JORLEY JOHNSON

SK

BNP PARIBAS
CORPORATE & INVESTMENT BANKING

TORE TEAM:

- PROJECT AS A BUSINESS ANALYST:
  - DECOMMISSION AN OUTSOURCED SYSTEM (FIMBOD)
  - ENGAGE WITH TRADERS AND RESEARCHERS TO OPTIMIZE THE SYSTEM

TORE TEAM(CONTD.)

PROJECTS AS A DATA SCIENTIST:

- BASEL 3 NORMS IMPLEMENTATION
- CLASSIFY FAULTY REPORTS
- ISOLATION FOREST
- NLP / CHATBOT MODEL DESIGN
- SVM(Gaussian Kernel) ~ 81% accuracy

TAKEAWAY FROM ESC'19

- INCREASE THE OPTIMIZATION OF THE PRICING MODELS USING MONTE CARLO SIMULATIONS

THANK YOU

Research & Interests

Francesco Manzali

Università degli Studi di Padova

October 19, 2019

- Three neutrinos: electronic $|\nu_e\rangle$, muonic $|\nu_\mu\rangle$ and tauonic $|\nu_\tau\rangle$.
- Three (different) mass eigenstates: m_1, m_2 and m_3.

Mass Hierarchy Problem. There are two possible *orderings* for the masses:

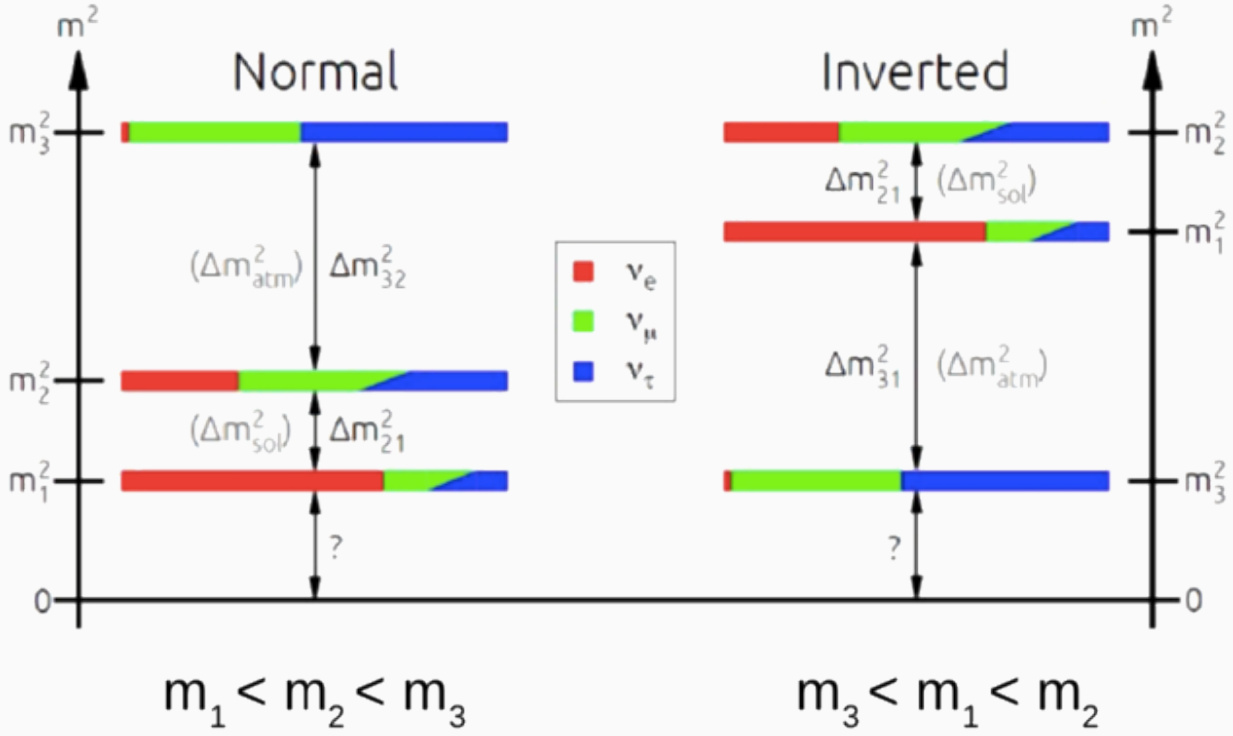
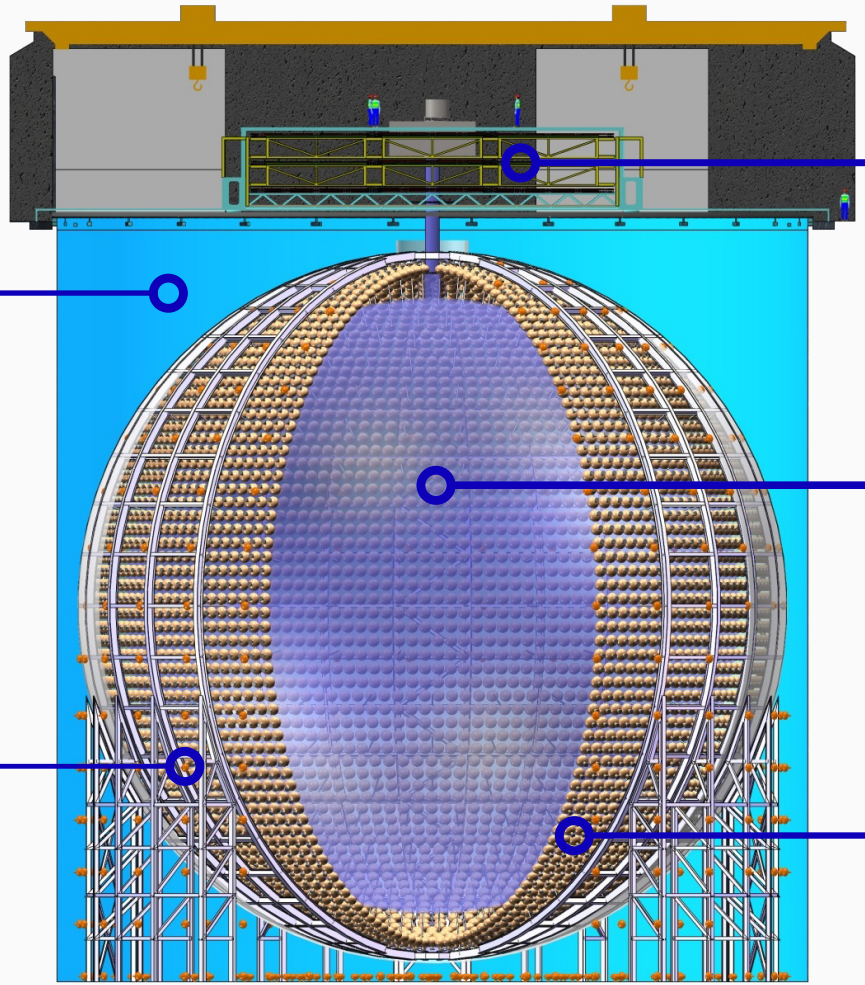


Figure 1 – The two possibilities for the neutrino mass hierarchy



Top Tracker
3 layer plastic scintillator
(muon tracking)

Water buffer
for shielding

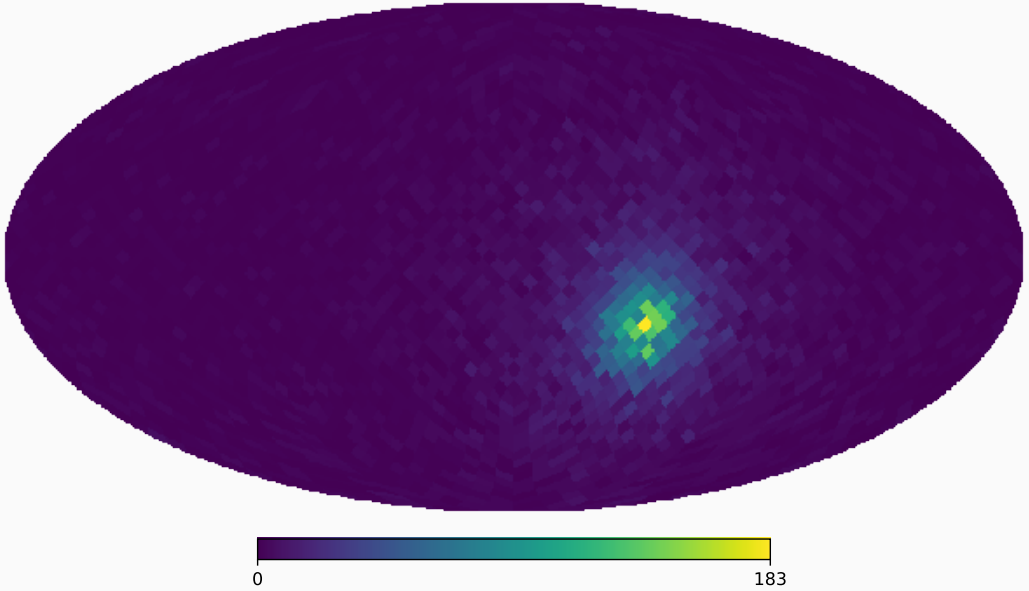
Active volume
$\varnothing 35.4\,\mathrm{m}$
$20\,\mathrm{kt}$ organic scintillator
$\sim 10^4$ photons/MeV

2400 large
veto PMTs

PMTs 78% coverage
$17\,571$ large $\varnothing$ 20 inch
$25\,600$ small $\varnothing$ 3 inch
~ 1200 PEs/MeV

Figure 2 – Structure of the Jiangmen Underground Neutrino Observatory (**JUNO**)

- **What?** Learn how to estimate **energy** from **raw data**, from **lots of examples**.



$\mapsto$ **Energy**

- **How?** DeepSphere model (Swiss DataScience centre), a Convolutional Neural Network on Graphs (adapted to spherical topology, achieves rotational invariance).
- Find all the details at `bit.ly/neutrinos_are_fun`

JUNO Padova Electronics Group Activities Presentation

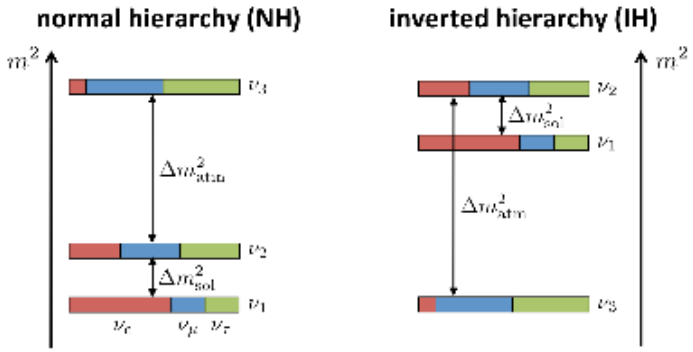
Filippo Marini

ESC:School on Efficient Scientific Computing

Università degli Studi di Padova

The JUNO Experiment

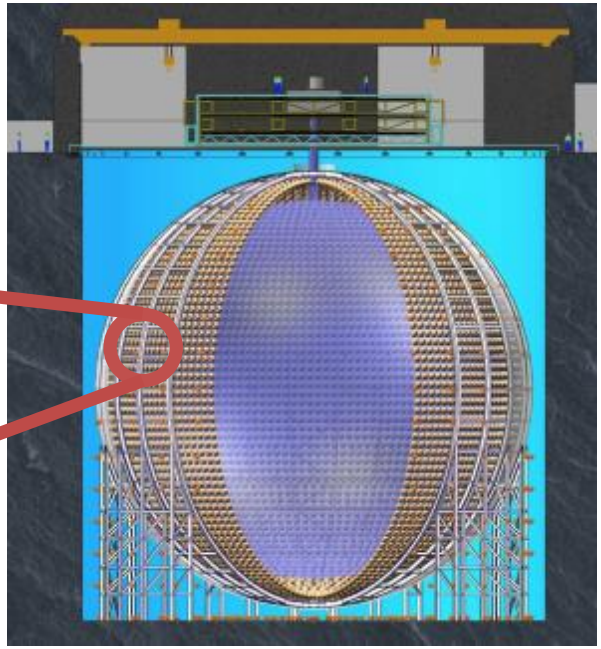
Determination of the neutrino's mass hierarchy



$m_1 < m_2 < m_3$ o $m_3 < m_1 < m_2$?

