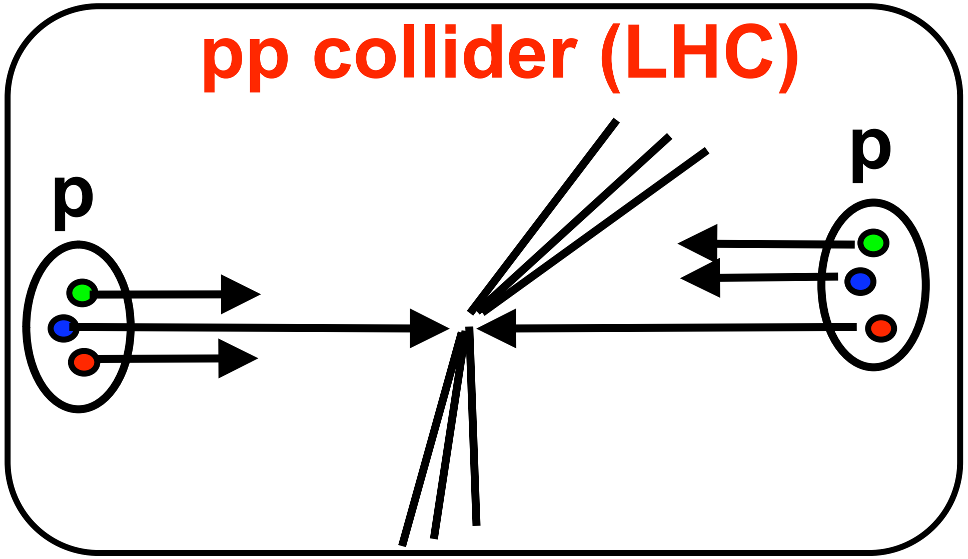
Energy Frontier Machines

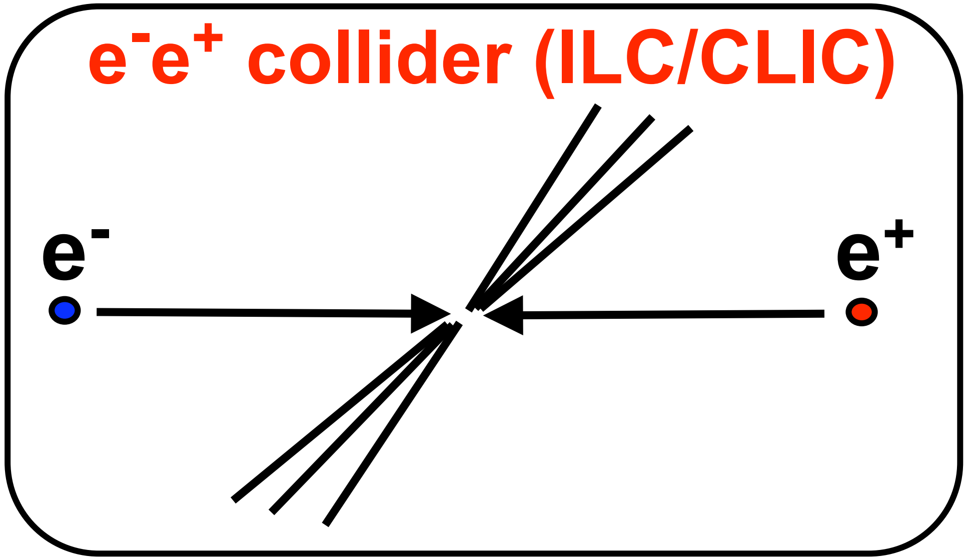




Why Linear Collider

Why we need e^-e^+ collider ?



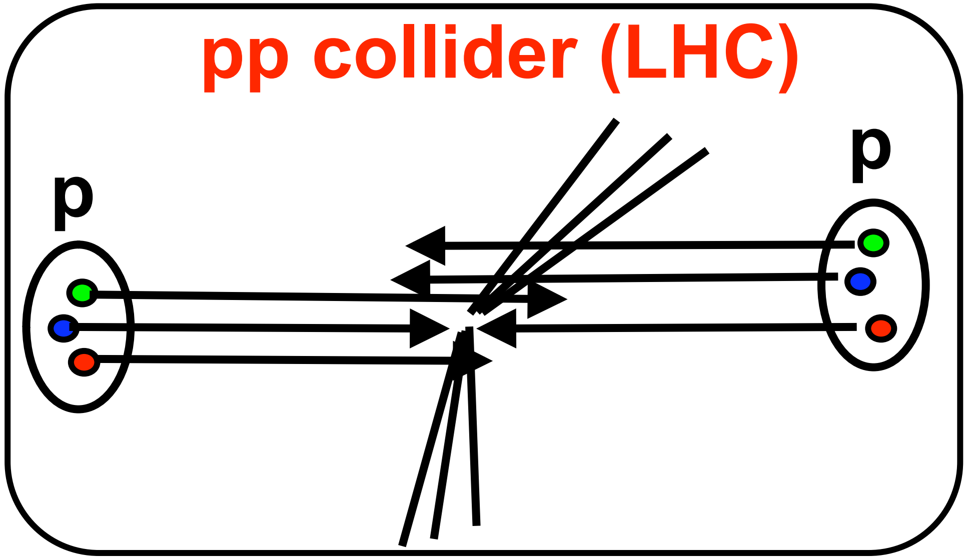


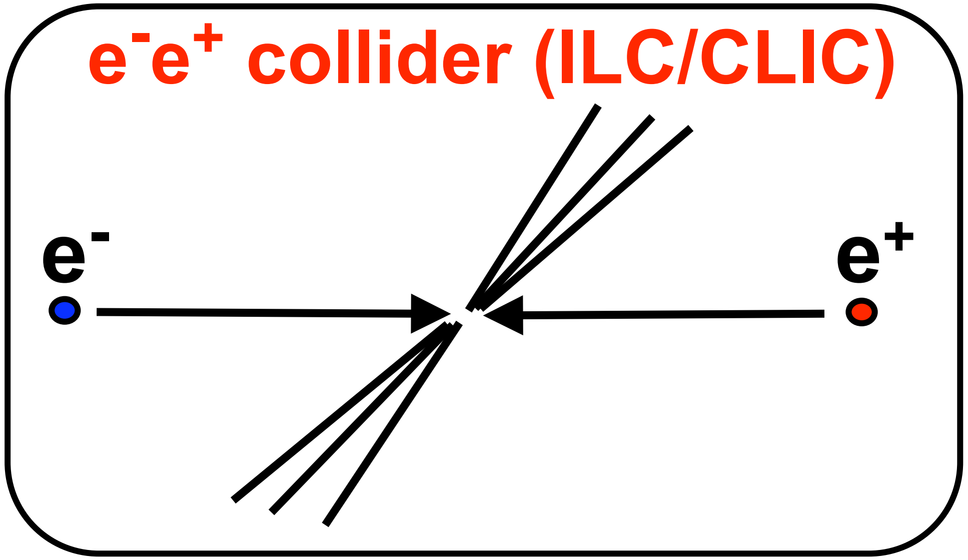
e^-e^+ : elementary particles

CMS energy = 2 x beam energy (well defined)

Total momentum = 0 (balanced)

Why we need e^-e^+ collider ?





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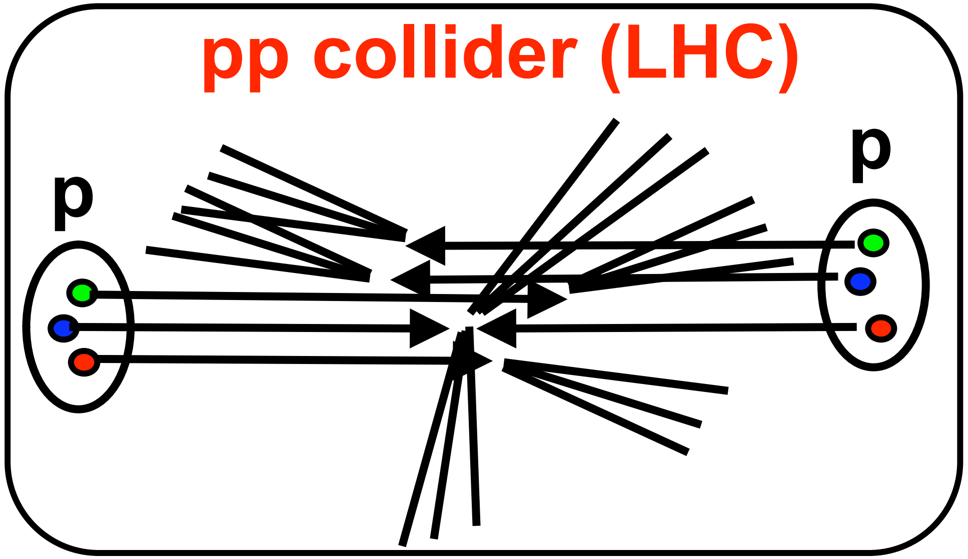

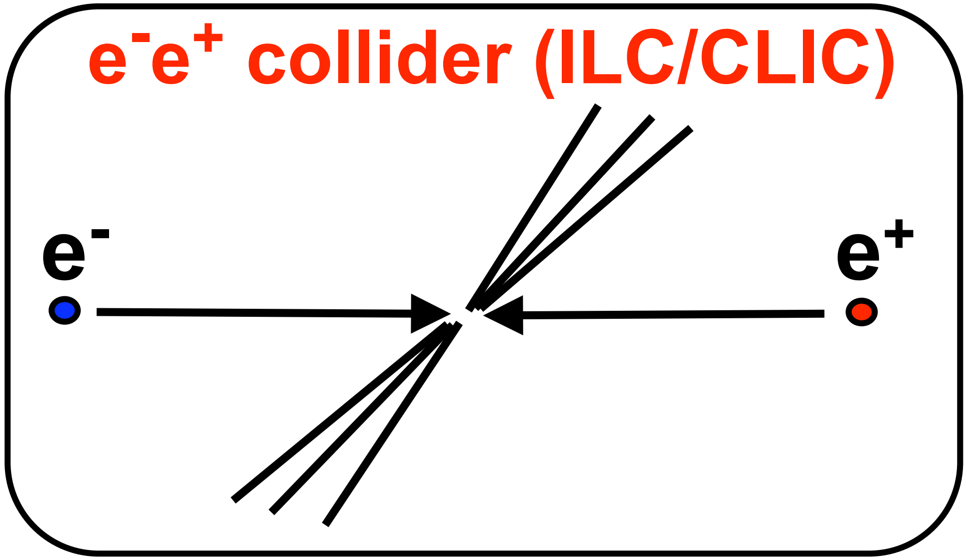

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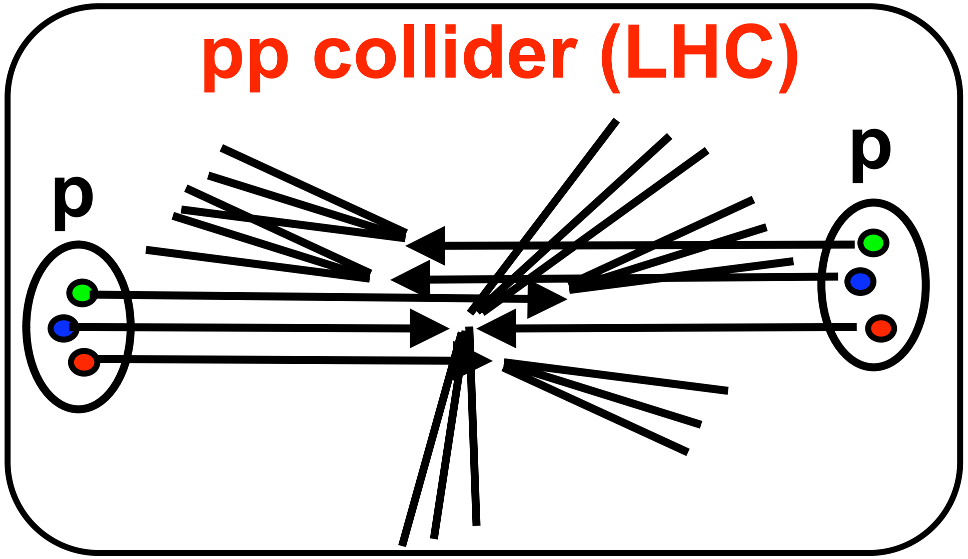

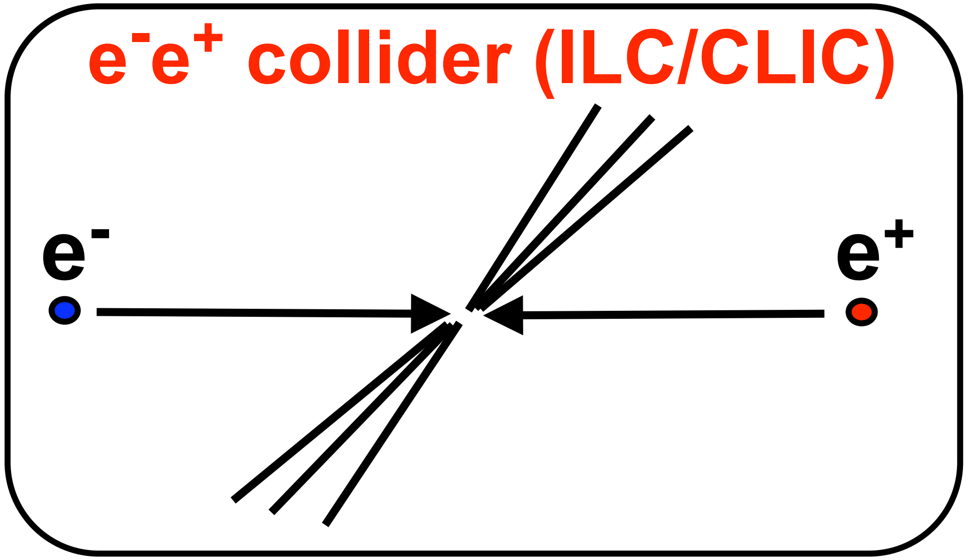

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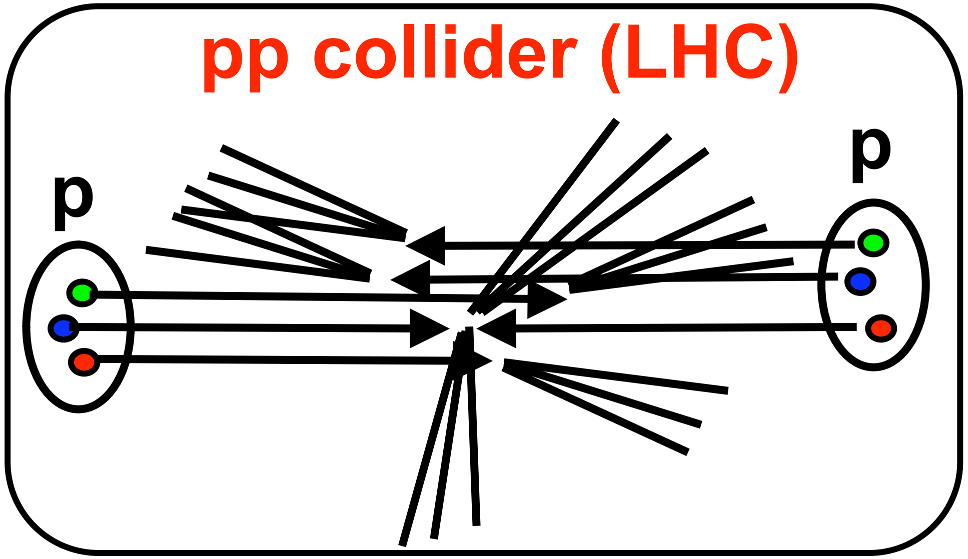
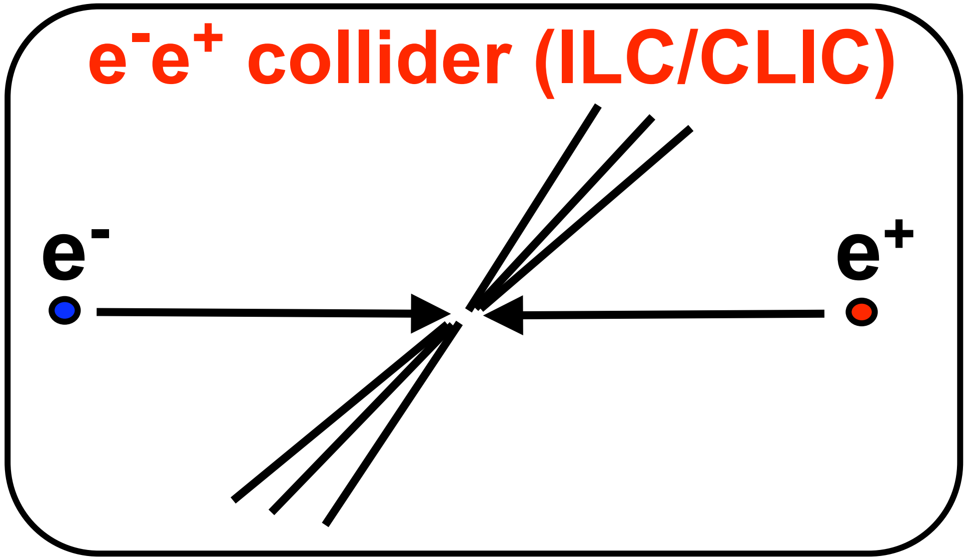
Small back ground

Mostly full reconstruction

Why we need e^-e^+ collider ?





e^-e^+ : elementary particles

CMS energy = 2 x beam energy (well defined)

Total momentum = 0 (balanced)

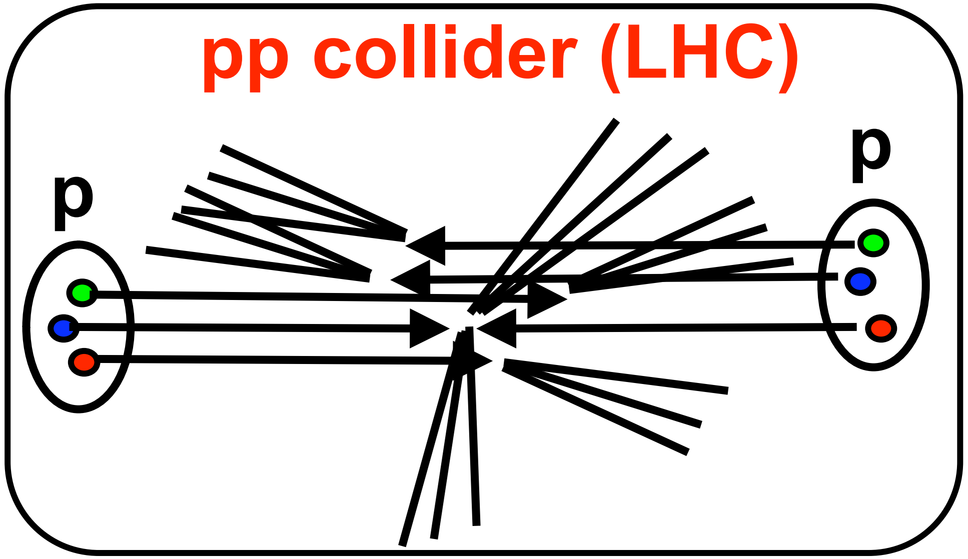
Small back ground

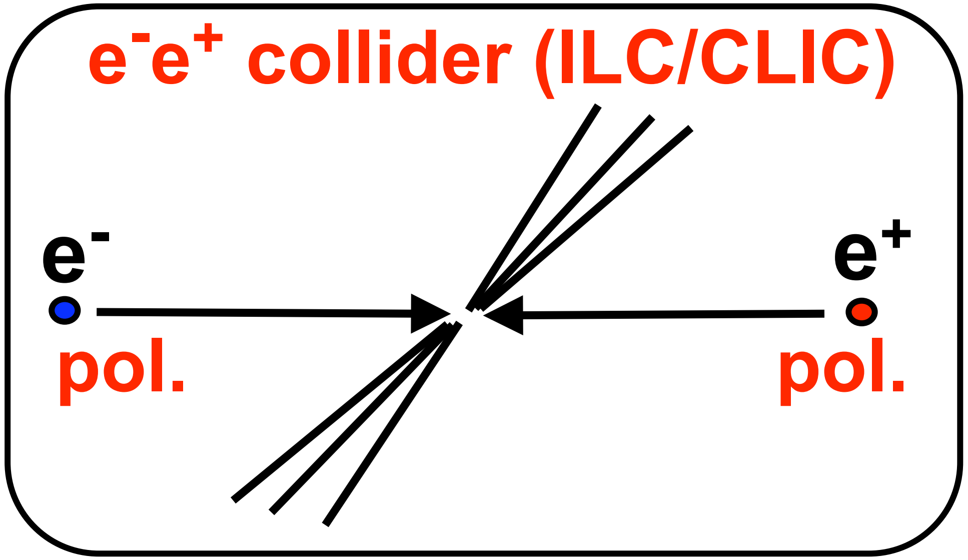
Mostly full reconstruction

Precision data

Reconstruct laws of physics

Why we need e^-e^+ collider ?





e^-e^+ : elementary particles

CMS energy = 2 x beam energy (well defined)

Total momentum = 0 (balanced)

Small back ground

Mostly full reconstruction

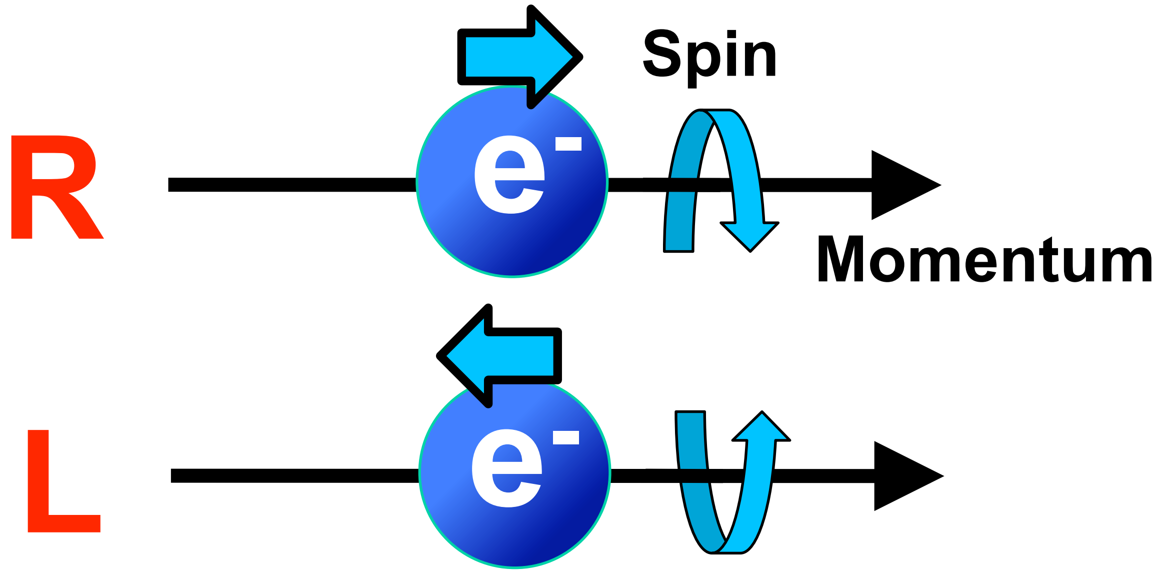
Beam polarization

⇩

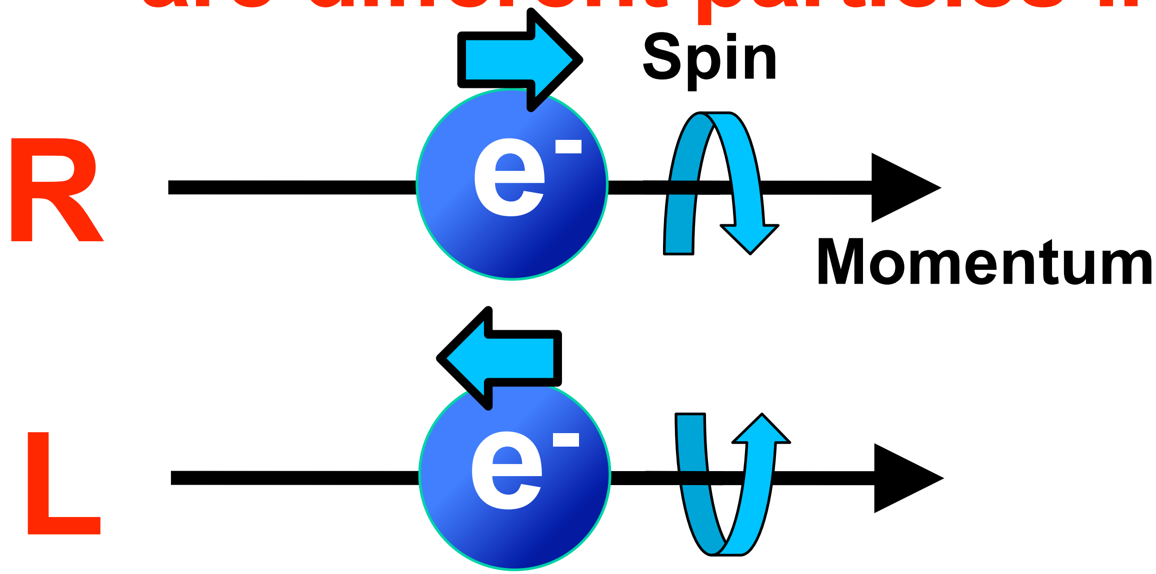
Why polarized beams?

Why Beam Polarization?

R-hand electron (e^-_R) and L-hand electron (e^-_L)



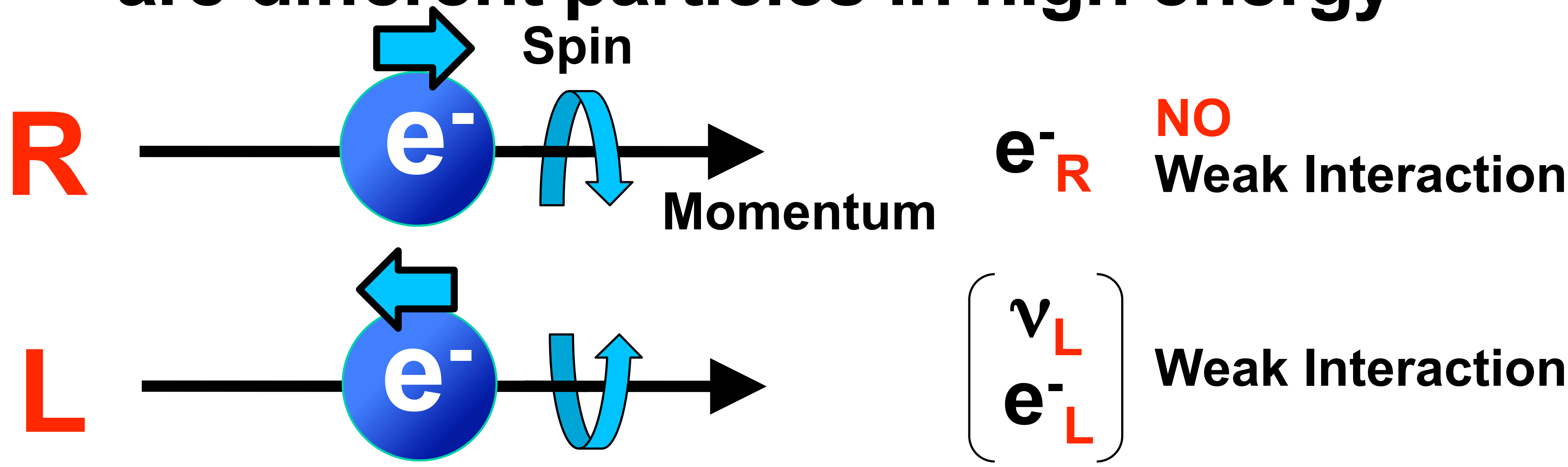
R-hand electron (e^-_R) and L-hand electron (e^-_L) are different particles in high energy



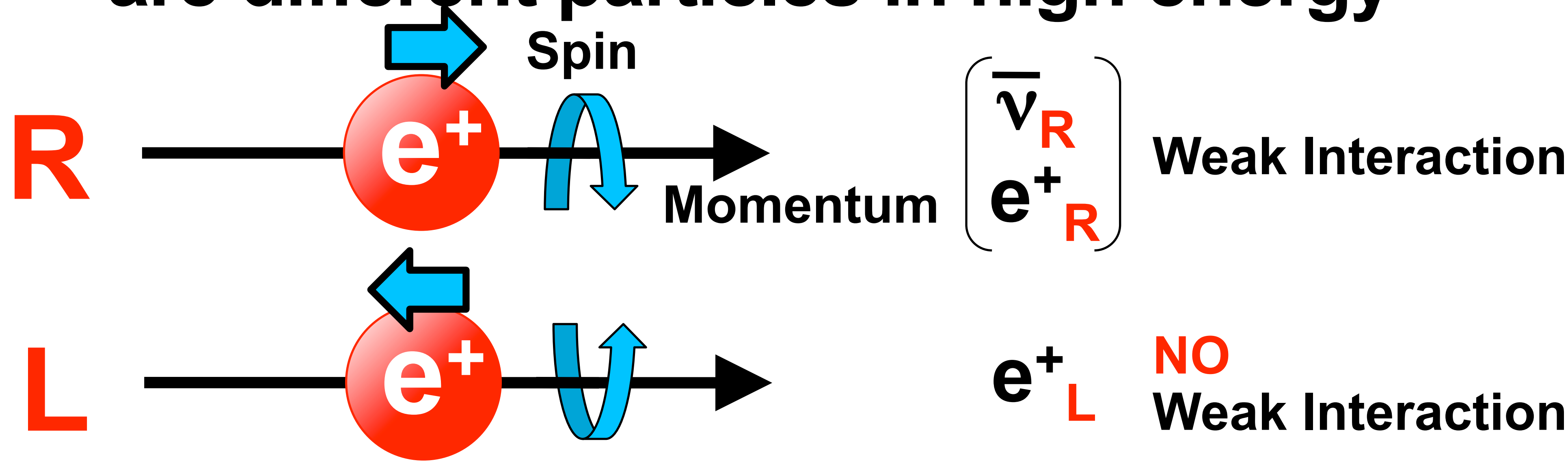
e^-_R NO Weak Interaction

$\begin{pmatrix} \nu_L \\ e^-_L \end{pmatrix}$ Weak Interaction

R-hand electron (e^-_R) and L-hand electron (e^-_L) are different particles in high energy