20 kton of Liquid Scintillator observed by:

- 20'000 large PMT - 75% Coverage
  - 5'000 Hamamatsu R12860-HQE
  - 15'000 NNVT MCP-PMT
- 25'000 small PMT - 2.5% Coverage



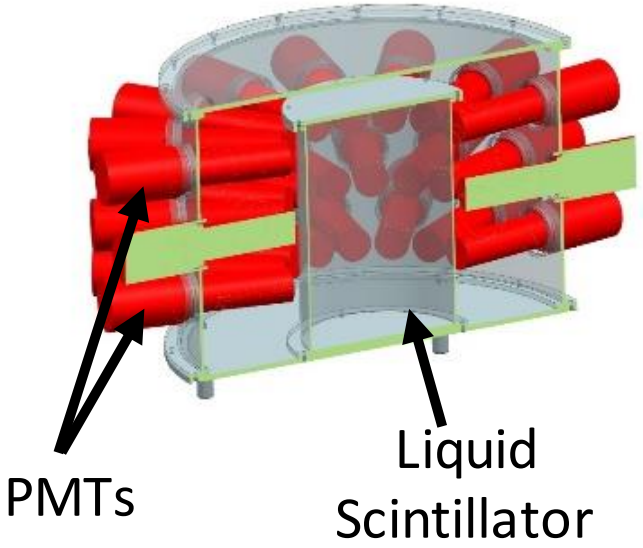
The Global Control Unit

My activity focuses on the development (FPGA firmware and readout software) of the GCU board. Among other things, the firmware is able to:

- Synchronize all GCU (~6000) inside a 16 ns window
- Global Clock received recovered on-board
- Perform a first online data processing, generating the local trigger requests
- Handle all data packaging and buffering
- Storage capability up to 1 s of raw data thanks to the on-board 2 GB DDR RAM
- Data sent to DAQ via Ethernet connection using the IPBus protocol (CERN)

The Padova "Washing Machine"

- 48 PMTs total. So far 9 PMTs are being read simultaneously by 3 GCUs
- The data readout is performed via Ethernet using the IPBus protocol
- To analyze the data efficiently, a software has been developed to allow data from IPBus to be stored in Root files.
- Data is then analyzed offline to extract some physics (Muons)
- Need to develop a Data Acquisition Software that performs some slow control and data monitoring during acquisition



Thank you!

Abdulla Mohamed

Currently:

- MSc student in Software Engineering - University of Bahrain.
- Technical Student at CMS - Working on GPUs under the supervision of Dr. Andrea Bocci.

Past work experience:

- Developer (Tawasul, Batelco, Freelancer on mobile apps projects).
- Research and Teaching assistant in University of Bahrain (Optimization, Multi Agent Reinforcement Learning, Simulation).

Interests

- HPC.
- Parallel Computing.
- Complexity Analysis.
- GPGPUS.

Project

FastJet is a software package for jet finding in pp and e+e− collisions.

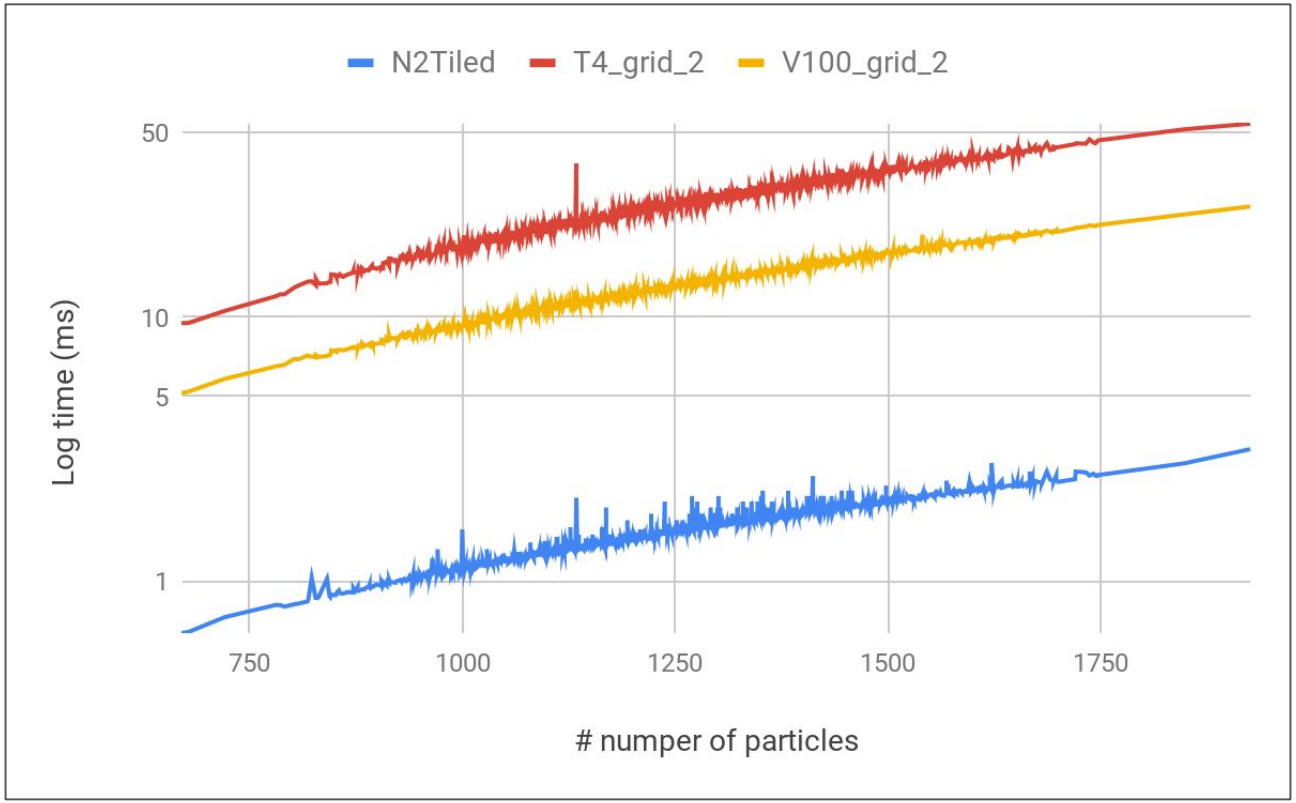
We are trying to port it to CUDA.

We have two main tasks:

1. Parallelizing the clustering algorithm (Not so good).
2. Processing Multiple events at the same time (Good).

https://github.com/asubah/fastjet_gpu

Current Performance



Near Infrared Spectroscopic Simulations for the Euclid Mission

Luca Paganin

Presentation for ESC19 INFN PhD school

UNIVERSITÀ DEGLI STUDI DI GENOVA

INFN Istituto Nazionale di Fisica Nucleare

Euclid scientific targets

- Euclid is an ESA mission aimed at mapping the *Dark Universe*
- Dark Universe = Dark Matter + Dark Energy
  - 95% of total energy content
  - **Dark Matter**: non-relativistic matter which does not emit or absorb electromagnetic waves
  - **Dark Energy (DE)**: some unknown form of energy with negative pressure
    - DE equation of state: $P(t) = [w_0 + w_a(1 - a(t))]\rho(t)$
    - P pressure $w_0 \simeq -1, \qquad w_a \ll 1$
    - ρ energy density

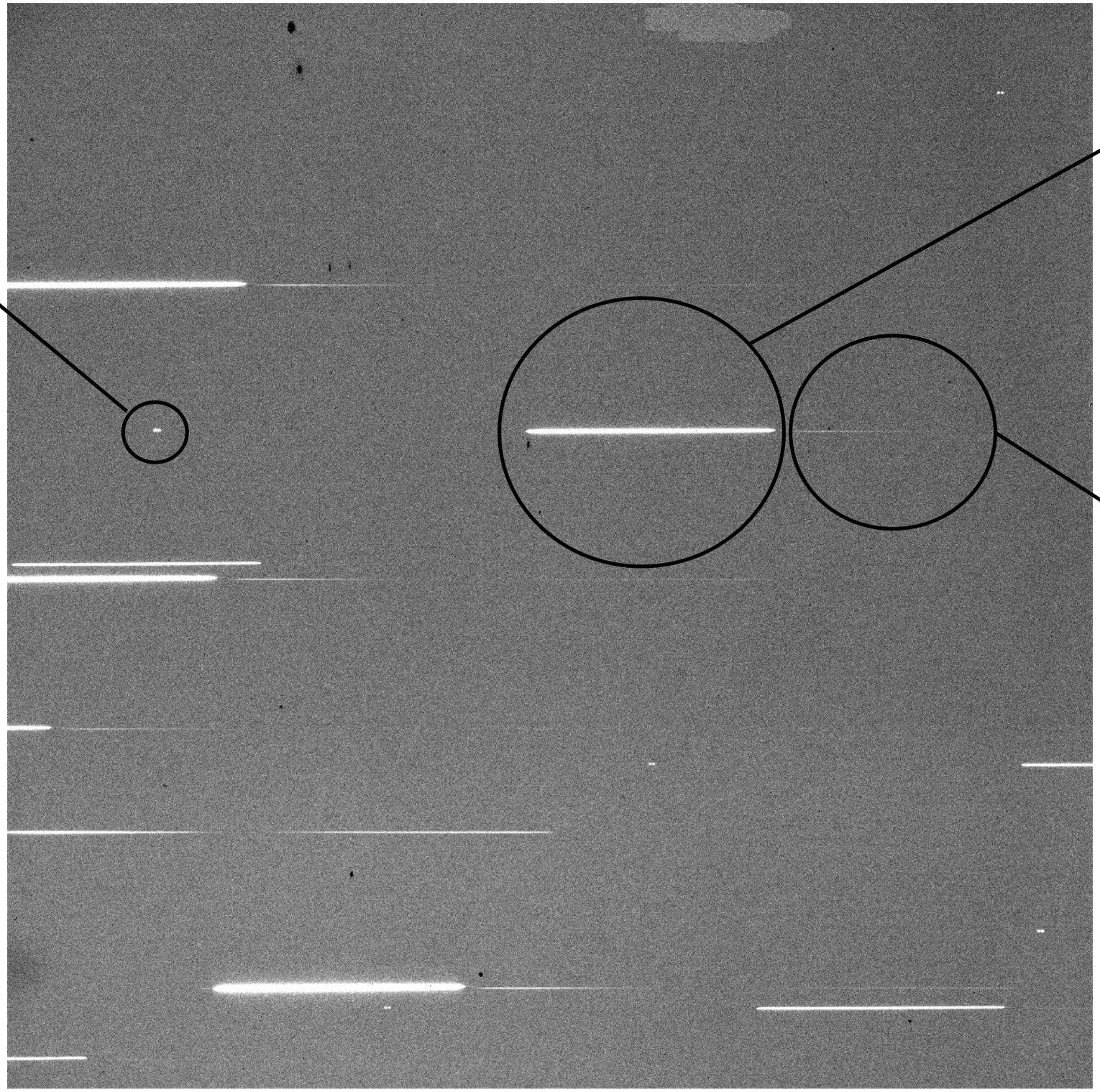
Euclid main scientific probes

- **Weak Lensing**:
  - Light rays bending of astrophysical source, caused by intervening masses
  - Indirect measure of mass distribution
  - Measured by VIS (Visual Imager)
- **Galaxy Clustering**:
  - Survey of about 50 million galaxies measuring their redshifts
  - Redshift —> Distance, assuming cosmological model
  - Redshift measured with **NISP** (Near Infrared Spectrometer and Photometer)