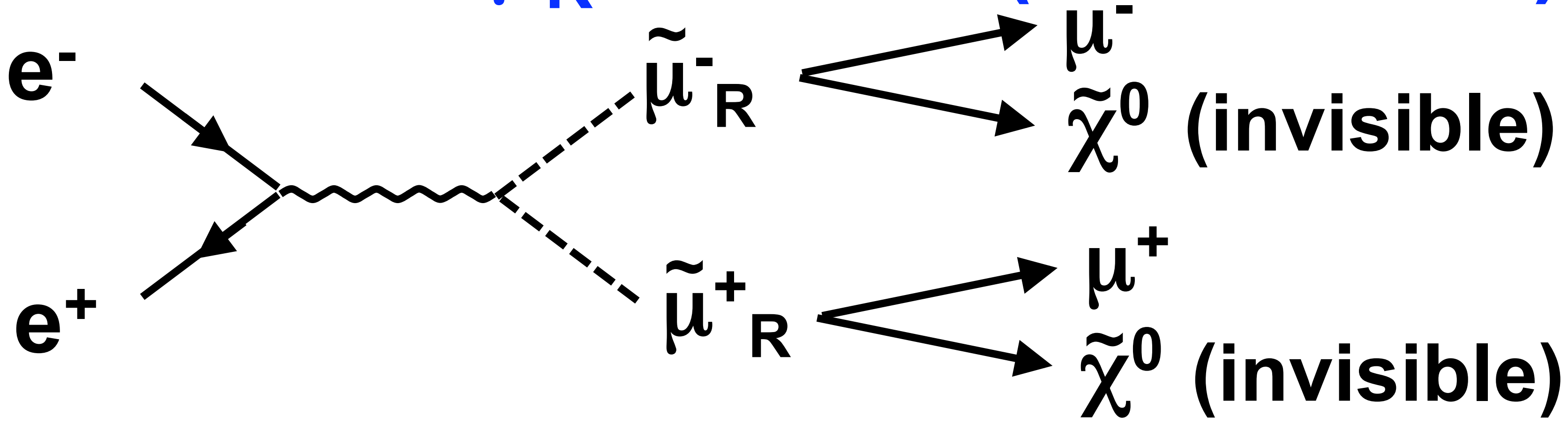


R-hand positron (e^+_R) and L-hand positron (e^+_L) are different particles in high energy



Example : Scaler μ_R search (Min. SUSY)

Signal



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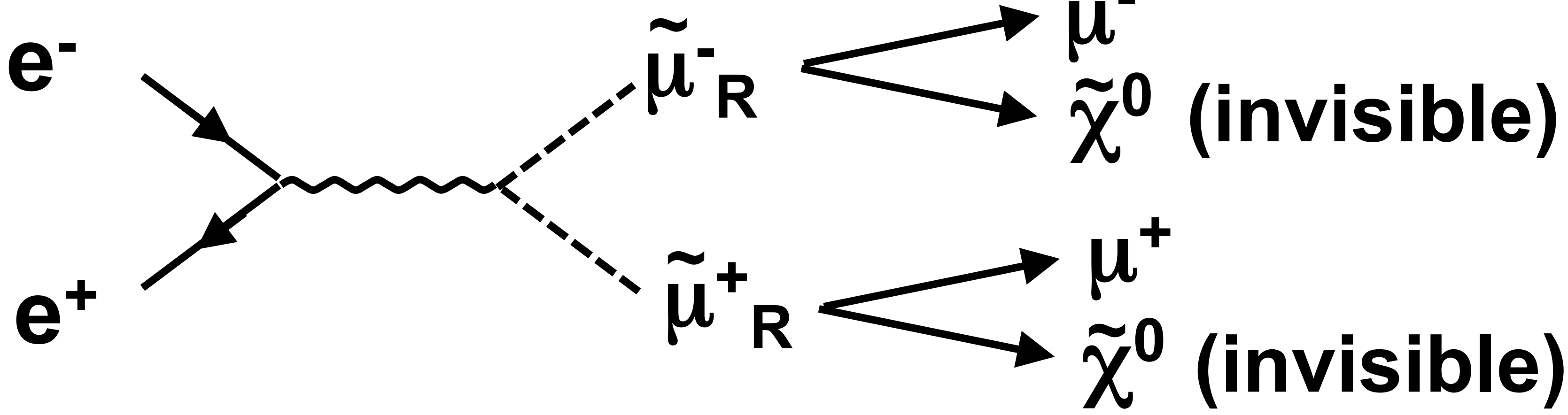
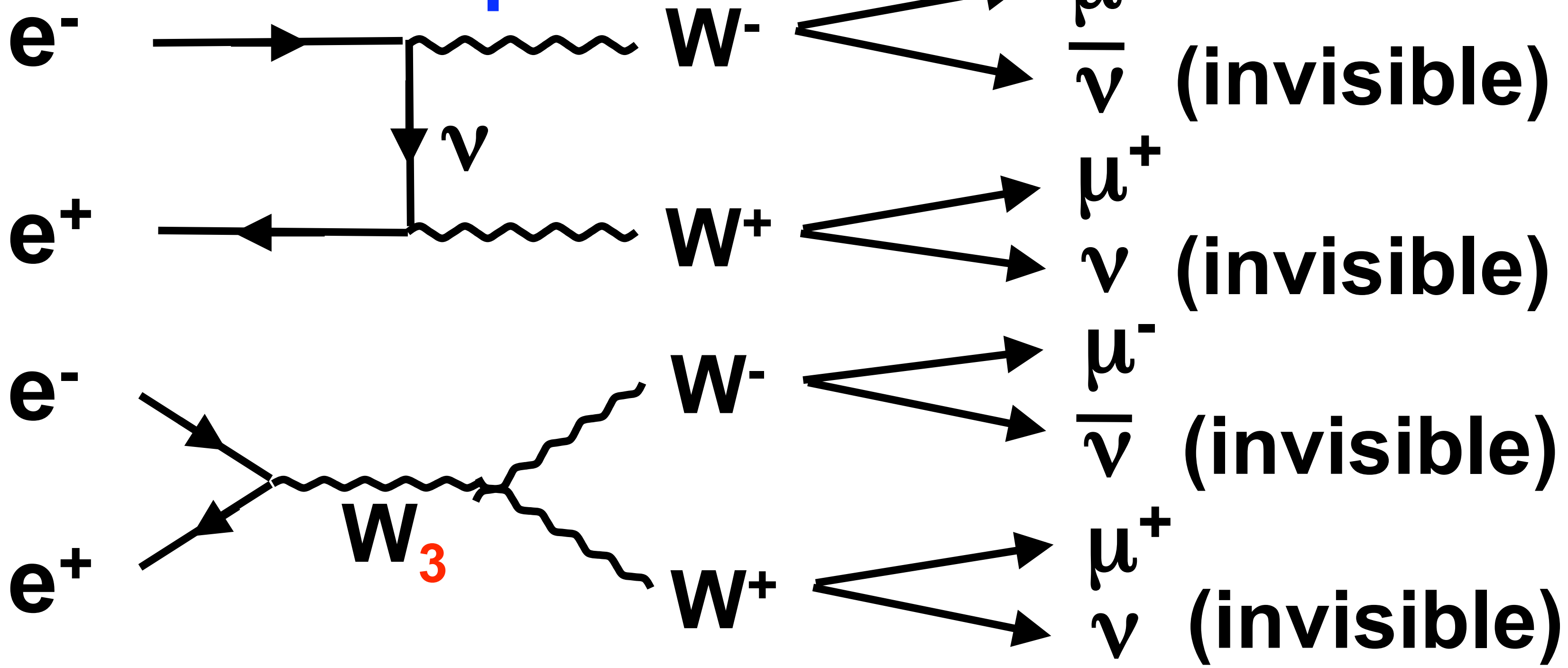


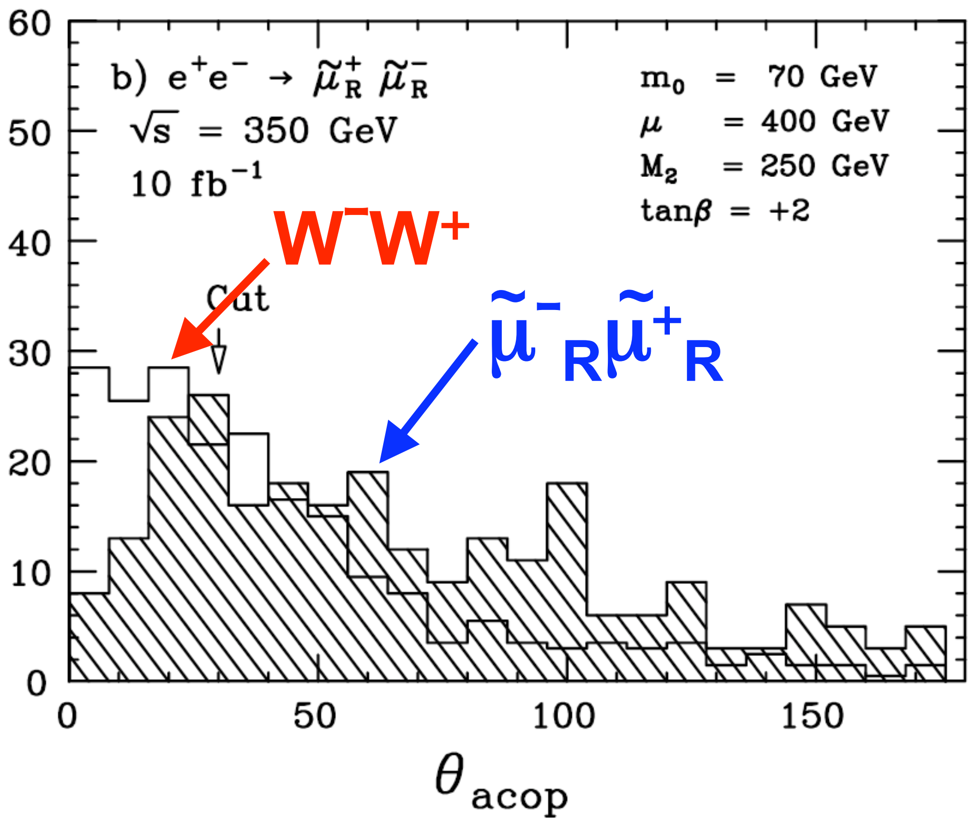
Background : $W^- W^+$ pair



Example : Scaler μ_R search (Min. SUSY)

Monte Carlo Sim.

non pol.



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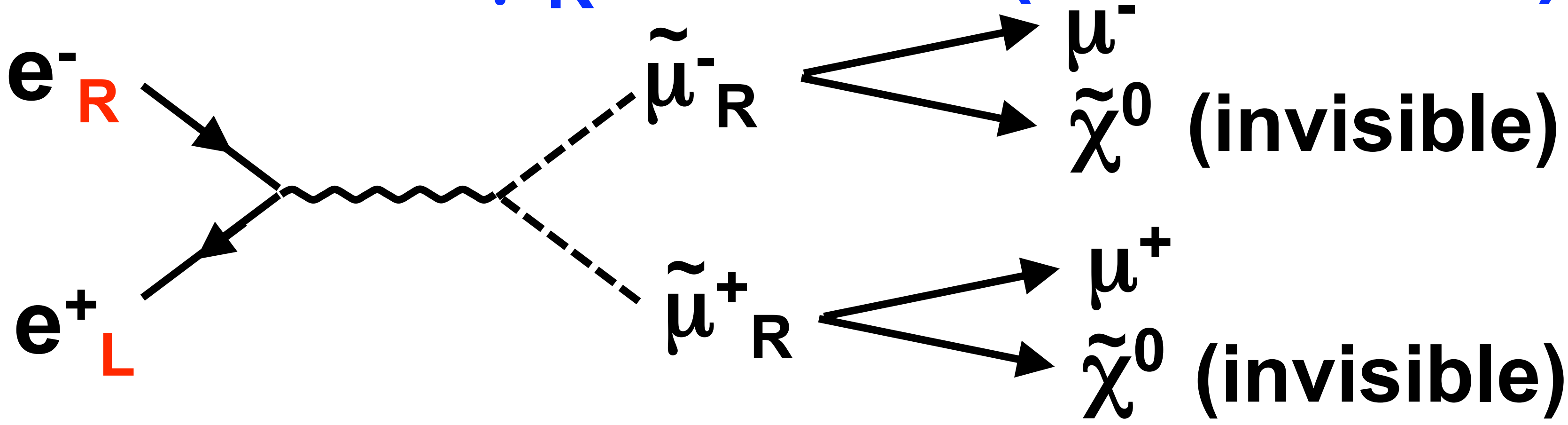

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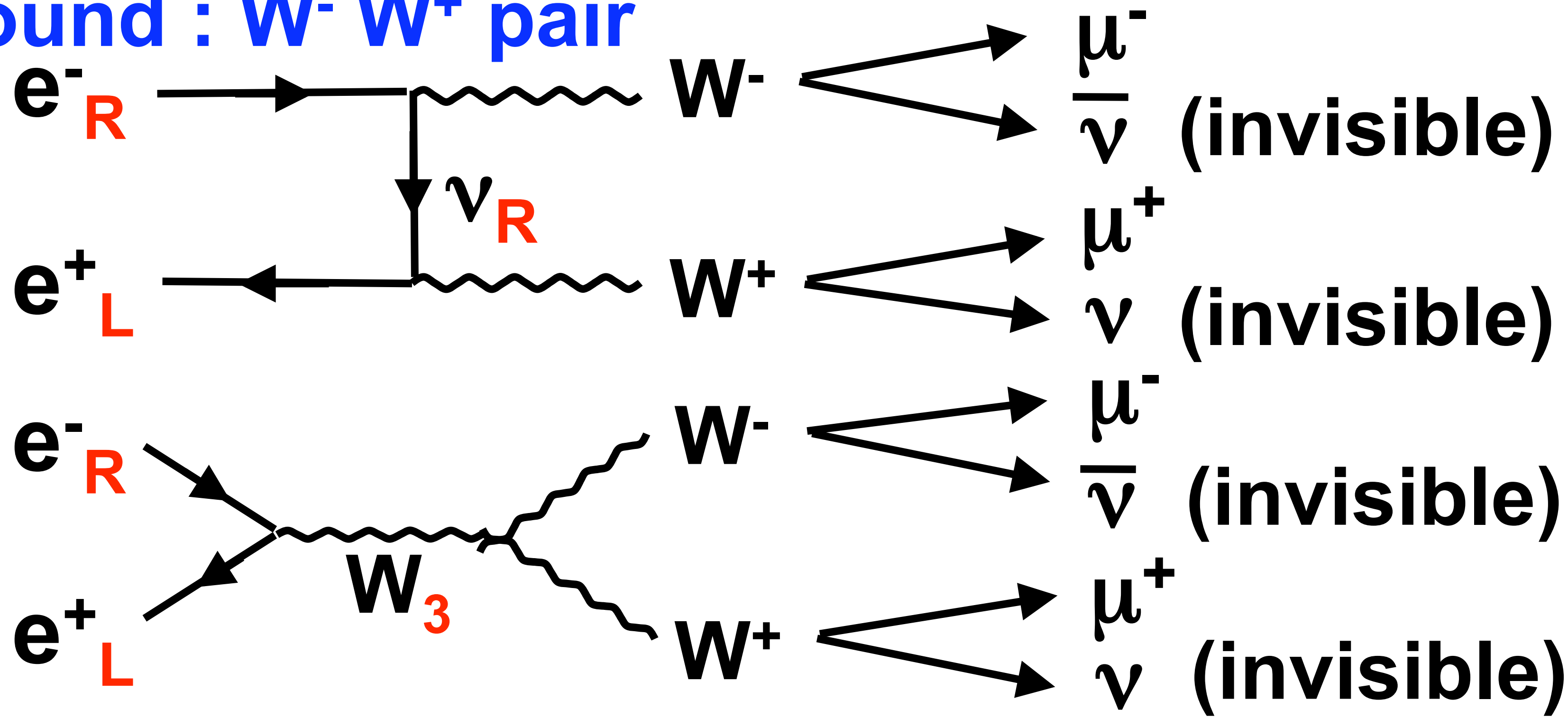

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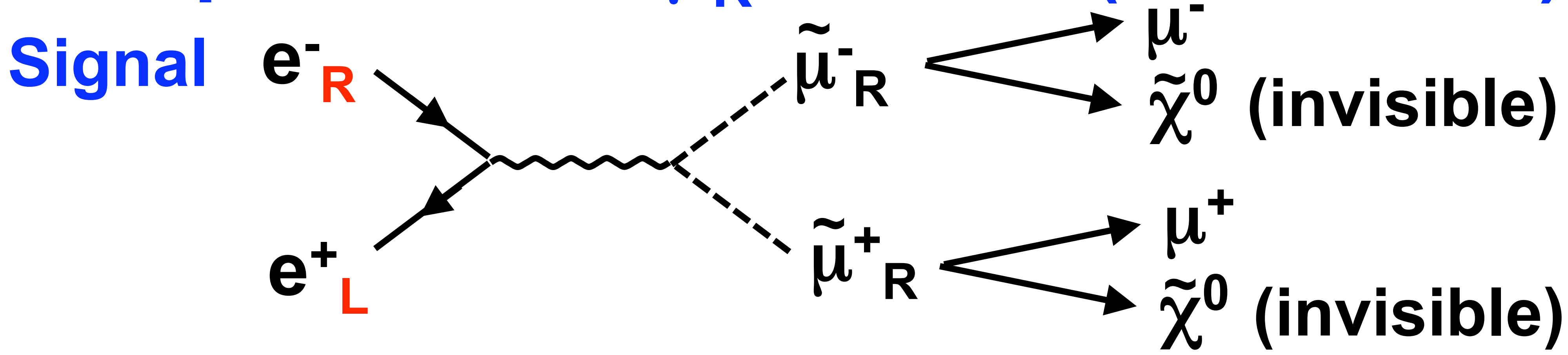

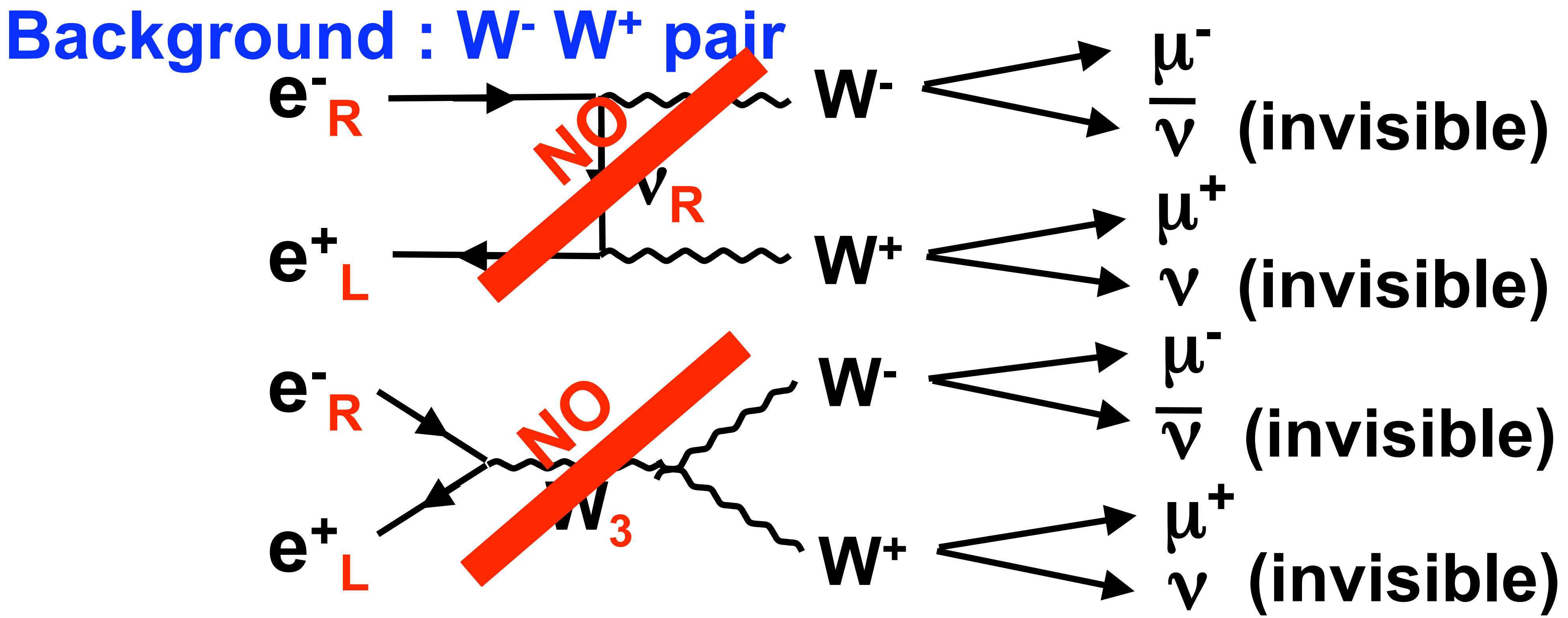

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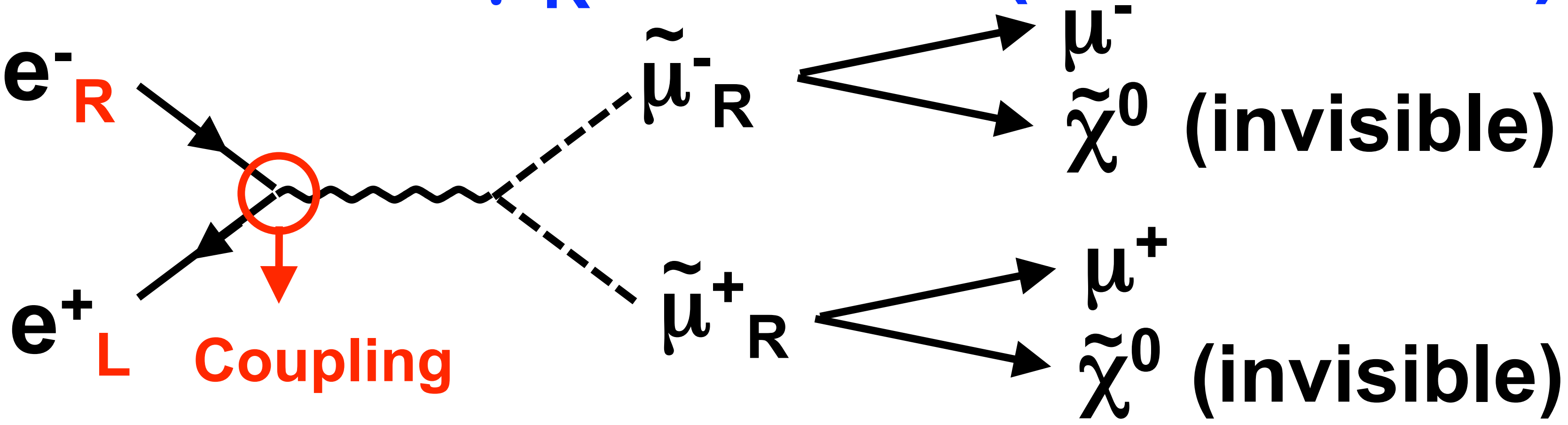
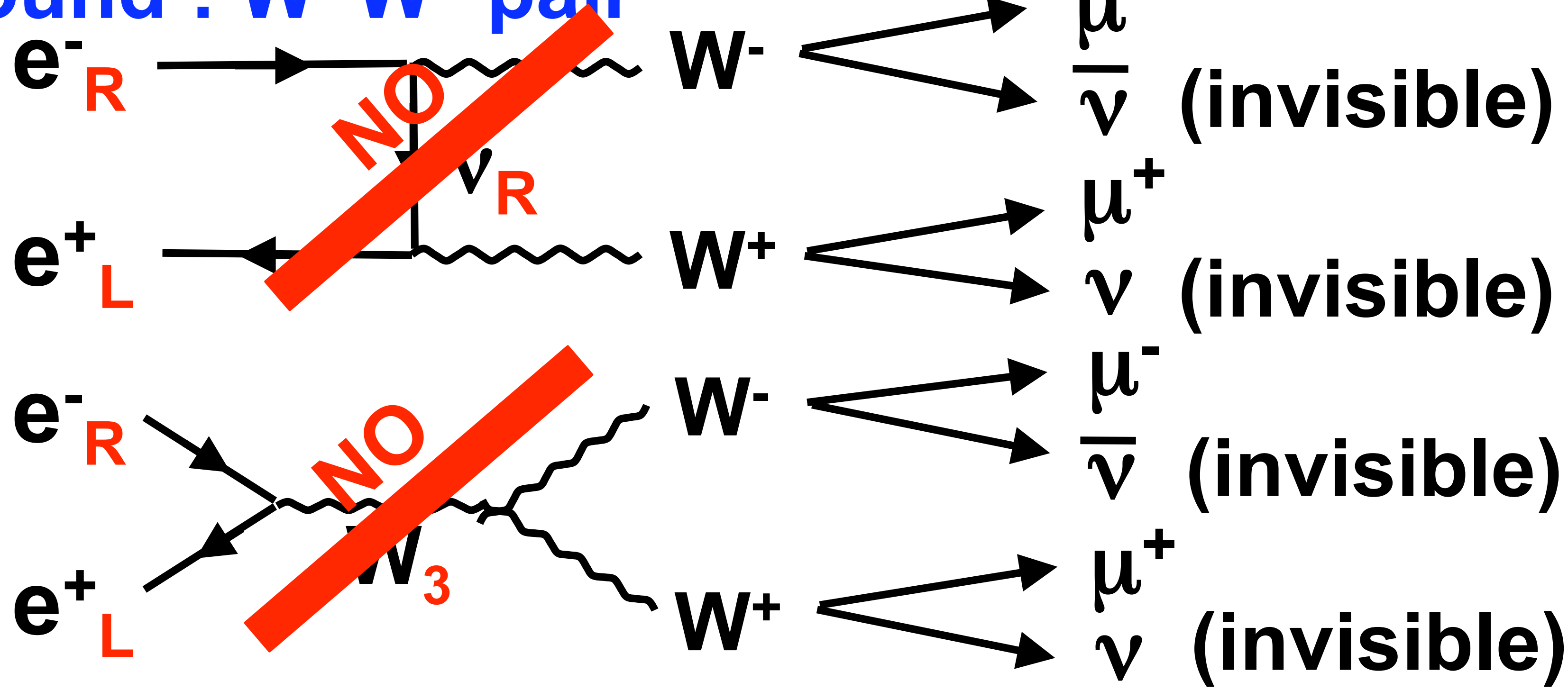


e^-_L e^+_R Y = -1/2 σ = 1

Larger e^-_R e^+_L Y = -1 σ = 4

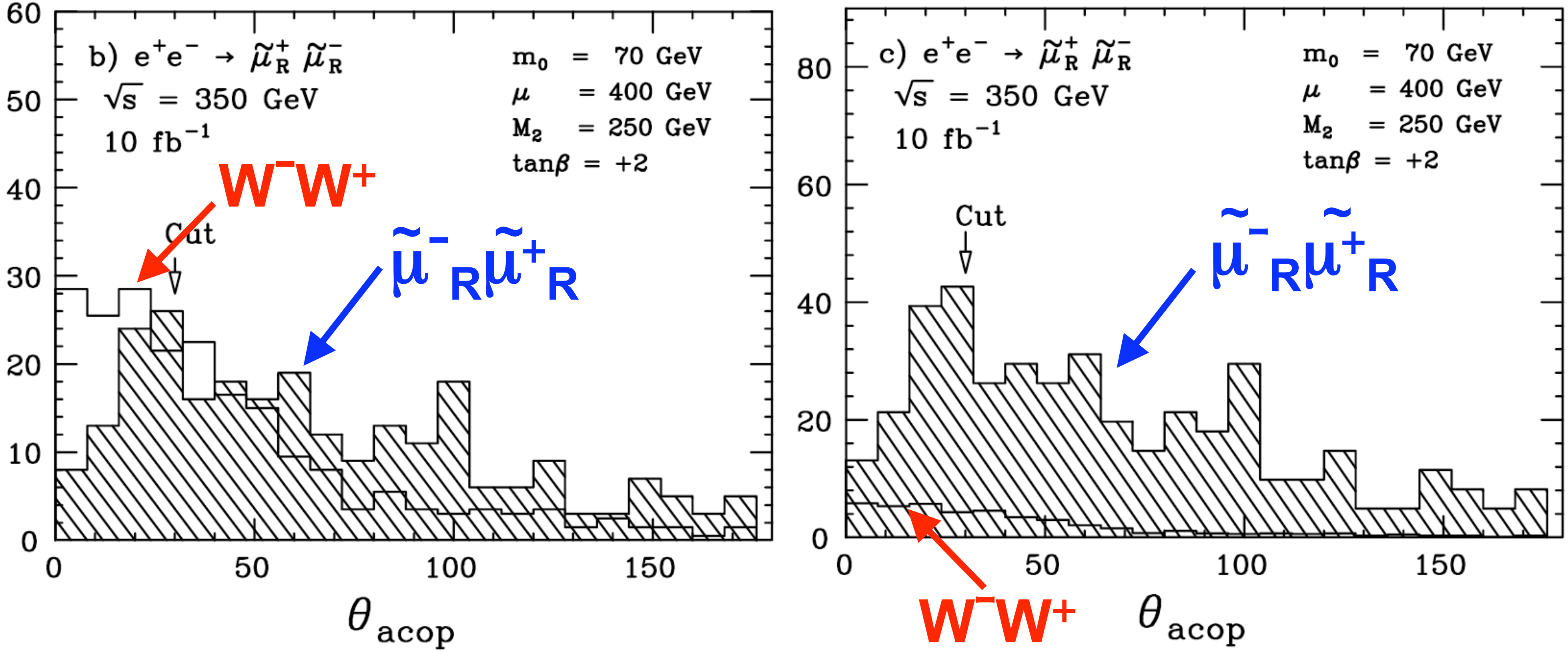
Background : W^- W^+ pair



Example : Scaler μ_R search (Min. SUSY)

Monte Carlo Sim.

non pol. **pol e^- = 80%(R) pol e^+ = 60%(L)**



Why polarized beams ?