Redshift measurement

- NISP: 4x4 matrix of near-infrared semiconductor detectors
  - Light from galaxies enters telescope aperture
  - A dispersing element (grism) is interposed between incoming light and detector:
    - a diffraction pattern (*spectrum*) is projected on photo-detector
    - extraction of Fourier spectrum for each source in the Field of View (FoV)
    - comparison with lab frame emission lines gives redshift
  - Extraction algorithm must be validated before launch
  - Euclid-like simulated data are needed

Single detector simulated FoV



Simulation code employed: TIPS

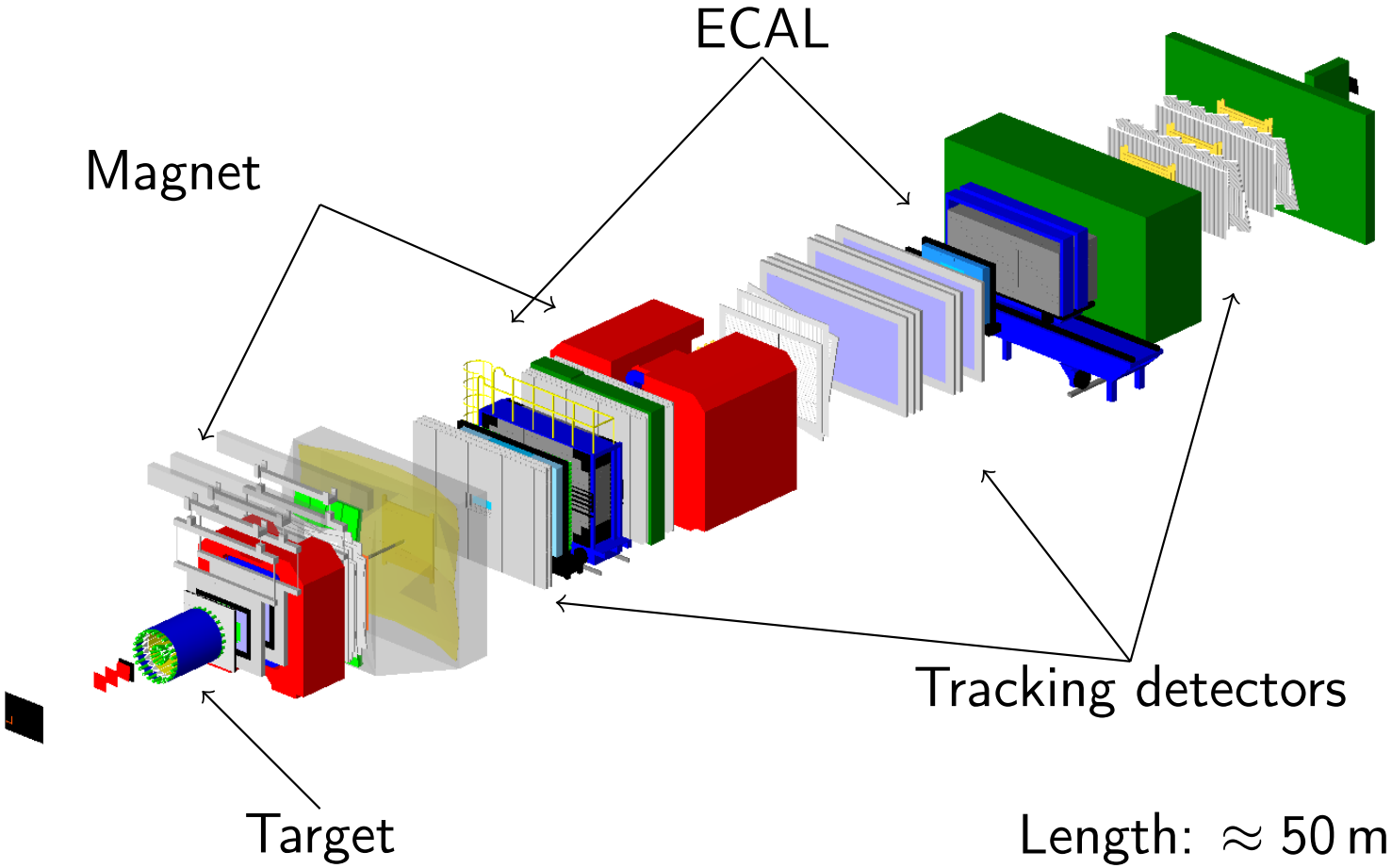
- Written in Python and C: 65k lines of Python and 45k lines of C
  - Python component:
    - It manages input and output data
    - It adds instrumental and physical noise to images
  - C component
    - It generates spectra of sources from input data (catalogs)
  - For each telescope pointing:
    - Exposure of the 16 detectors —> 1 frame
    - 4 frames acquired for same FoV, interleaved by small movements of telescope (dithers)
    - 16*4 = 64 detector images per pointing—> need for parallelization

Current research activities connected to C++ programing

Henri Pekeler

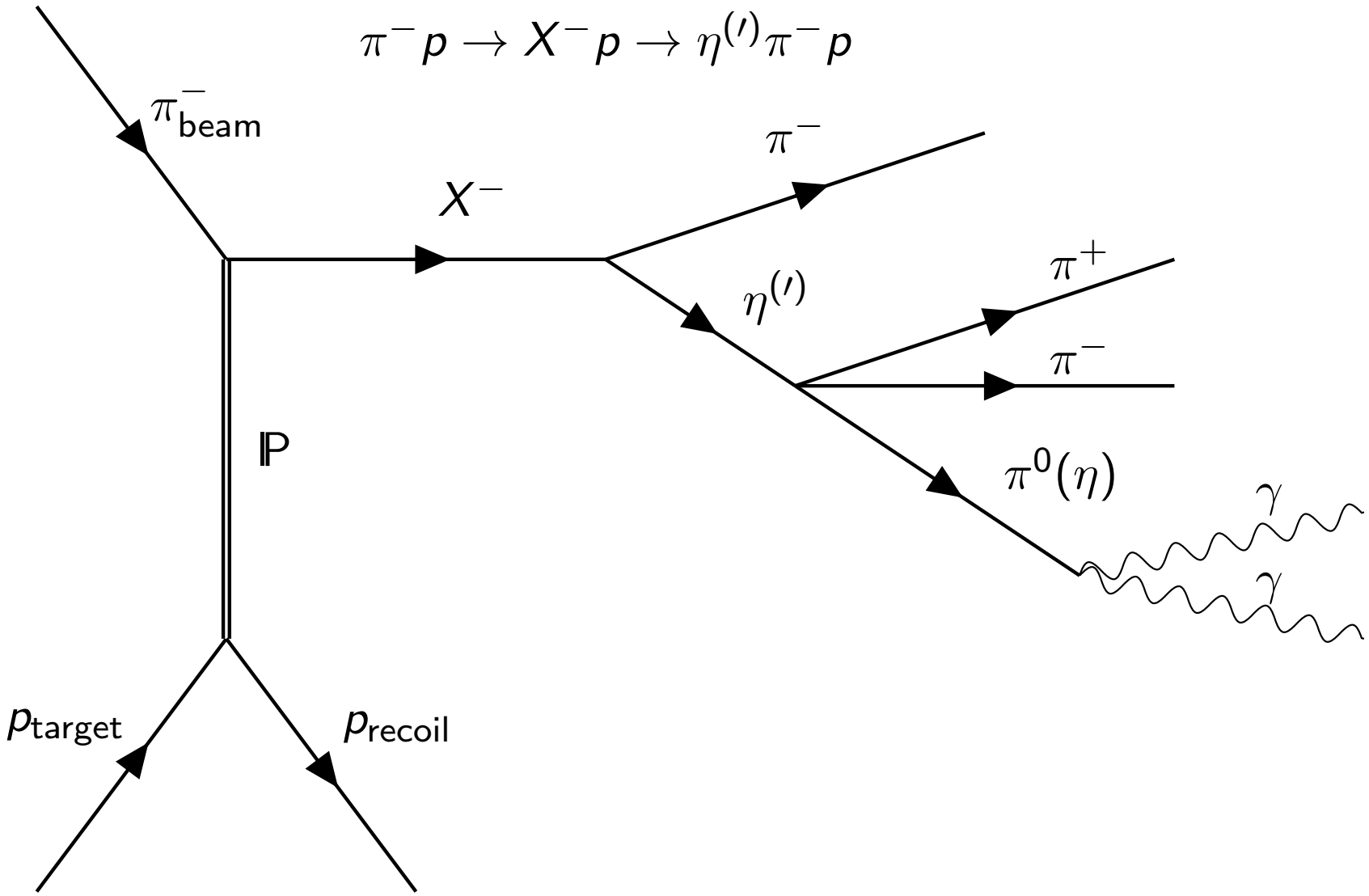
HISKP, Bonn University

October, 2019



Length: $\approx 50\,\mathrm{m}$

The chosen reaction



New analysis of the 2008 COMPASS data

What changed?

- Improved calorimeter description
- New program for Monte-Carlo simulations
- New reconstruction

$\Rightarrow$ >40% more selected events in $\eta\pi^-$ and $\eta'\pi^-$ for 2008

Next step

- Analyzing the newly selected events

Analysis of the 2008 COMPASS data

Goals of the analysis

- Partial-wave analysis (pwa) of the given final state

Requirements

- Produce Monte-Carlo (MC) data to figure out acceptance
- Select the given final state for COMPASS and MC data

Realization

- TGEANT operated at BlueWaters supercomputer for MC
- PHAST modified for selection of the given final state
- New written C++ program for pwa of the given final state

QCD on the lattice

Simone Romiti

Roma Tre University

21 October 2019

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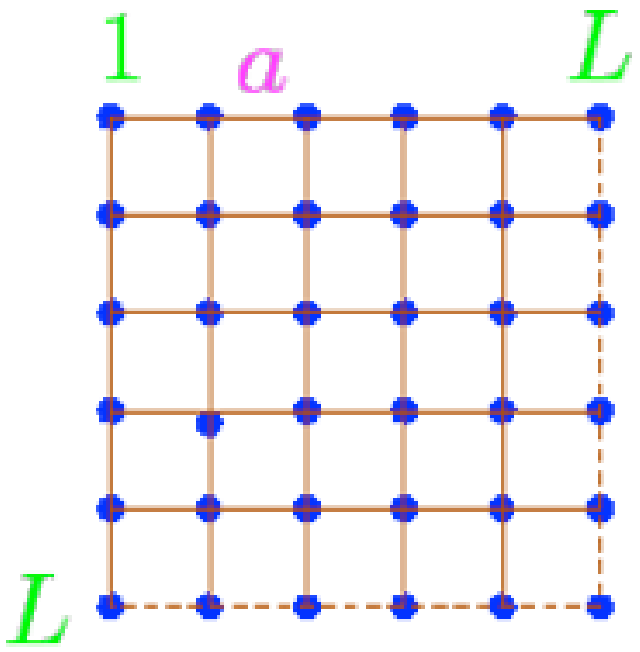
Quantum mechanics on the lattice

Questions:

1. What is QM on the lattice?
2. How does it work?
3. Why do we need it?

QM on the lattice



The lattice is an approximation of our universe:

- Discretization of spacetime (discontinuity)
- Finite time extension and finite volume (boundary issues)

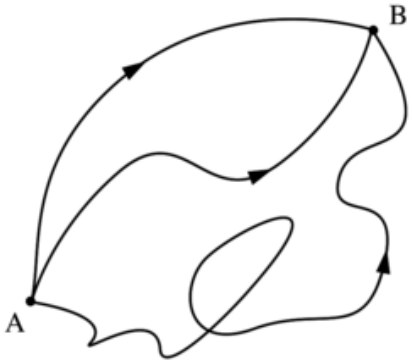
Main idea

Evaluate physical observables numerically on the lattice and extrapolate to the physical point.