(A) In high energy,

e^-_R and e^-_L are different particles

e^-_R NO Weak Interaction

$\begin{pmatrix} \nu_L \\ e^-_L \end{pmatrix}$ Weak Interaction

e^+_R and e^+_L are different particles

$\begin{pmatrix} \bar{\nu}_R \\ e^+_R \end{pmatrix}$ Weak Interaction

e^+_L NO Weak Interaction

(B) Chose initial state ($e^-_R e^+_L$, $e^-_L e^+_R$, ...)

(1) Suppress background (esp. e^-e^+ -> W^-W^+)

(2) Enhance specific int.

(3) Control angular dist. of final state

(4) Determine weak mix of the final

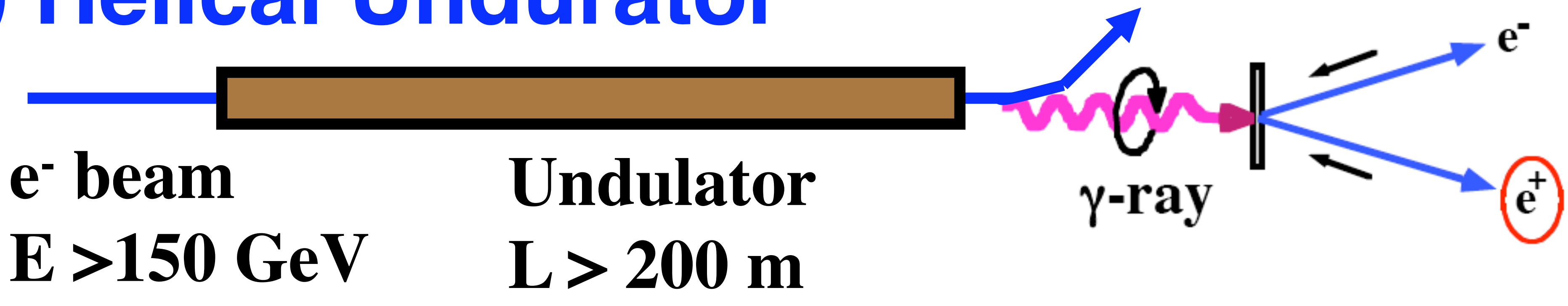
(5) Reduce sys. errors

(6) Study why nature chose (A) (hint neutrino osc.)

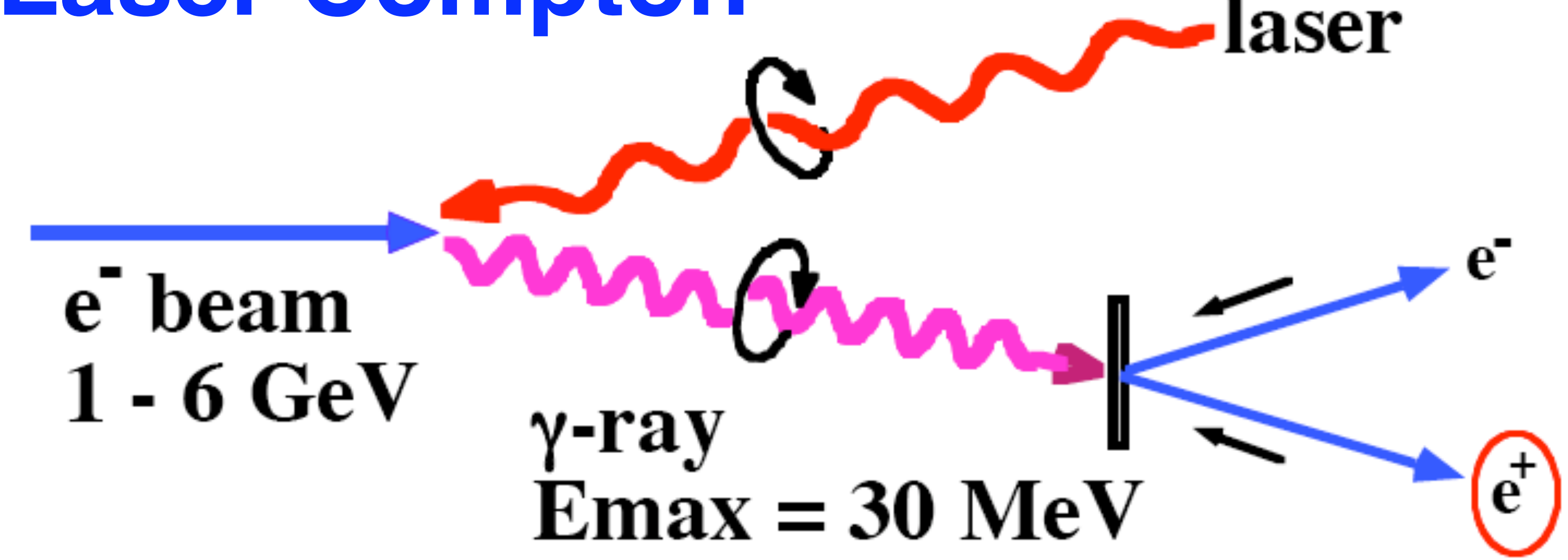
Why Laser-Compton for ILC/CLIC e^+ source

Two ways to get pol. e^+

(1) Helical Undurator



(2) Laser Compton



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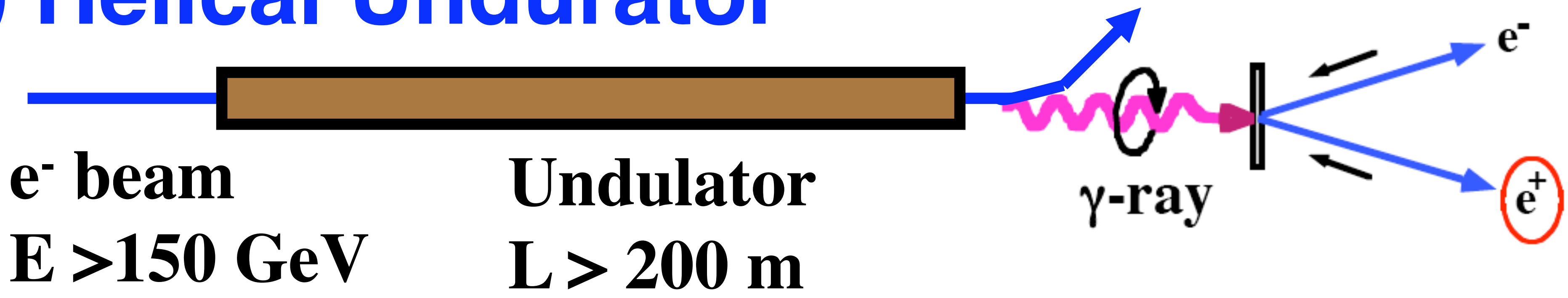
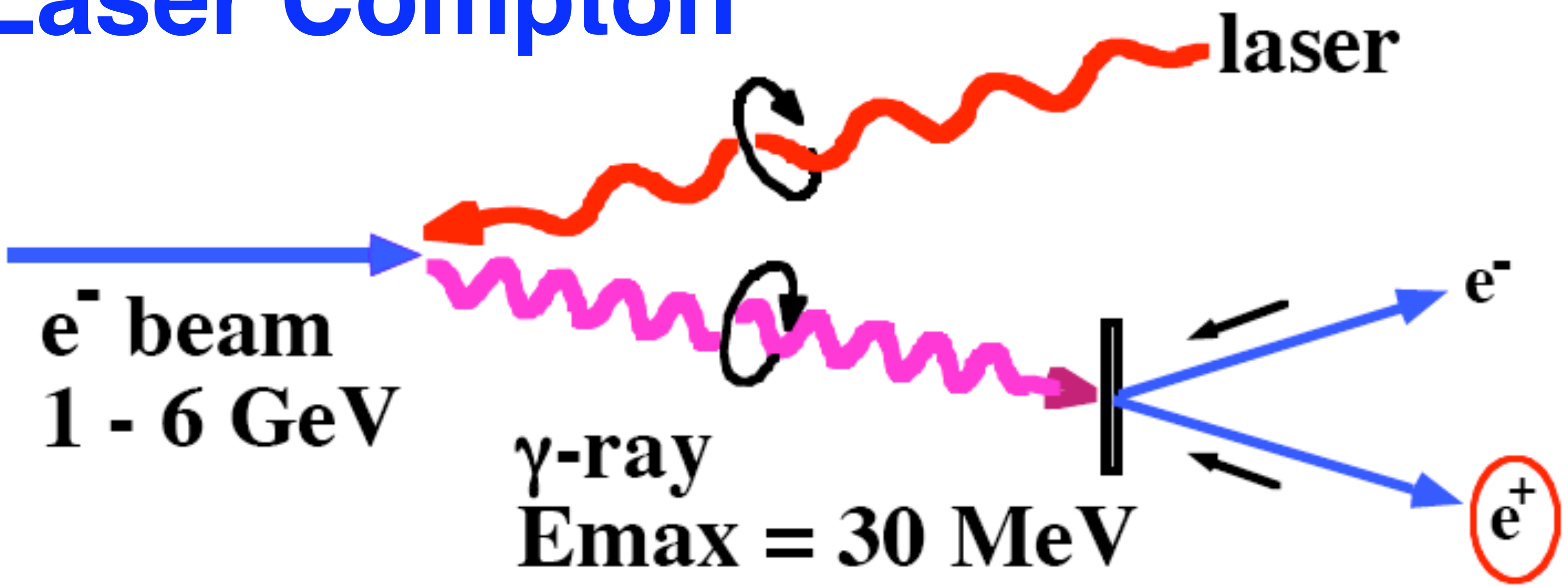


Our Proposal

(2) Laser Compton



Why Laser-Compton ?

i) Positron Polarization.

ii) Independence

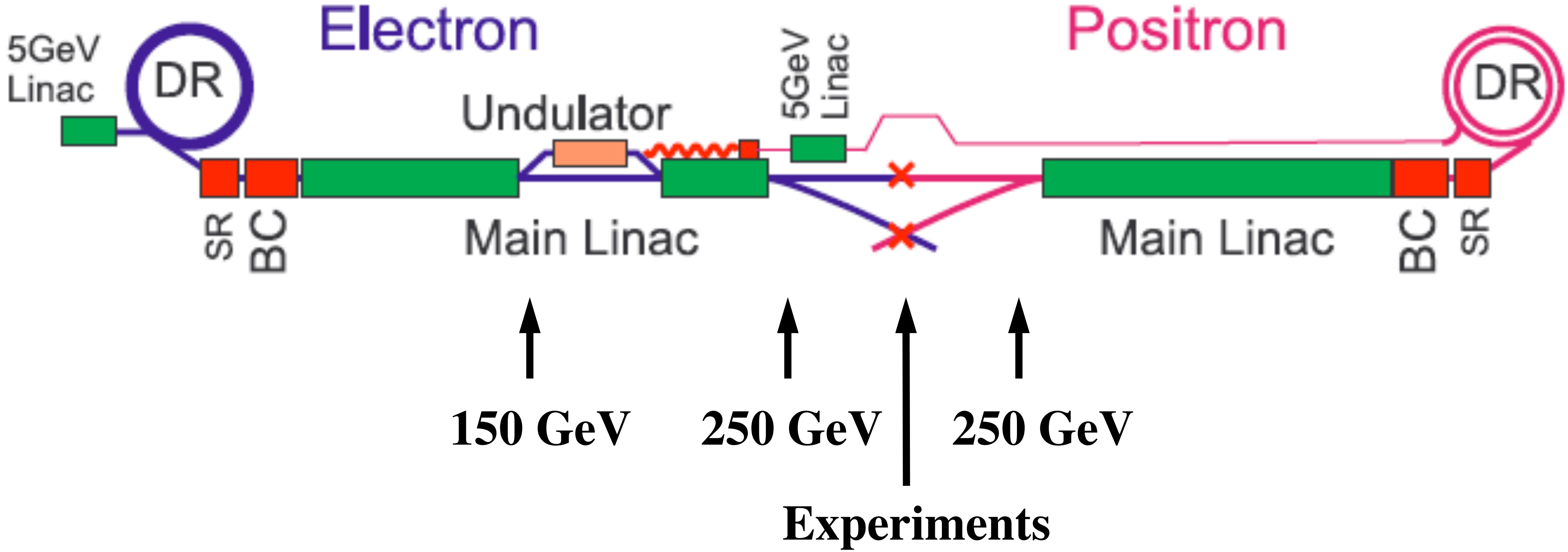
Undulator-base e^+ : use e^- main linac

Problem on design, construction, commissioning, maintenance,

Laser-base e^+ : independent

Easier construction, operation, commissioning, maintenance

ILC Undulator-base e^+ Source



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Easier construction, operation, commissioning, maintenance

iii) Polarization flip @ 5Hz (for CLIC @ 50 Hz)

iv) High polarization

v) Low energy operation

Undulator-base e^+ : need deceleration

Laser-base e^+ : no problem

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Undulator-base e^+ : need deceleration

Laser-base e^+ : no problem

vi) Synergy in wide area of fields/applications

Status of Compton e^+ Source

Proof-of-Principle demonstration was done.