Path integral (NRQM)

Probability amplitudes can be evaluated as functional integrals over all possible "paths"

$$\langle x|e^{-HT}|x\rangle = \int \mathcal{D}x e^{i\int dt\mathcal{L}}$$



Path integral (QFT)

Euclidean correlators

$$C(t) = \langle A(t)B(0)\rangle_T := \frac{Tr\left(e^{-(T-t)H}Ae^{-tH}B\right)}{Tr\left(e^{-HT}\right)}$$

$$C(t) = \frac{\int \mathcal{D}A_\mu \mathcal{D}\psi \mathcal{D}\overline{\psi} AB e^{-S_E}}{\int \mathcal{D}A_\mu \mathcal{D}\psi \mathcal{D}\overline{\psi} e^{-S_E}}$$

$\downarrow$

numerical computation
(not so easy actually)

$$C(t) = \sum_n A_n e^{-E_n t}$$

$\downarrow$

data analysis

Simulation

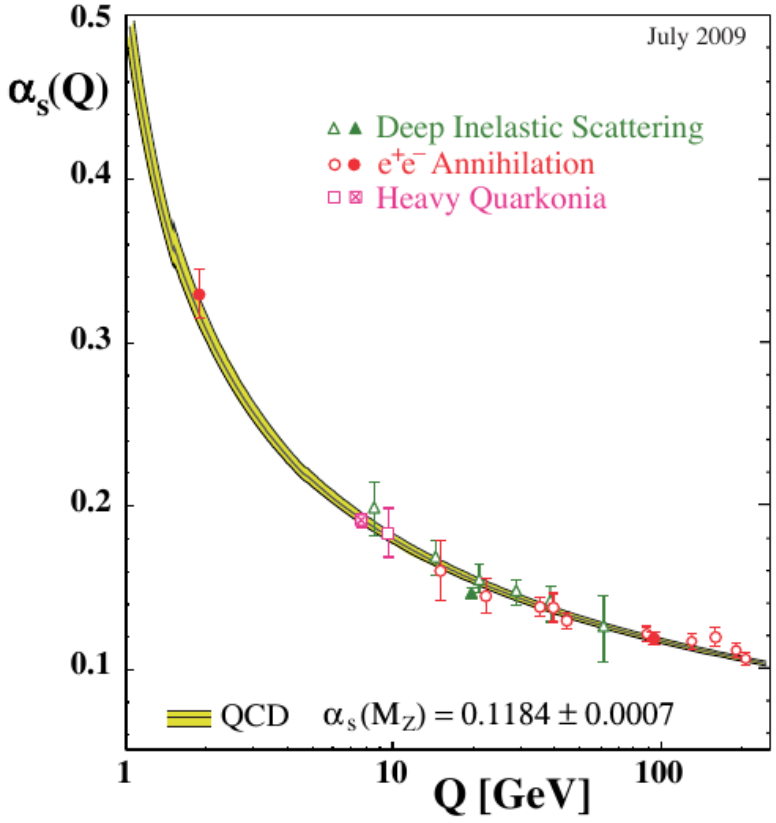
Main idea

1. Set the parameters: a, L, T, g, m_f, ...
2. Monte Carlo integration: gauge configurations
3. Average of the gauge configurations
4. Observables on the lattice (fit)
5. Repeat for many ensembles
6. Extrapolation:
   - Physical point
   - Continuum $a \to 0$
   - Infinite spacetime

Lattice QCD

QCD

- Eigenvalue problem for H_{QCD} hasn't a analytic solution
- Non perturbative behavior for small energies



Lattice QCD

- Masses of hadrons
- Vacuum polarization effects
- Form factors
- ...

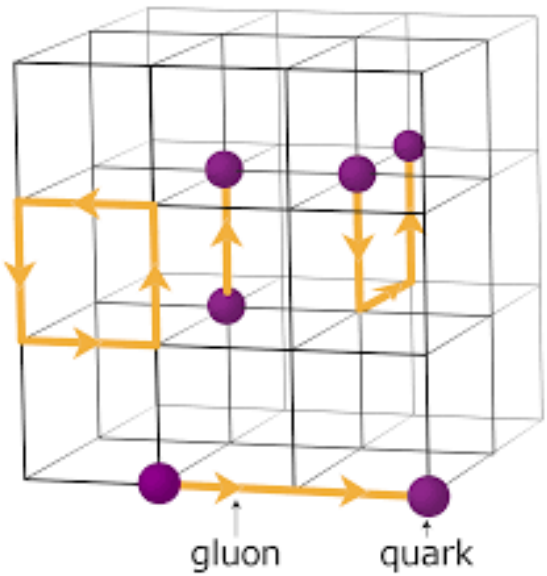
No expansion in the coupling!

Lattice QCD

Gauge invariance

Gauge invariance requires to define:

- Fermions on the point of the lattice
- Gauge bosons on the links between nearest neighbours



$$\mathcal{L}_{QCD} = \mathcal{L}_D + \mathcal{L}_G$$

$$\mathcal{Z} = \int \prod_{n,f} d\psi_F(n) d\overline{\psi}_f(n) dU_\mu(n) e^{-S[\psi,\overline{\psi},U]} \tag{1}$$

ESC school

INFN International School on
Architectures, Tools and Methodologies for Developing Efficient Large Scale Scientific Computing Applications

- Improve my knowledge of C++
- Get a deep understanding of precision floating point arithmetic
- Acquire the basics to implement large scale numerical simulations and parallel computing

Thanks for the attention

Differential Geometry for statistical applications

Jacopo Schiavon

Bertinoro, October 2019

jacopo.schiavon.1@phd.unipd.it
Department of Statistical Sciences, University of Padova

The Problem

In general, statisticians do not know much about Differential Geometry, but they should:

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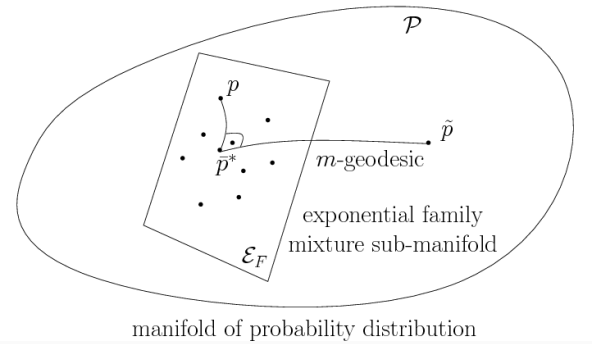
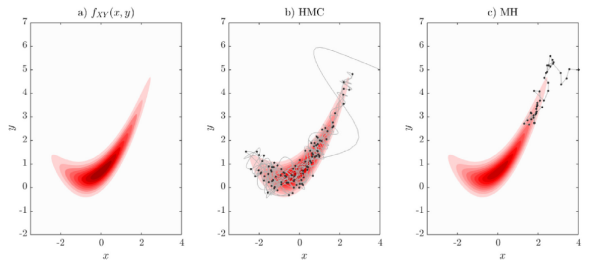
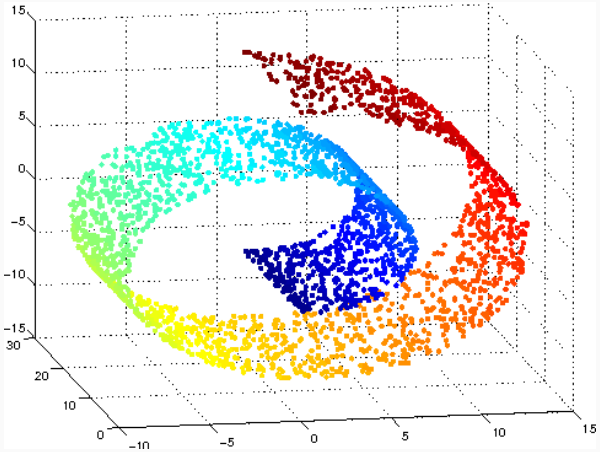
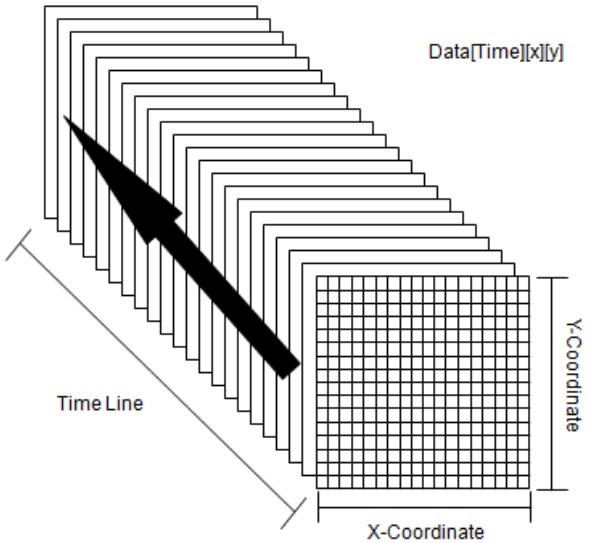
1. Study of the space of probability distributions
2. Optimal parameters search on complicated manifolds
3. Data that lie on non-linear sub-manifold of $\mathbb{R}^n$
4. Data that are not even in $\mathbb{R}^n$ to begin with

In general, statisticians do not know much about Differential Geometry, but they should:









Approaches in literature

1. Information Geometry (Amari, 2016)

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2. Riemannian Manifold HMC (Girolami *et al.*, 2011)
3. Manifold learning (Li and Dunson, 2019)
4. Manifold of Symmetric Positive Definite matrices (Barachant *et al.*, 2012)

My research interests

1. Information Geometry
2. Riemannian Manifold HMC
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   Warm up problem:

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   Real applications:

   - Gaussian dynamic model for volatility matrix in finance
   - Model for anomaly detection in submarine cables: covariance matrix of different measures on a cable section

Computational Aspect

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- Gradient based methods on a matrix space: fast computation of gradient with respect to a matrix
- Efficient mental framework to optimize the number of actual computation

mia tosi

who am I ?

- a physicist
  - 2006 master degree @uniPD
  - 2011 PhD @uniPD
  - 2011÷2017post-doc @uniPD+CERN
  - 2018÷present **researcher @uniPD**

- --mainly-- interested in the frontier of fundamental physics
- involved in **High Energy Physics at colliders**
- member of the **CMS collaboration** (since 2008)
- my research interests
  - understanding of the electroweak breaking mechanism
    - **search** for the **Higgs boson**
      both within the Standard Model and beyond the Standard Model framework
    - measure the Higgs boson **properties**
  - **measuring** properties of **rare processes** (i.e. $B_s \rightarrow \mu\mu$)
  - search for **Dark Matter**

  - **trigger** algorithms and software
  - **reconstruction** algorithms and software
  - **monitoring** algorithms and software
  - optimized **software** to handle larger amounts of data
  - development and maintenance of **silicon detectors**

- skills
  - knowledge of C++ and python
  - experience in developing the CMS software
  - data analysis
  - machine learning
  - teaching / supervising

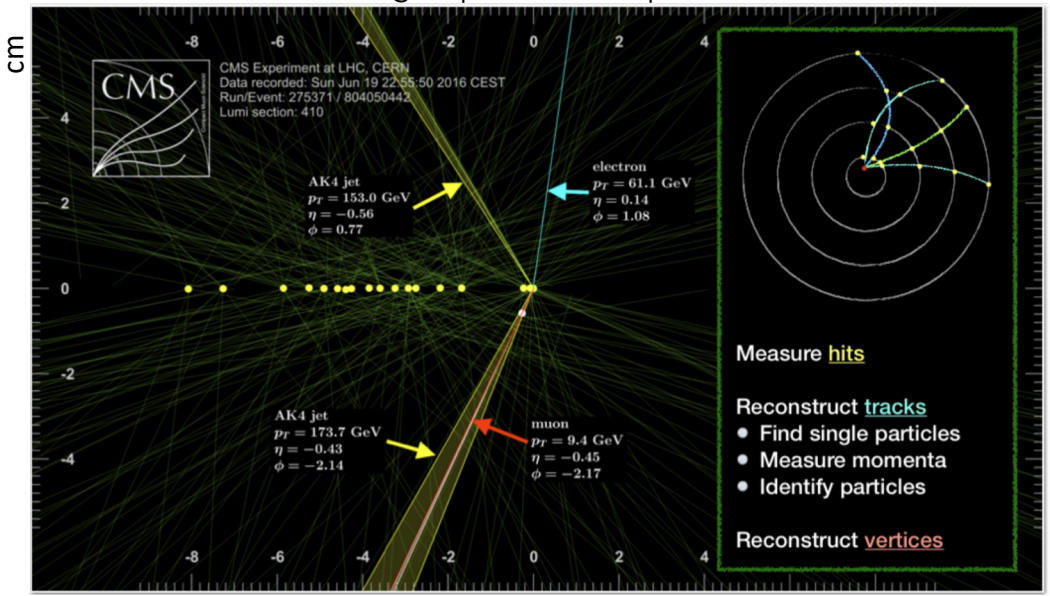
I had leading roles under
- the CMS Tracker project
- the CMS Trigger group
- the CMS Physics group

my work has been recognized with the CMS Achievement Award in 2014

"designing new trigger strategies and in developing techniques, and the corresponding validation, for the track reconstruction and track detectors monitoring"

Tracking in High Energy Physics (HEP)

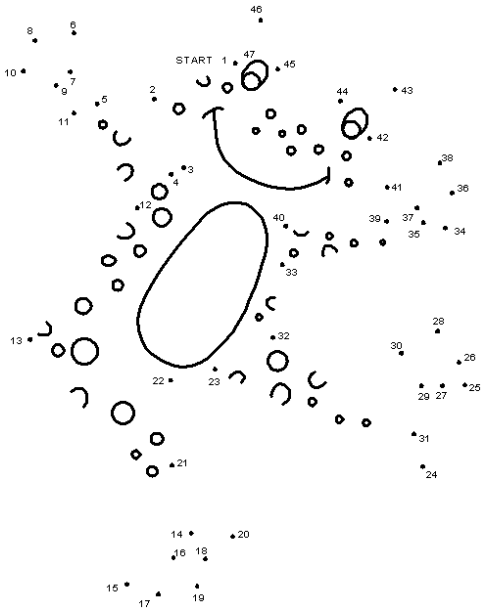
- we can search for new physics processes in collisions of protons at high energy
- after the collision,
  more than 1000 (new) charged particles are produced



- we make 3D "pictures" of these particles,
  ..and then, we need to reconstruct –possibly– all of them
  and measure their properties : direction, position, momentum and charge

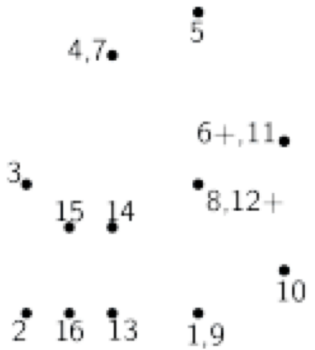
Connecting the dots

it is nothing but a "*connecting the dots*" game



Connecting the dots : hands-on

A)

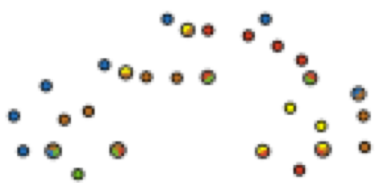


follow the numbering

B)

look at the details

C)



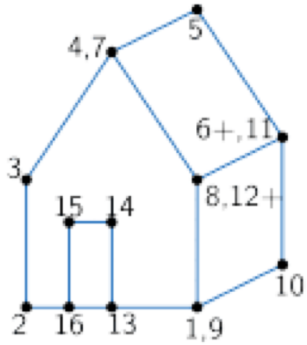
match by color

D)

look at the details

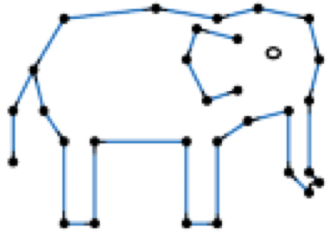
Connecting the dots : hands-on

A)



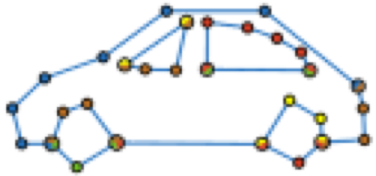
house

B)



elephant

C)



car

D)

fish

Connecting the dots

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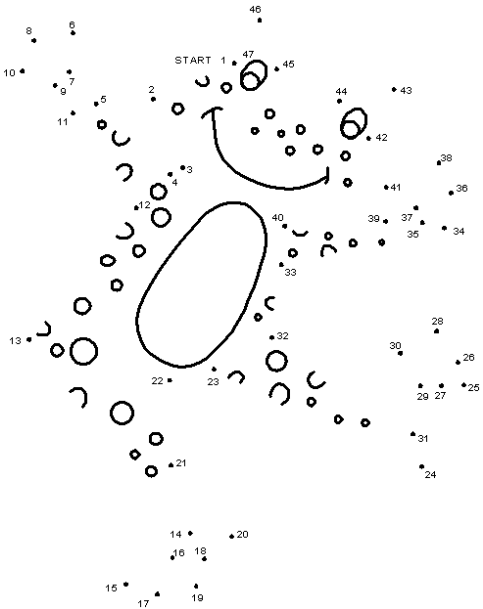
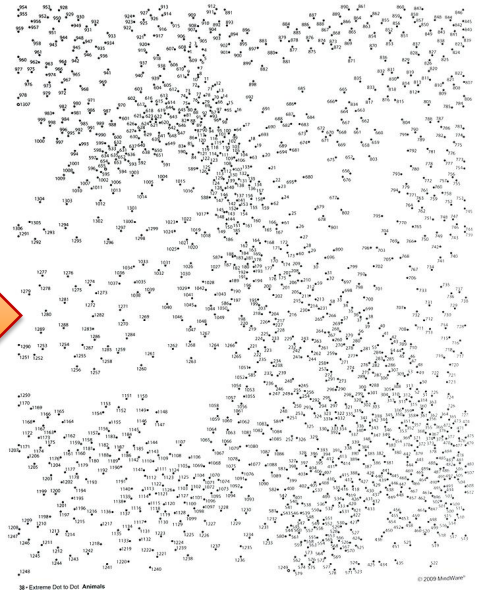


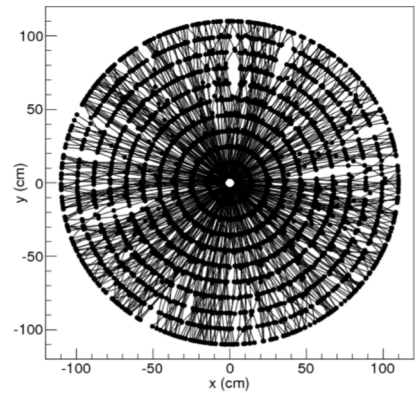


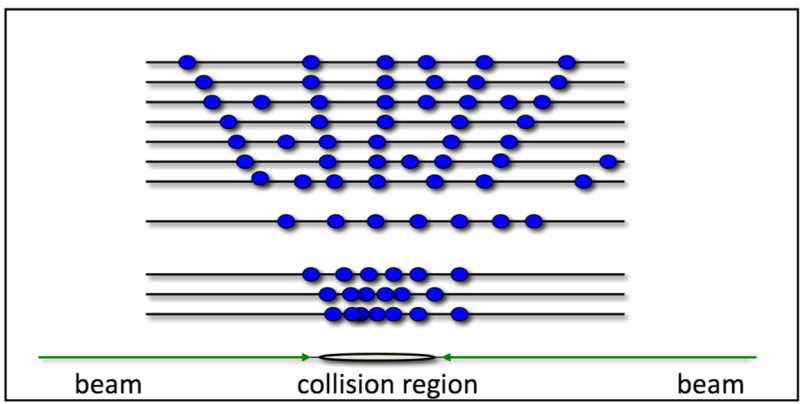
..in a dense environment, though

requirements & challenges

list of some of the requirements

- existence of the dot
- position coordinates
- order
- position precision
- hits multiplicity
- alignment
- …





list of some of the challenges

- ➢ combinatorics !
  - timing
  - computational resources
  - fake pattern
  - efficiency
  - resolution
  - precision (multiple scattering)
  - …

The iterative tracking approach

in each iteration, tracks are reconstructed in four steps:

1. seeding:

provides track candidates,
with an initial estimate of the trajectory parameters and their uncertainties

2. pattern recognition:

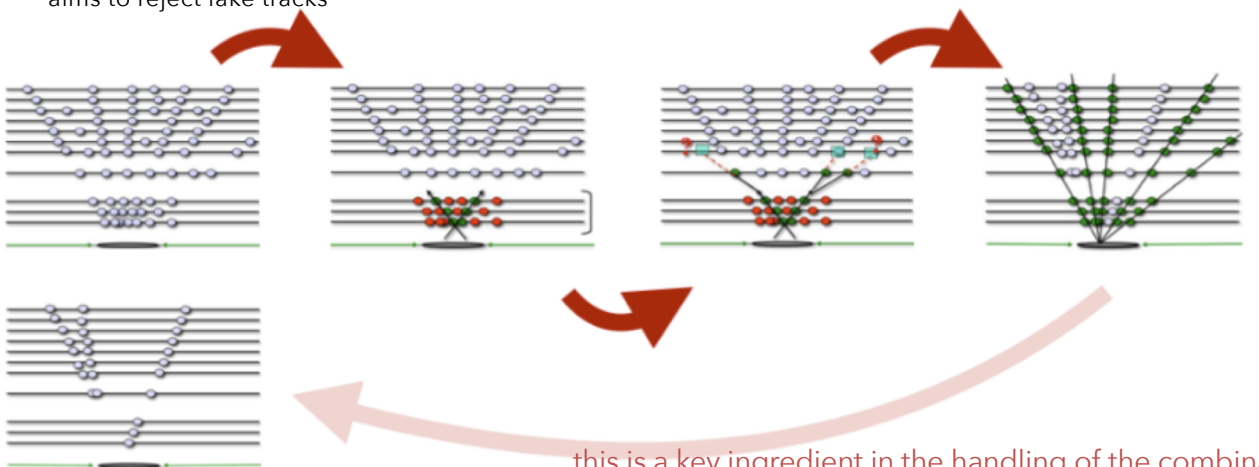
track candidates are propagated to find new compatible hits
track parameters are updated

3. final fitting:

provides the best estimate of the parameters of each smooth trajectory
after combining all associated hits