ATF-Compton Collaboration

Polarized γ-ray generation: M. Fukuda et al., PRL 91(2003)164801

Polarized e+ generation: T. Omori et al., PRL 96 (2006) 114801

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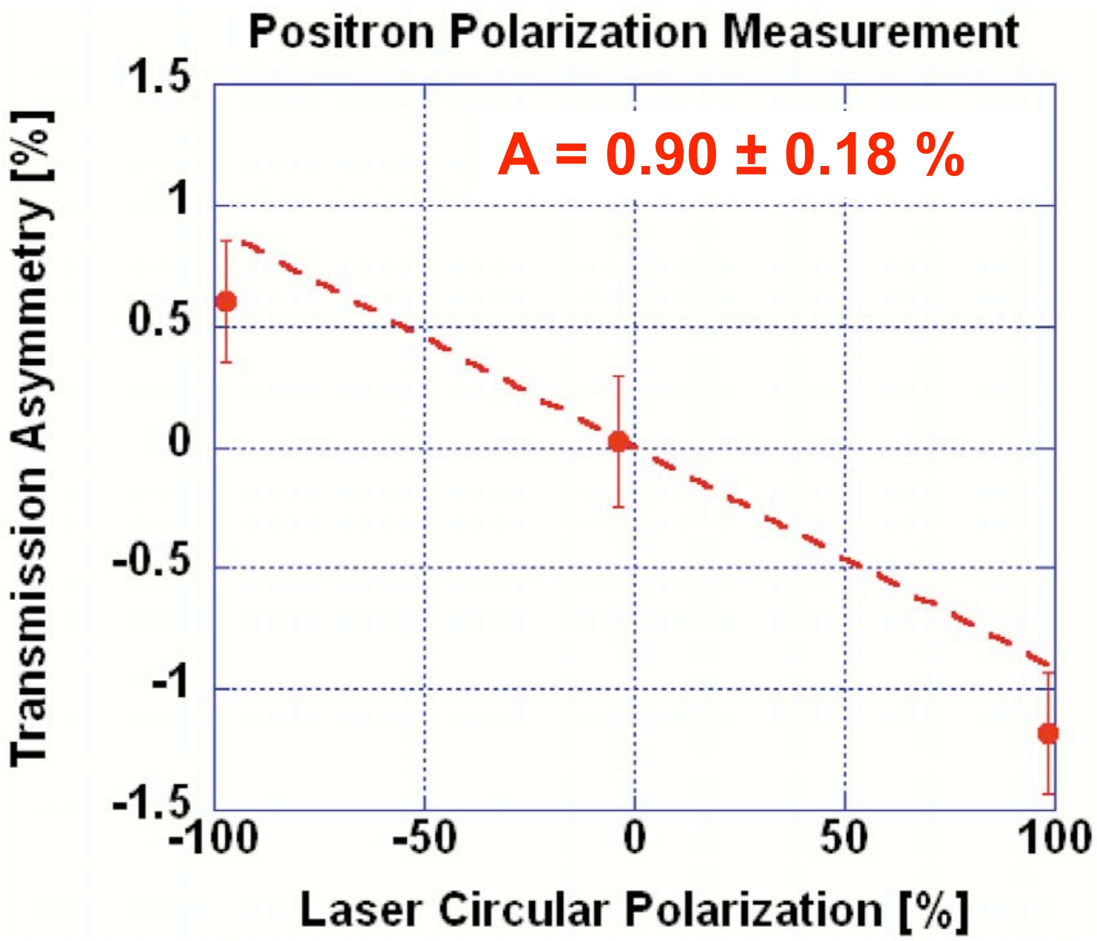
Asymmetry Measurements

e^+ run



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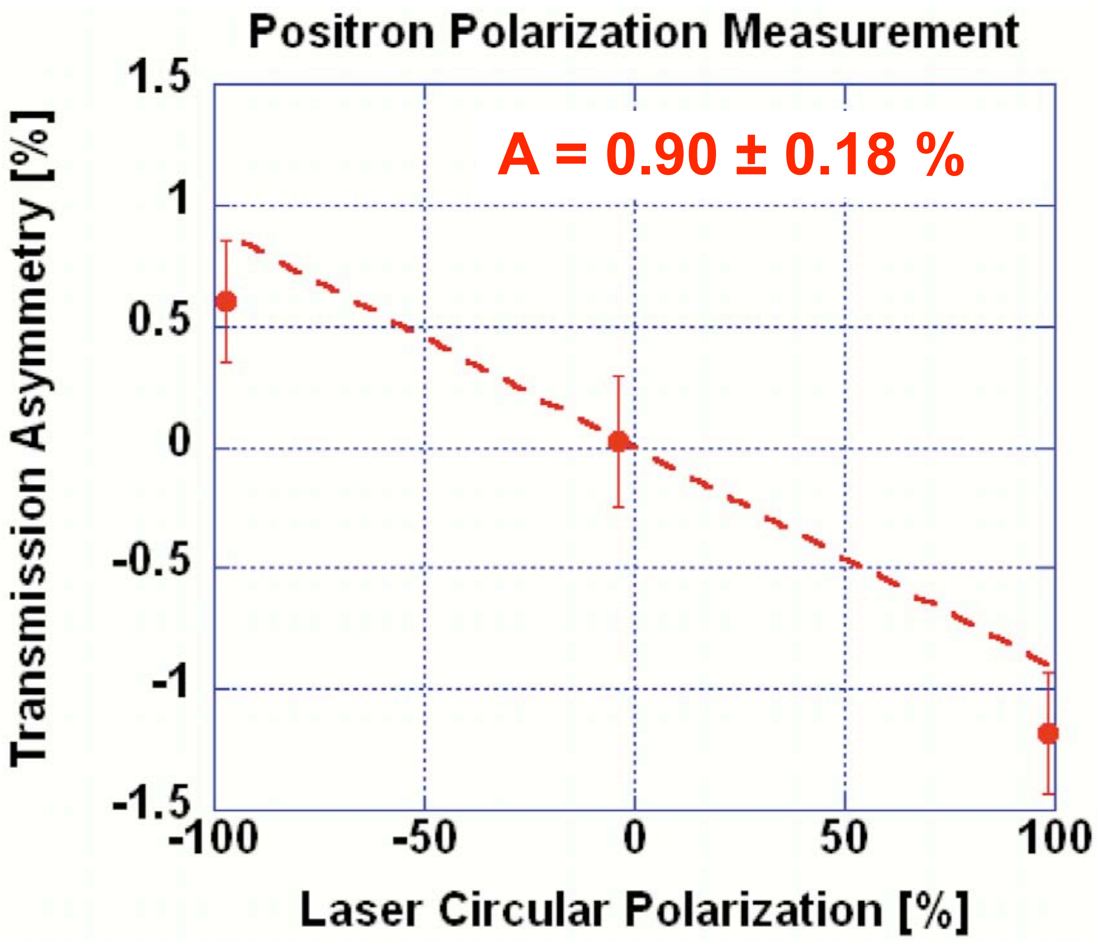
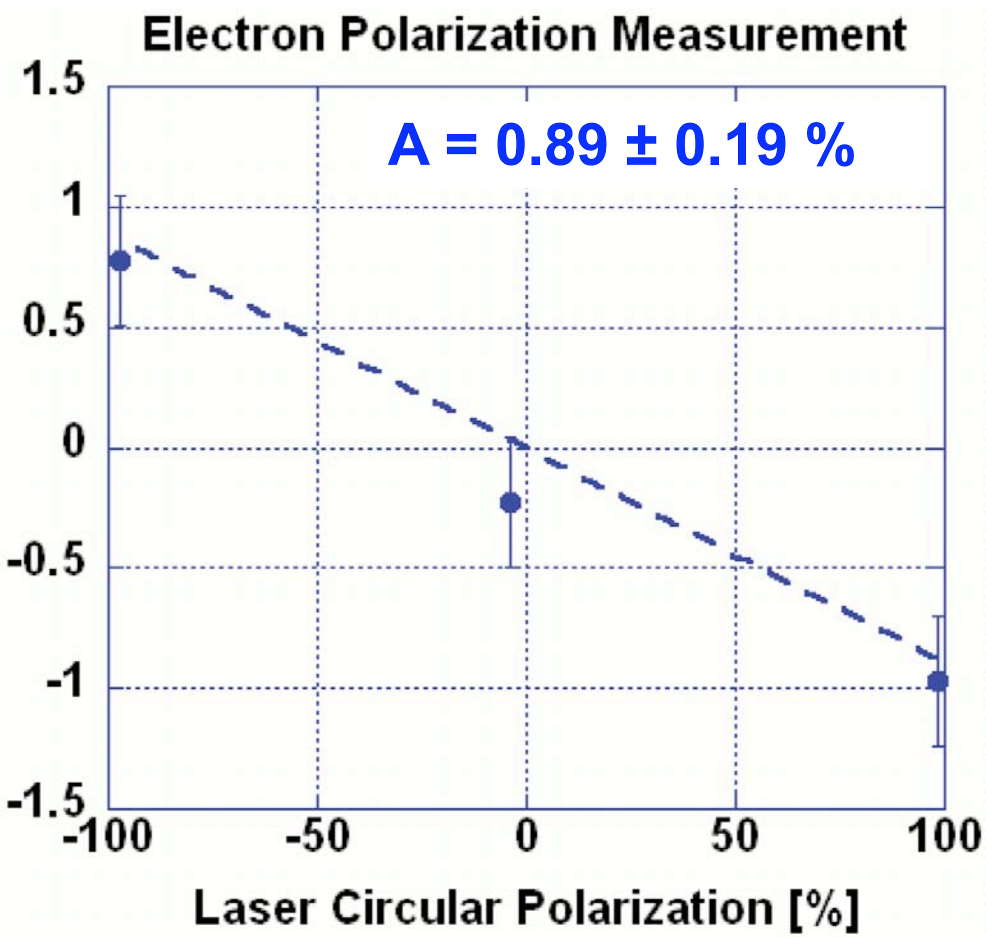


e^- run



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We still need many R/Ds and simulations.

We heard many talks in this WS

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We heard many talks in this WS

We have 3 schemes.

Choice 1 : How to provide e- beam
Storage Ring, ERL, Linac

Choice 2 : How to provide laser beam
Wave length (λ=1μm or λ=10μm)
staking cavity or non stacking cavity

Choice 3 : e+ stacking in DR or Not

Laser Compton e^+ Source for ILC/CLIC

We have 3 schemes.

1. Ring Base Laser Compton
   Storage Ring + Laser Stacking Cavity (λ=1μm),
   and e+ stacking in DR
   S. Araki et al., physics/0509016

2. ERL Base Laser Compton
   ERL + Laser Stacking Cavity (λ=1μm),
   and e+ stacking in DR

3. Linac Base Laser Compton
   Linac + non-stacking Laser Cavity (λ=10μm),
   and No stacking in DR
   Proposal V. Yakimenko and I. Pogorersky
   T. Omori et al., Nucl. Instr. and Meth. in Phys. Res., A500 (2003) pp 232-252

Good! But we have to choose!

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   Vitaly's talk today

   Proposal V. Yakimenko and I. Pogorersky
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   Variola's talk on 11th

   S. Araki et al., physics/0509016

2. ERL Base Laser Compton

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   and e+ stacking in DR

   Variola's talk on 11th

3. Linac Base Laser Compton

   Linac + non-stacking Laser Cavity (λ=10μm),
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   Vitaly's talk today

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Laser Compton e+ Source for ILC/CLIC

We have 3 schemes.

My talk today

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   Storage Ring + Laser Stacking Cavity (λ=1μm), and e+ stacking in DR
   Variola's talk on 11th
   S. Araki et al., physics/0509016

2. ERL Base Laser Compton
   ERL + Laser Stacking Cavity (λ=1μm), and e+ stacking in DR
   Variola's talk on 11th

3. Linac Base Laser Compton
   Linac + non-stacking Laser Cavity (λ=10μm), and No stacking in DR
   Vitaly's talk today
   Proposal V. Yakimenko and I. Pogorersky
   T. Omori et al., Nucl. Instr. and Meth. in Phys. Res., A500 (2003) pp 232-252

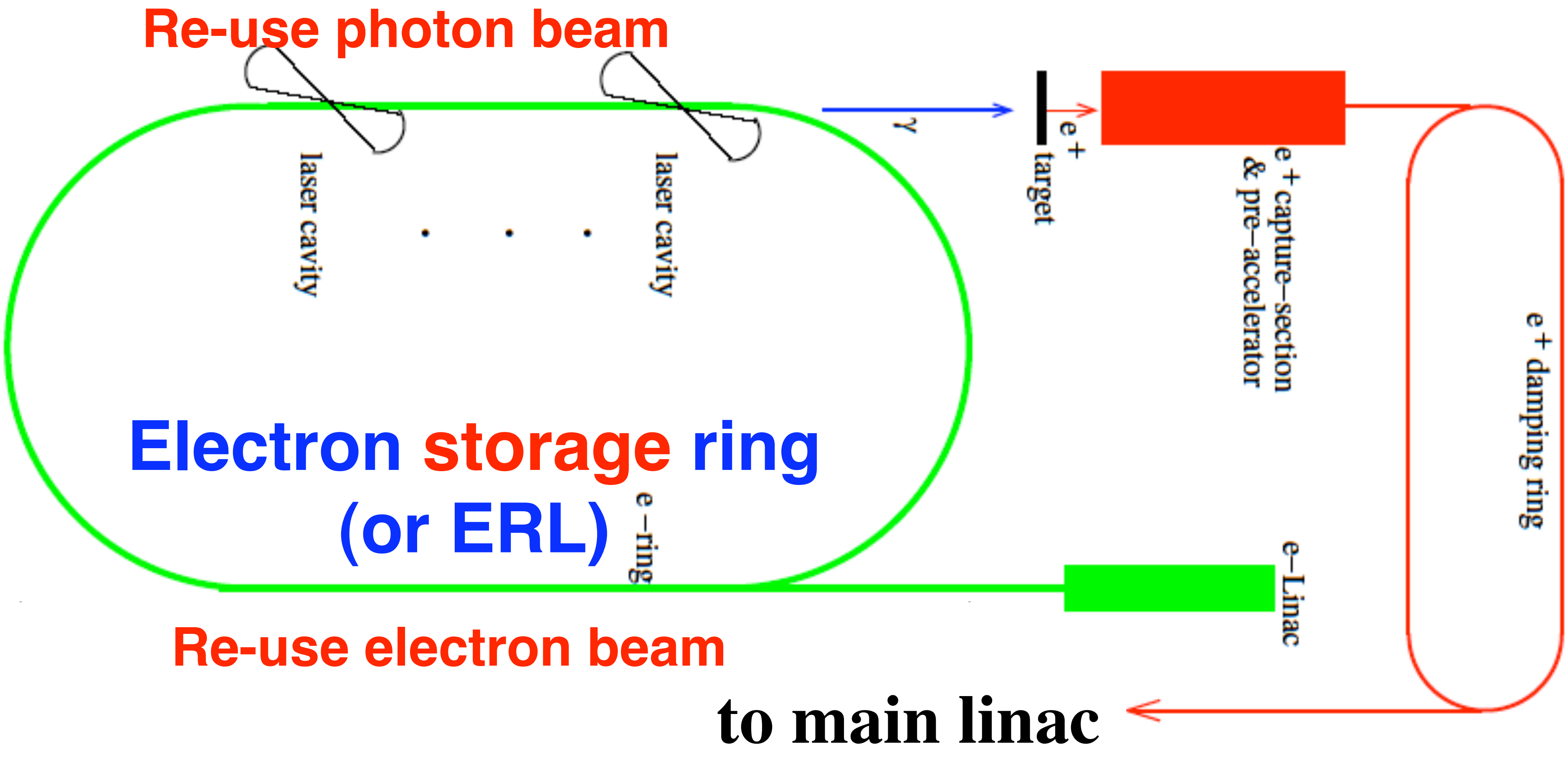
Good! But we have to choose!