4. selection:

sets quality flags based on the fit χ^2 and the track compatibility w/ interaction region
aims to reject fake tracks

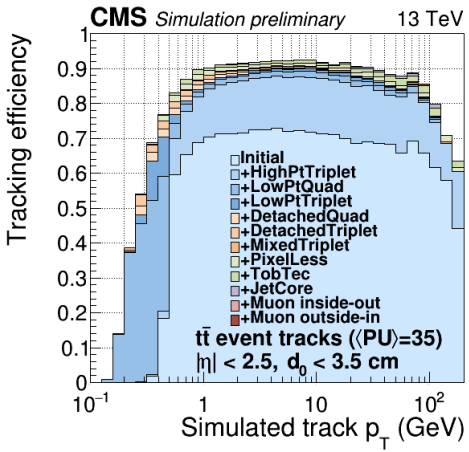


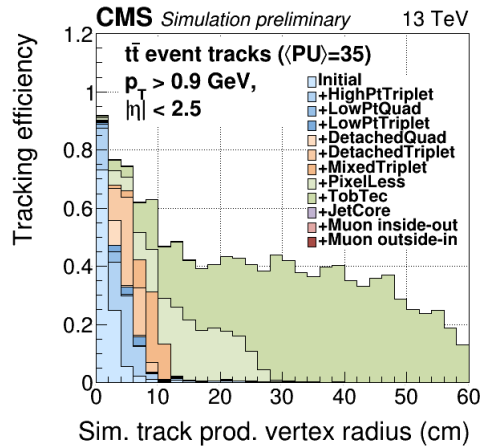
this is a key ingredient in the handling of the combinatorics

Iterative tracking

In CMS, tracks reconstruction is an iterative procedure:
high-quality tracks are reconstructed first,
their hits are removed,
and other tracks are reconstructed from the remaining hits

- in the InitialStep, high-p_T quadruplets coming from the beam spot region are used
- subsequent steps use triplets, or improve the acceptance either in p_T or in displacement
- the later steps use seeds with hits from the strip detector to find detached tracks,
- final steps are dedicated to special phase-space
  - highly dense environment (i.e. w/in jets)
  - clean environment (i.e. muons)

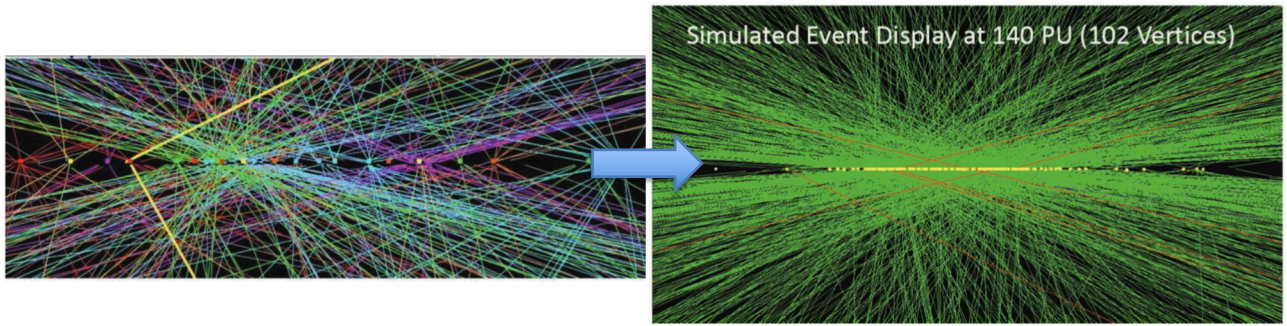




What next ?

- the track reconstruction in HEP is a challenging task
  - dense environments
  - limited resources
  - demanding precision and purity
  - ..

- in the upcoming years, the conditions will be even more severe

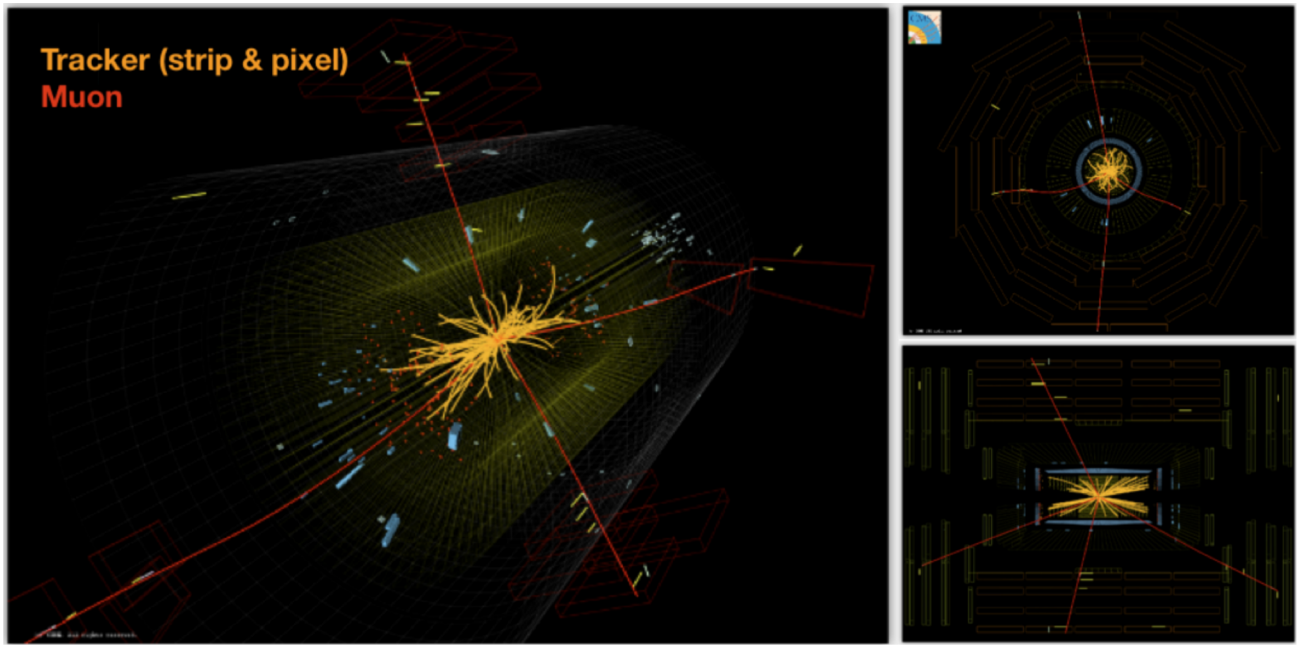


- one of the main points of the track reconstruction is the pattern recognition

➔ the track reconstruction in HEP is an interesting and challenging task
for developing and practicing the most advance
Machine Learning techniques / approaches

BACKUP

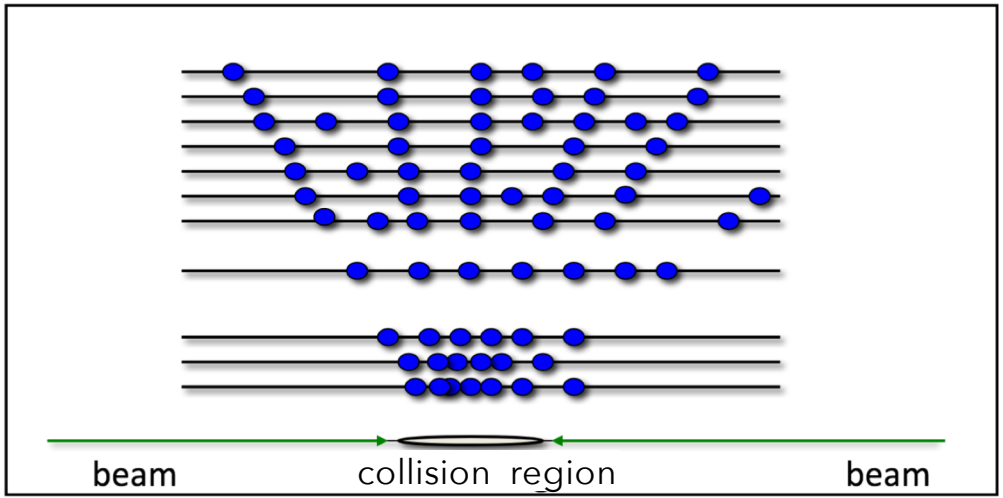
Tracking ingredients



Track reconstruction

Local Tracker reconstruction

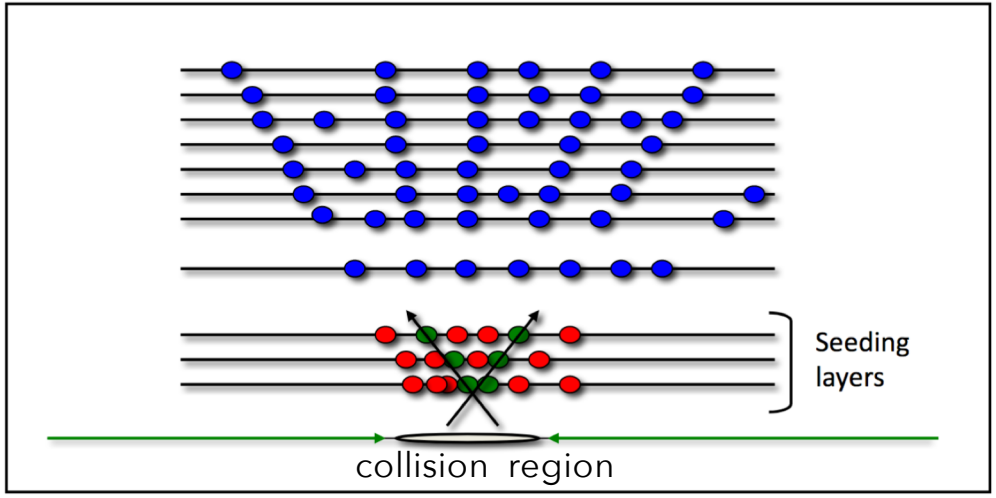
- the signals from the detectors are clustered into "hits"
- "Coarse" position and corresponding error matrix of each hit are evaluated



Track reconstruction

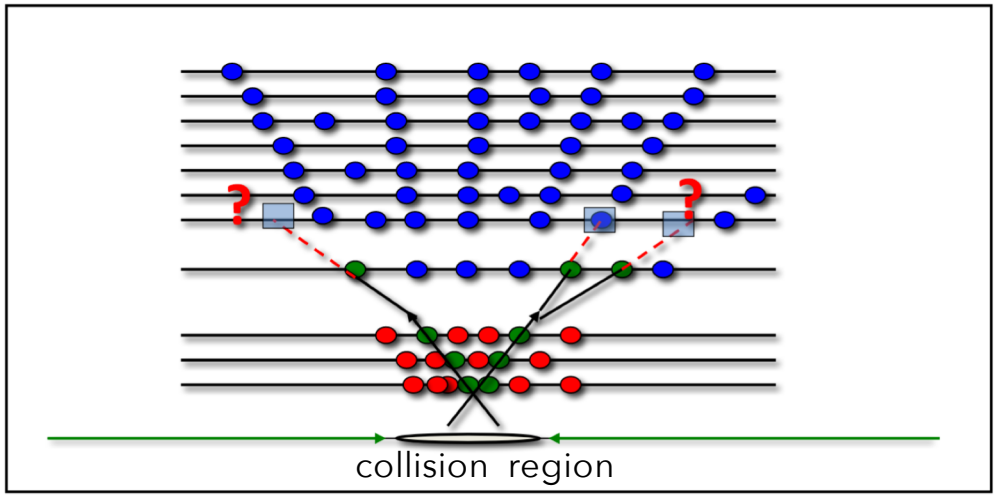
Trajectory seeding

initial estimate of trajectory parameters
from a small subset of measurements,
i.e. the hits on the seeding layers of the detector



Track reconstruction

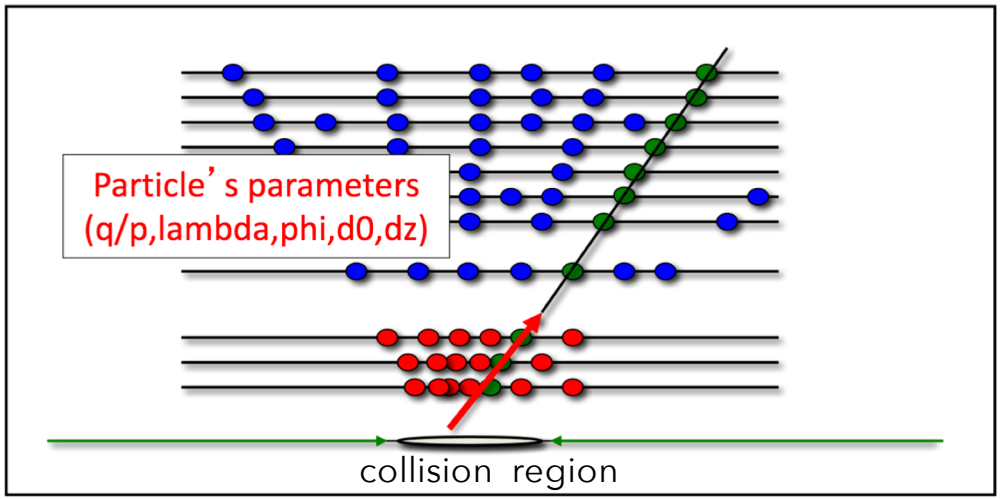
Trajectory building iterative process(*) that aims to collect all hits originating from the same charged particle



(*) KalmanFilter

Track reconstruction

Trajectory fitting estimation of final track parameters from the fit (*) of the full set of hits associated to the same charged particle

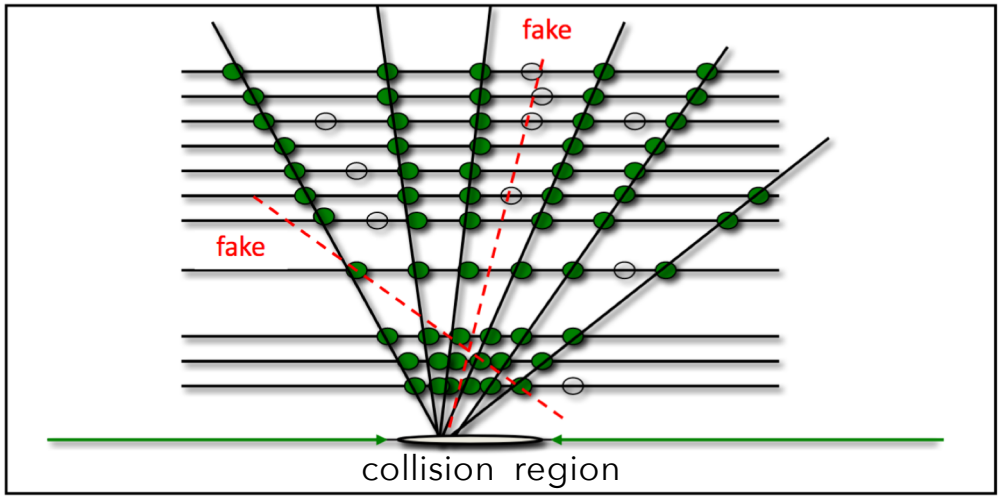


(*) KalmanFilter+Smoother

Track reconstruction

Track collection filtering

removal of fake or badly reconstructed tracks



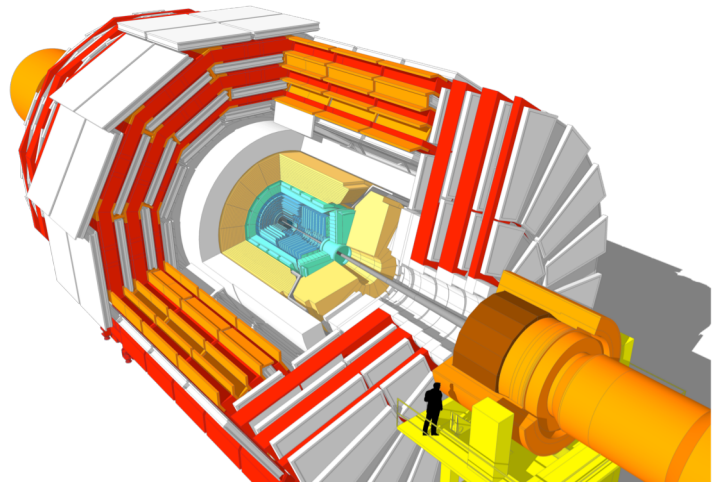
CMS tracker

Position information from finely segmented silicon sensors:
- Record the path of charged particles
- Measure momentum from bending radius in the magnetic field
- Reconstruct primary and secondary vertices

performance:
[typically ~15 hits per track]
$\sigma(p_T)/p_T$ ~ 1-2% @ 100 GeV/c
σ(IP) ~ 10-20 μm @ 10-100 GeV/c

Requirements:
- **High resolution** & **low occupancy**:
  resolve and isolate individual tracks, reconstruct vertices

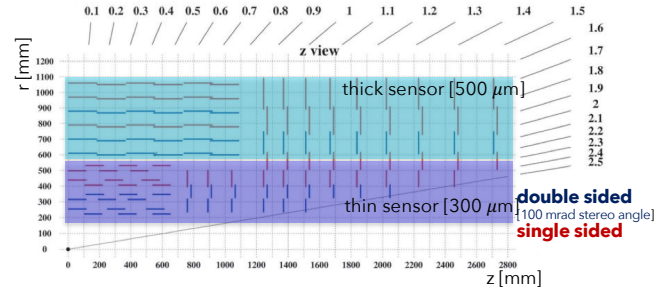
  Finer granularity is needed closer to the IP [High particle density, small tracking volume]
- **High rate capability**:
  fast charge collection time and read-out electronics to keep up with the expected event rates
- **Low material budget**:
  minimize multiple scattering
- **Radiation hardness**:
  innermost subdetectors
  ⇒ receive highest particle fluence

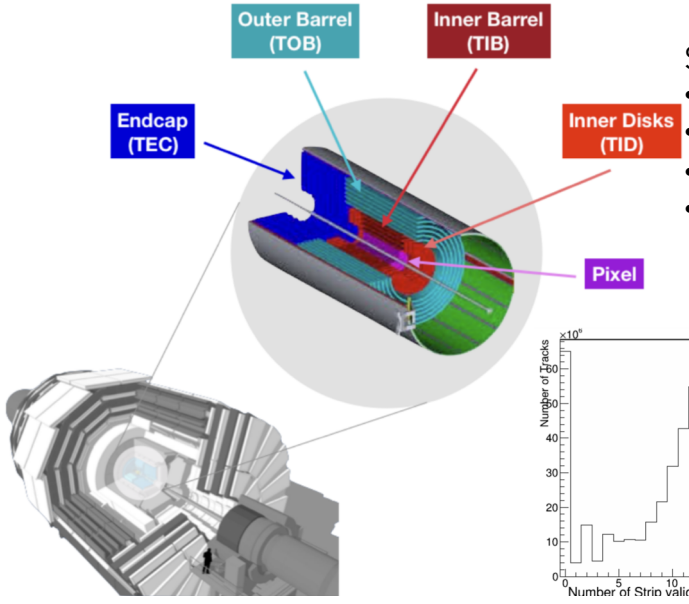


immersed in a 3.8 T magnetic field

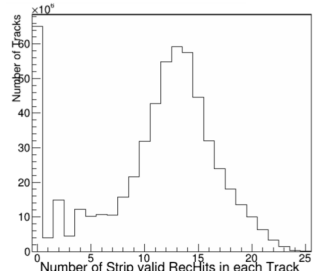
CMS tracker: Silicon Strips

- O(10) million strips
- O(200) m^2 of sensors
- hit resolution: (10,40)x(230,530) μm
- occupancy: 1-3%
- coverage up to $|\eta| < 2.5$





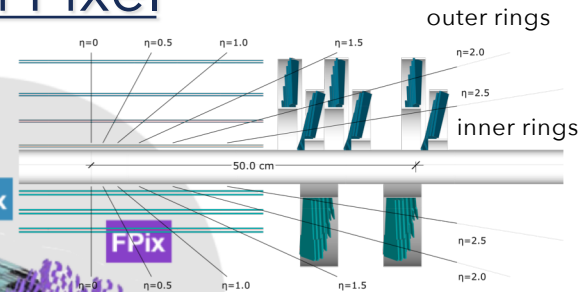
Sub-detectors
- Inner Barrel (**TIB**): 4
- Inner Disks (**TID**): 3 (x 2)
- Outer Barrel (**TOB**): 6
- Endcap (**TEC**): 9 (x 2)

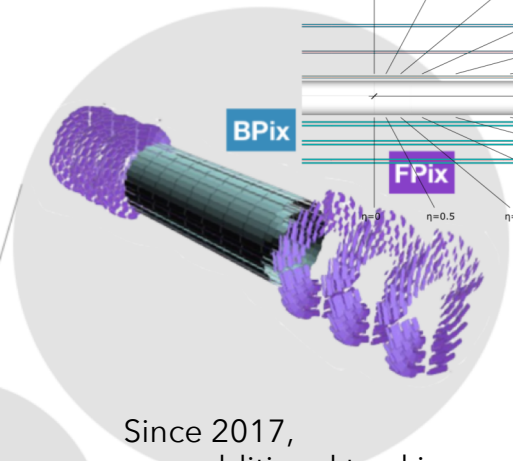


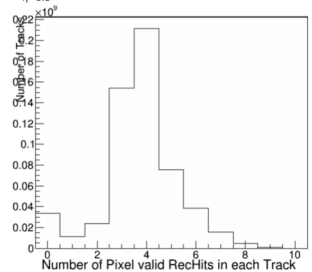
Many layers:
redundancy
12 hits per track on average

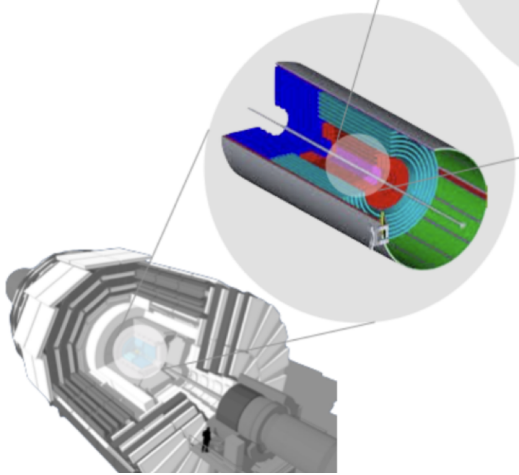
CMS tracker: Silicon Pixel

- 127 million pixels,
- 100x150 μm^2 in size
- hit resolution: 10x(20,40) μm
- occupancy: 10^{-3}
- coverage up to $|\eta| < 2.5$ (even 3.0)
- layer position [cm]:
  BPix: 2.9, 6.8, 10.9, 16.0
  FPix: 29.1, 39.6, 51.6
- high segmentation:
  high quality seeds for offline tracking







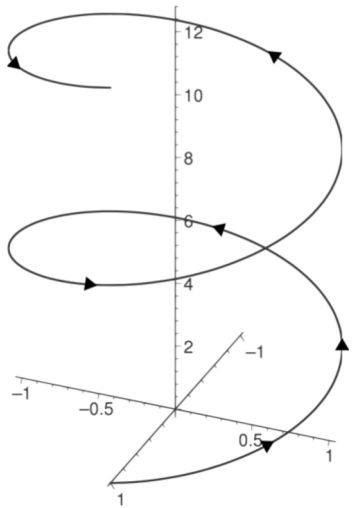


Since 2017,
one additional tracking point,
in both barrel and forward regions:
- 4-hit seeds
- lower fake rate!

smaller radius of the innermost pixel layer
- closer to the interaction region
- improve tracking and vertexing performance

reduced material budget
- reduce multiple scattering

Trajectory parametrization



A helical trajectory can be expressed by 5 parameters,
but the parameterization is not unique.