Ring/ERL
Compton Scheme

Ring Base Compton (an example)

Re-use Concept

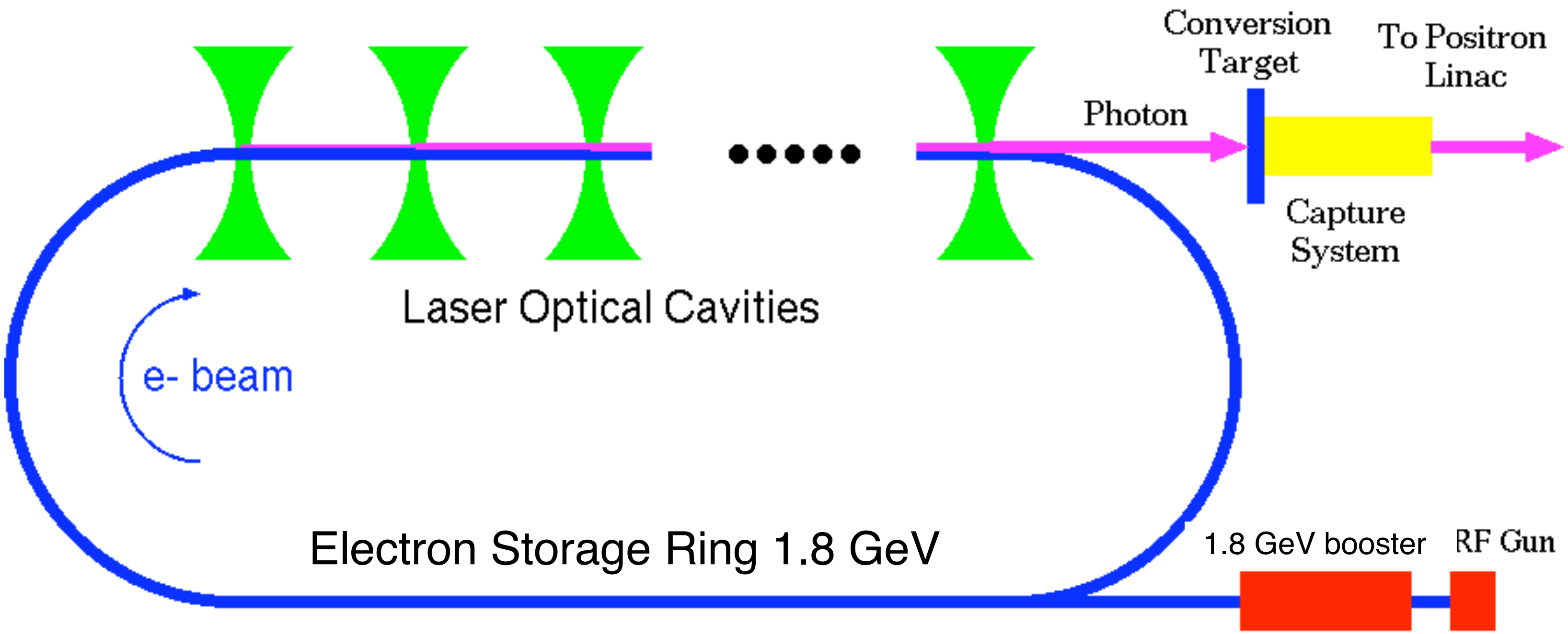
laser pulse stacking optical cavities



positron stacking in main DR

Compton Ring Scheme for ILC

- Compton scattering of e- beam stored in storage ring off laser stored in Optical Cavity.
- 5.3 nC 1.8 GeV electron bunches x 5 of 600mJ stored laser -> 2.3E+10 γ rays -> 2.0E+8 e+.
- By stacking 100 bunches on a same bucket in DR, 2.0E+10 e+/bunch is obtained.

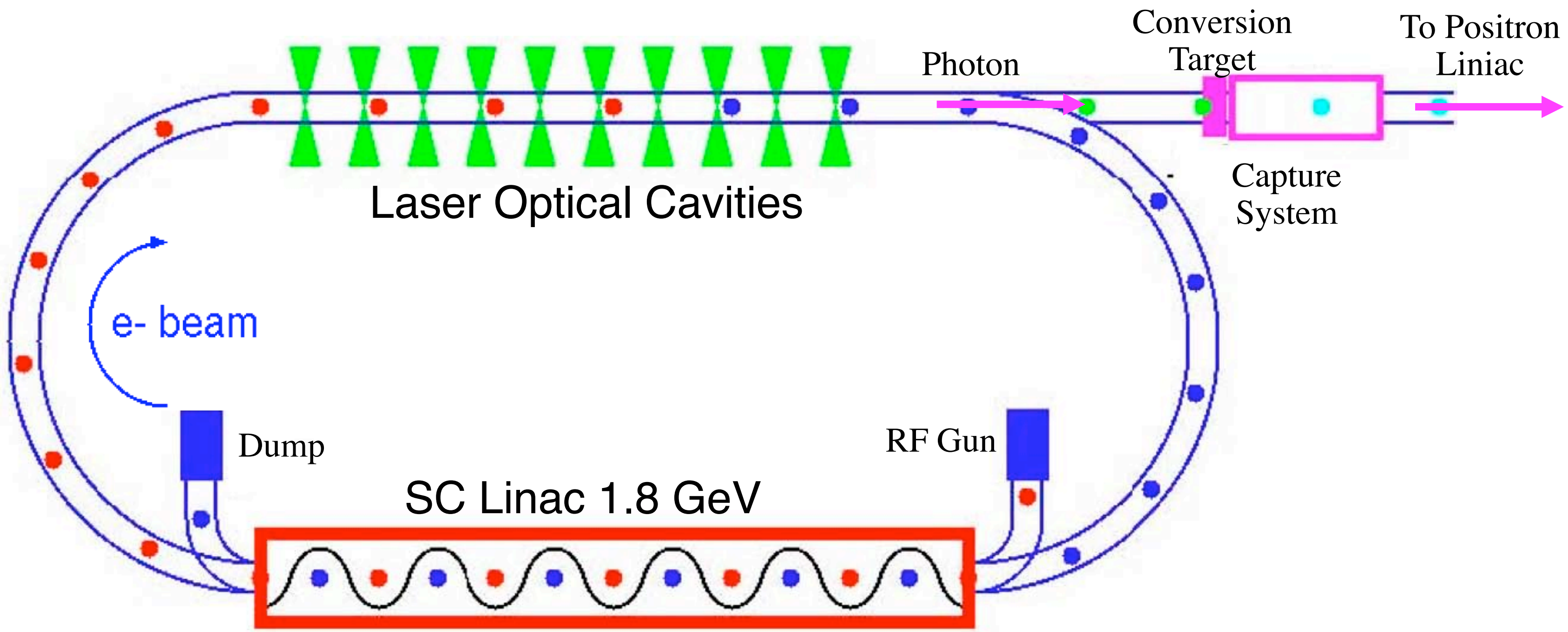


preliminary

ERL scheme for ILC

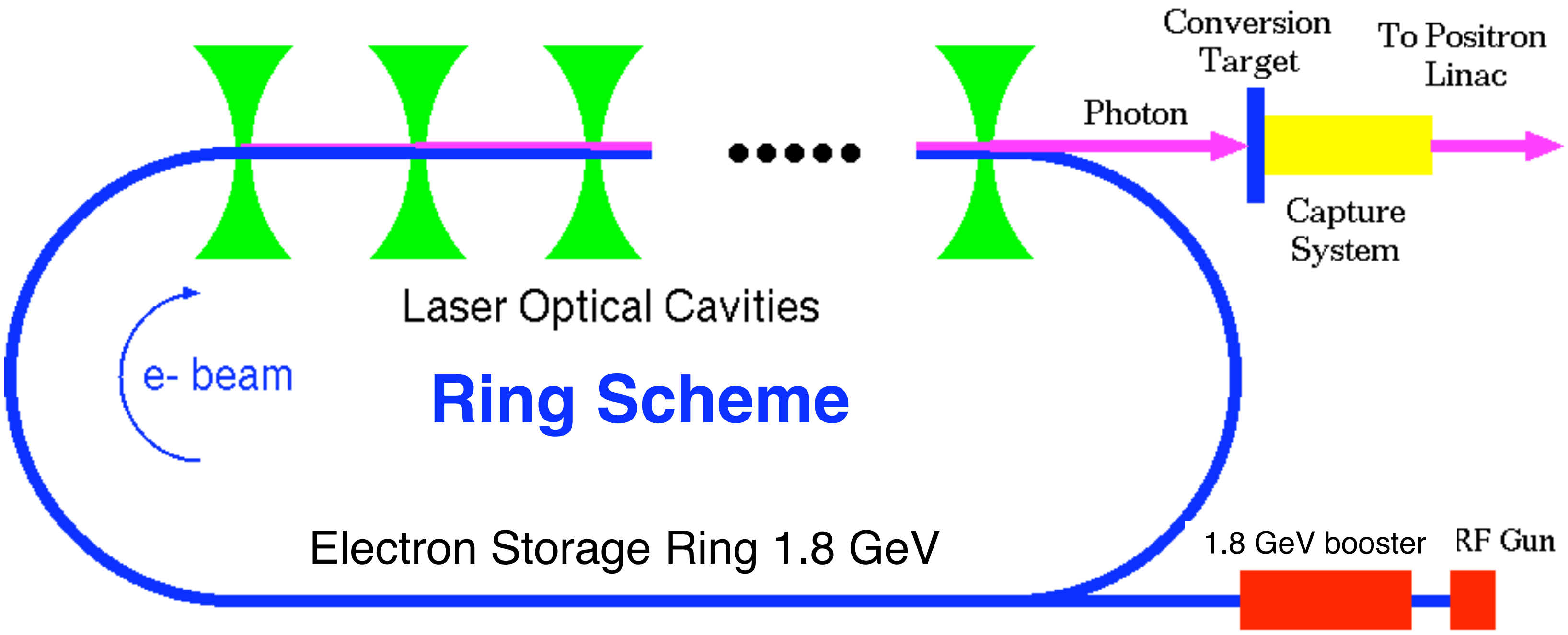
- High yield + high repetition in ERL solution.
  - 0.48 nC 1.8 GeV bunches x 5 of 600 mJ laser, repeated by 54 MHz -> 2.5E+9 γ-rays -> 2E+7 e+.
  - Continuous stacking the e+ bunches on a same bucket in DR during 100ms, the final intensity is 2E+10 e+.

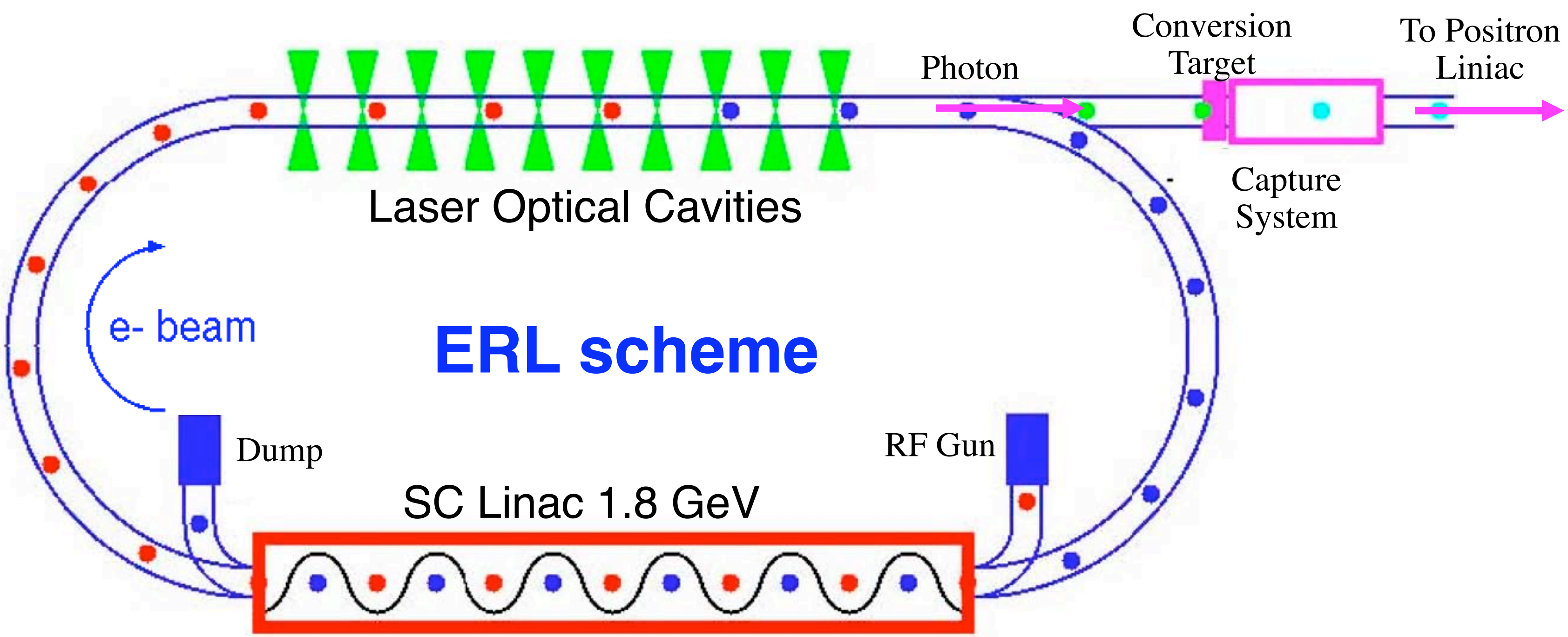
1000 times of stacking in a same bunch



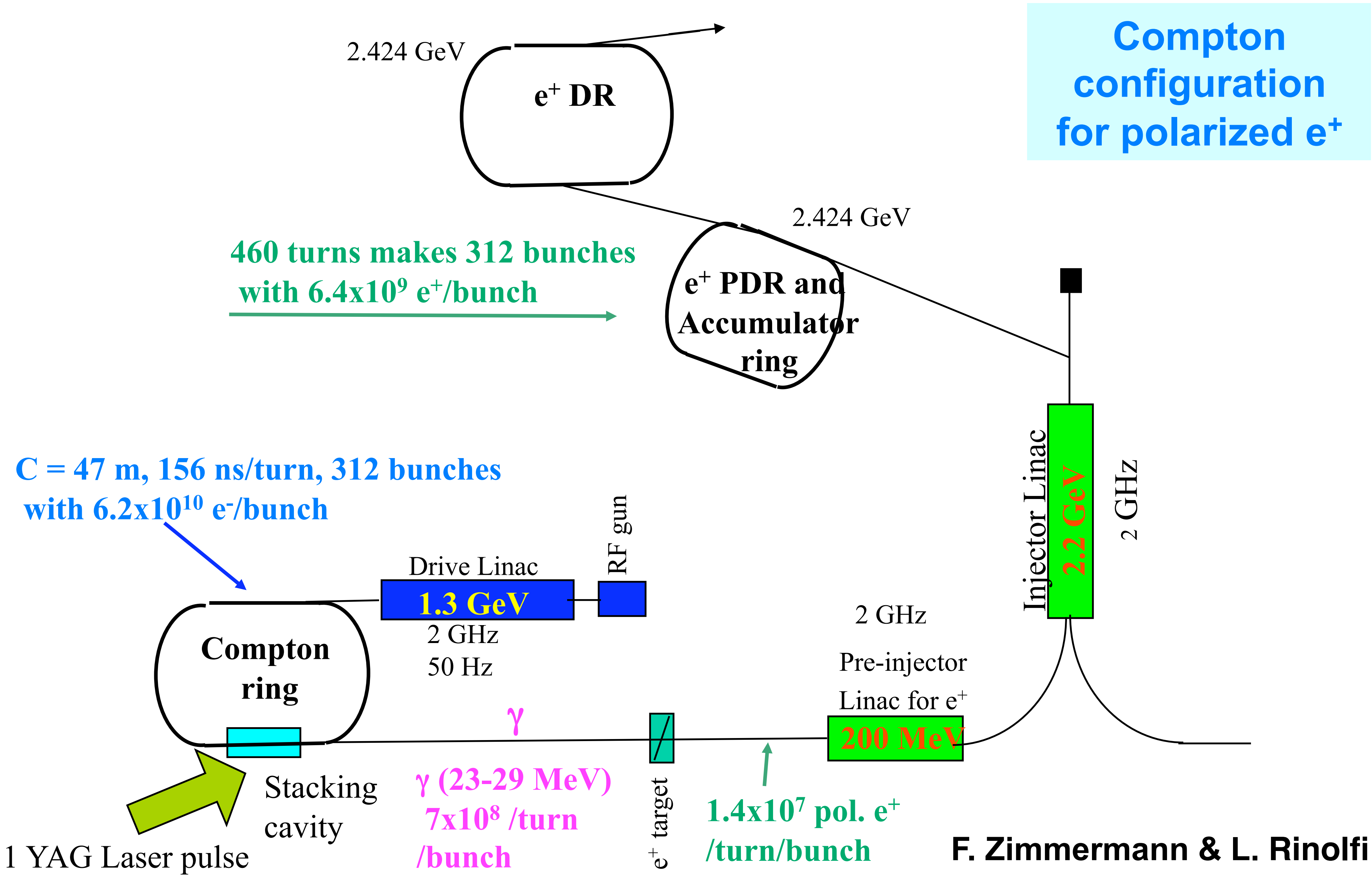
preliminary

Ring scheme and ERL scheme are SIMILAR





Compton Ring scheme for CLIC (2008)



F. Zimmermann & L. Rinolfi

R/Ds

and

PosiPol Collaboration

R&D items

CR/ERL simulations studies (Kharkov, LAL, JAEA, KEK)

design studies

beam dynamics studies

Optical Cavity (LAL, Hiroshima, KEK)

experimental R/D

Urakawa-san's talk 11th

Variola-san's talk 11th

Fabian-san's talk 10th

e+ capture (LAL, ANL)

We will start collaboration with KEKB upgrade study

e+ stacking in DR (CERN)

Basic beam dynamics studies

Laser

Fiber laser / Mode-lock laser (CELIA/Bordeaux)

CO2 laser (BNL)

Fabian-san's talk 11th

Vitaly-san's talk today

World-wide PosiPol Collaboration

Collaborating Institutes:

BINP, CERN, DESY, Hiroshima, IHEP, IPN, KEK, Kyoto, LAL, CELIA/Bordeaux, NIRS, NSC-KIPT, SHI, Waseda, BNL, JAEA and ANL

Sakae Araki, Yasuo Higashi, Yousuke Honda, Masao Kuriki, Toshiyuki Okugi, Tsunehiko Omori, Takashi Taniguchi, Nobuhiro Terunuma, Junji Urakawa, Yoshimasa Kurihara, Takuya Kamitani, Yoshisato Funahashi, X. Artru, M. Chevallier, V. Strakhovenko, Eugene Bulyak, Peter Gladkikh, Klaus Meonig, Robert Chehab, Alessandro Variola, Fabian Zomer, Alessandro Vivoli, Richard Cizeron, Viktor Soskov, Didier Jehanno, M. Jacquet, R. Chiche, Yasmina Federa, Eric Cormier, Louis Rinolfi, Frank Zimmermann, Kazuyuki Sakaue, Tachishige Hirose, Masakazu Washio, Noboru Sasao, Hirokazu Yokoyama, Masafumi Fukuda, Koichiro Hirano, Mikio Takano, Tohru Takahashi, Hirotaka Shimizu, Shuhei Miyoshi, Yasuaki Ushio, Tomoya Akagi, Akira Tsunemi, Ryoichi Hajima, Li XaioPing, Pei Guoxi, Jie Gao, V. Yakinenko, Igo Pogorelsky, Wai Gai, and Wanming Liu

POSIPOL 2006
CERN Geneve
26-27 April
http://posipol2006.web.cern.ch/Posipol2006/

POSIPOL 2007
LAL Orsay
23-25 May
http://events.lal.in2p3.fr/conferences/Posipol07/

POSIPOL 2008
Hiroshima
16-18 June
http://home.hiroshima-u.ac.jp/posipol/

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POSIPOL 2009
CERN/ near CERN

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Common in most of Compton Applications

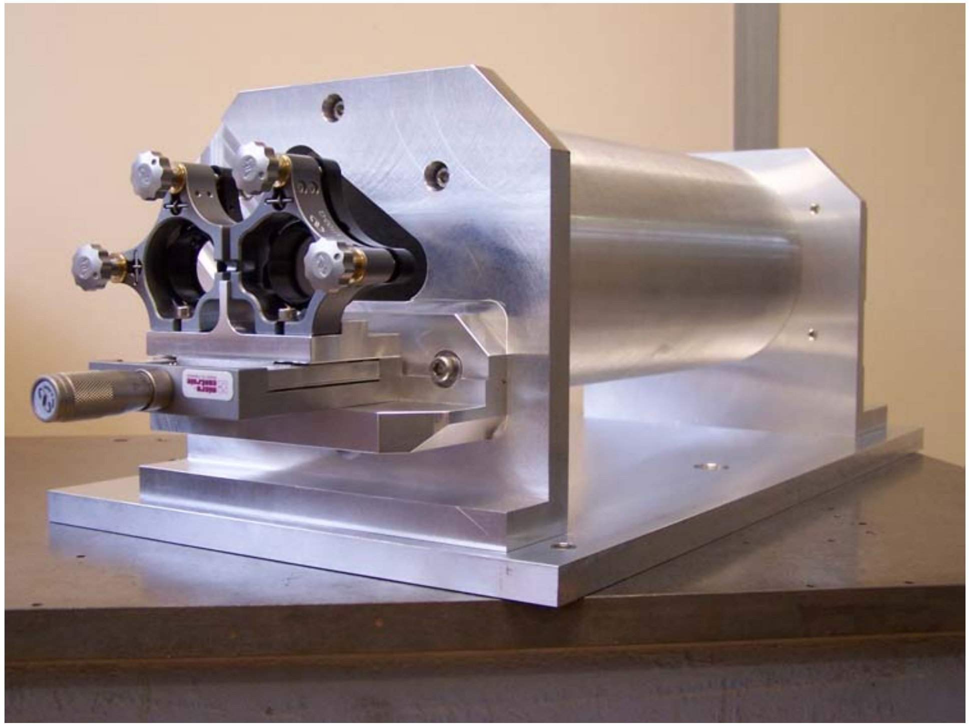
Example of Common R/Ds

Optical Super Cavities

2-mirror cavity (Hiroshima / Weseda / Kyoto / IHEP / KEK)

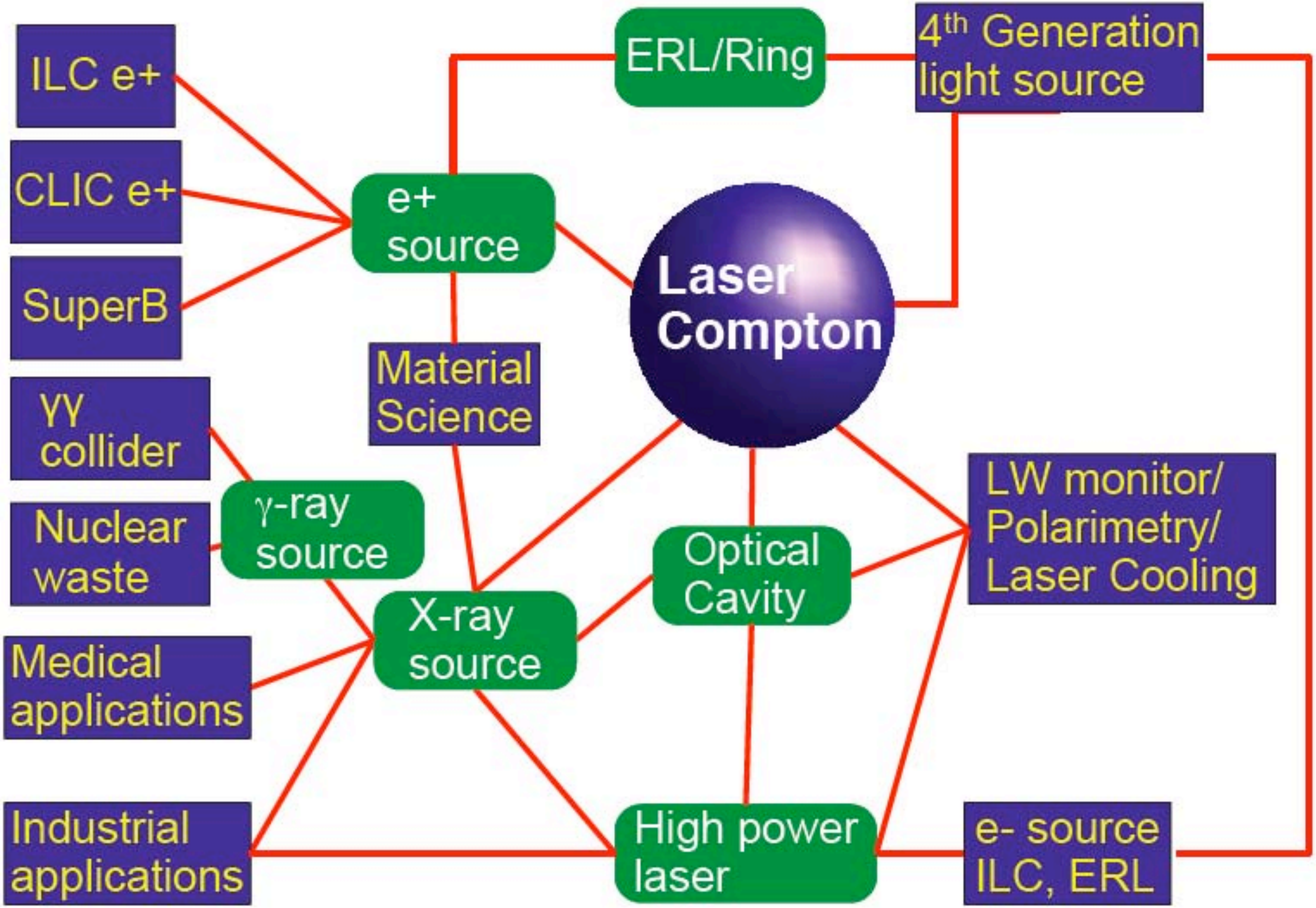
moderate enhancement
moderate spot size
simple control

4-mirror cavity (LAL)



high enhancement
small spot size
complicated control

World-Wide-Web of Laser Compton



Laser-Compton R/D

1. Laser-Compton has a large potential as a future technology.
2. Many common efforts can be shared in a context of various applications.
   - Compact and high quality X-ray source for industrial and medical applications
   - γ-ray source for disposal of nuclear wastes
   - Beam diagnostics with Laser
   - Laser Cooling
   - Polarized Positron Generation for ILC and CLIC
   - $\gamma\gamma$ collider
3. State-of-the-art technologies are quickly evolved with world-wide synergy.
   - Laser Stacking Optical Cavity,
   - Laser,
   - ERL ....

Summary

Summary 1

1. Two Energy Frontier Machines

LHC   pp collider

Will Open New Era in Particle physics

ILC $e^- e^+$ collider

Will follow LHC and provide precision data

Summary 1

1. **Two Energy Frontier Machines**

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   Will Open New Era in Particle physics

   ILC e^-e^+ collider

   Will follow LHC and provide precision dada

2. **Beam polarization plays important roles in e^-e^+ colliders**

   Suppress back ground
   Enhance specific interaction
   Determine Weak mixing of final state

Summary 1

1. Two Energy Frontier Machines

   LHC   pp collider

   Will Open New Era in Particle physics

   ILC e^-e^+ collider

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2. Beam polarization plays important roles in e^-e^+ colliders

   Suppress back ground
   Enhance specific interaction
   Determine Weak mixing of final state

3. Compton pol. e^+ source is attractive option for ILC/CLIC

   Independent system

   high polarization

   5 Hz polarization flip (for CLIC 50 Hz flip)

   Operability

Summary 2

4. Three schemes are proposed

Ring Laser Compton

ERL Laser Compton

Linac Laser Compton

Summary 2

4. Three schemes are proposed

- Ring Laser Compton
- ERL Laser Compton
- Linac Laser Compton

My talk Today

Summary 2

4. Three schemes are proposed

   Ring Laser Compton

   ERL Laser Compton

   Linac Laser Compton

My talk Today

5. We still need many R/Ds

   (a) e+ stacking, (b) Ring, (c) ERL, (d) e+ capture

   (e) e+ production target, (e) Laser

   (g) Laser stacking optical cavity

Summary 2

4. Three schemes are proposed

Ring Laser Compton

ERL Laser Compton

My talk Today

Linac Laser Compton

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(e) e+ production target, (e) Laser

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Summary 2

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Ring Laser Compton
ERL Laser Compton
Linac Laser Compton

My talk Today

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(a) e+ stacking, (b) Ring, (c) ERL, (d) e+ capture
(e) e+ production target, (e) Laser
(g) Laser stacking optical cavity

6. Laser-Compton has many applications in many field.

Medical applications, Industrial applications,
γ-ray source for disposal of nuclear wastes,
cargo inspections, research of cultural heritages,
and
also for ILC/CLIC e^+ source.
Many of R/D are common in most of applications