Given one parameterization, we can always re-express the same trajectory in another parameterization.

In general terms, the five parameters are:

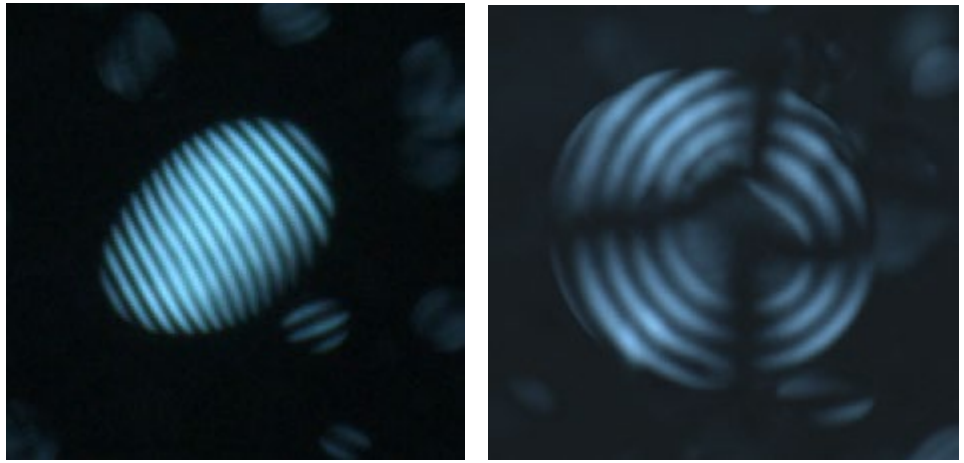
- **signed radius of curvature** (units of cm),
  which is proportional to particle charge
  divided by the **transverse momentum**, $\mathbf{p_T}$, (units of GeV);
- **angle of the trajectory** at a given point on the helix,
  in the plane **transverse to the beamline** (usually called $\boldsymbol{\varphi}$);
- **angle of the trajectory** at a given point on the helix
  with respect to the beamline (θ, or equivalently $\lambda = \pi/2 - \theta$),
  which is usually expressed
  in terms of pseudorapidity $\boldsymbol{\eta} = -\ln(\tan(\theta/2)))$;
- offset or "**impact parameter**" relative to some reference point
  (usually the beamspot or a selected primary vertex),
  in the plane **transverse to the beamline** (usually called $\mathbf{d_{xy}}$);
- **impact parameter** relative to a reference point
  (beamspot or a selected primary vertex),
  along the beamline (usually called $\mathbf{d_z}$)

Efficient Scientific Computing 2019

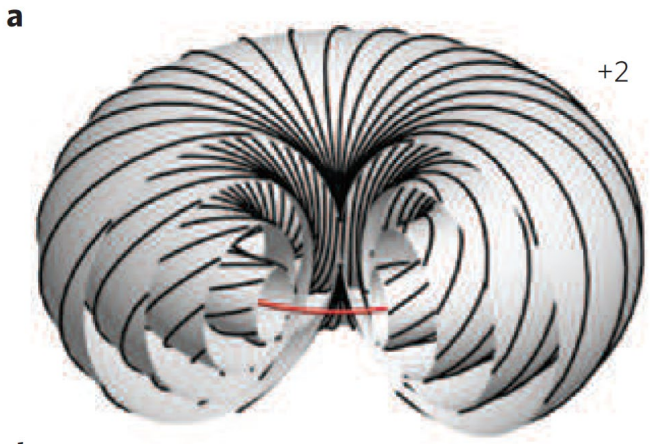
Bertinoro, 21 Ottobre 2019 – 26 Ottobre 2019

Vito Turco's Research Presentation

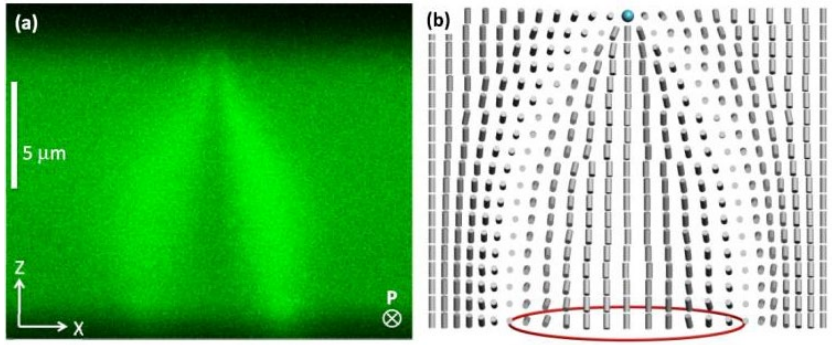
Defects In Chiral Liquid Crystals



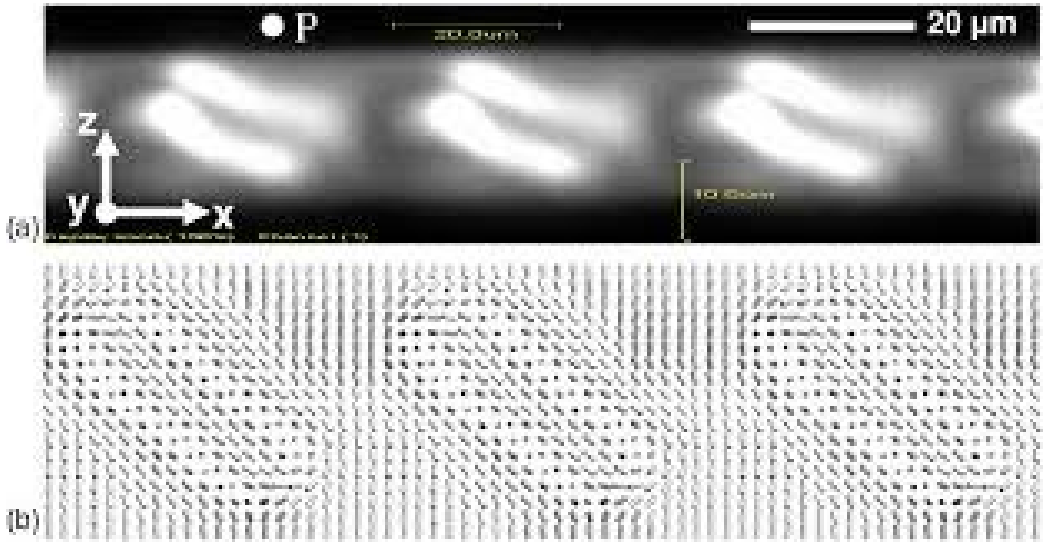
Nature Nanotechnology **volume 13**, pages330–336 (2018)



NATURE MATERIALS | VOL 9 | FEBRUARY 2010



PHYSICAL REVIEW E **72**, 061707 2005



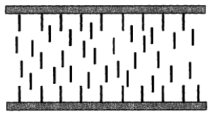
PHYSICAL REVIEW E **72**, 061707 2005

Static Theory of Frustrated Cholesterics

$$\mathbf{n}(\mathbf{r}) \in \mathbb{RP}^2$$

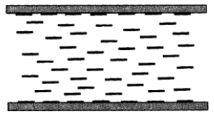
$$\mathcal{E}_{FO} = \frac{K_1}{2}(\nabla \cdot \mathbf{n})^2 + \frac{K_2}{2}(\mathbf{n} \cdot \nabla \times \mathbf{n} - q_0)^2 + \frac{K_3}{2}(\mathbf{n} \times \nabla \times \mathbf{n})^2 + \frac{(K_2+K_4)}{2}\nabla \cdot [(\mathbf{n} \cdot \nabla)\mathbf{n} - (\nabla \cdot \mathbf{n})\mathbf{n}]$$

$$\mathcal{E}_{\mathbf{E}} = -\frac{\varepsilon}{2}(\mathbf{n} \cdot \mathbf{E})^2$$



homeotropic

$\mathbf{n} = \pm\mathbf{z}$



homogeneous

$\mathbf{n} = \pm\mathbf{x}$

$$\mathcal{B} = \{(x, y, z) \in \mathbb{R}^3, \mid z \mid \leq \frac{L}{2}\}$$

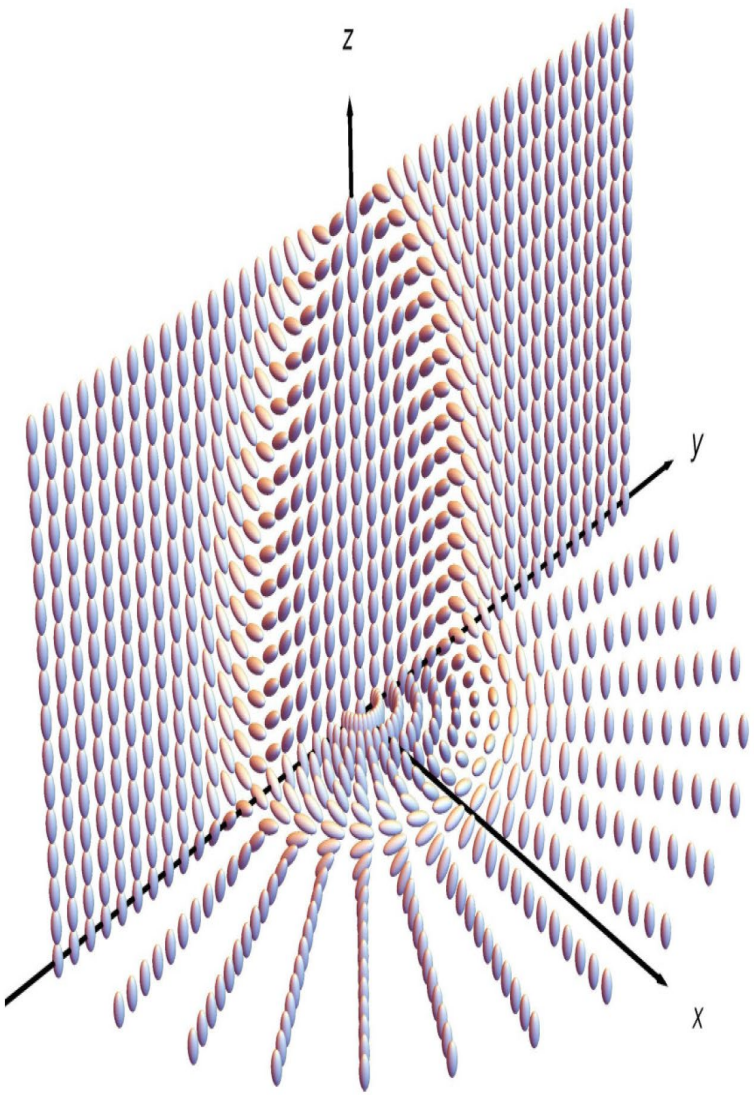
$$\mathcal{E}_s = \frac{1}{2}K_s(1 + \alpha(\mathbf{n} \cdot \nu)^2)$$ (Rapini-Popoular term)

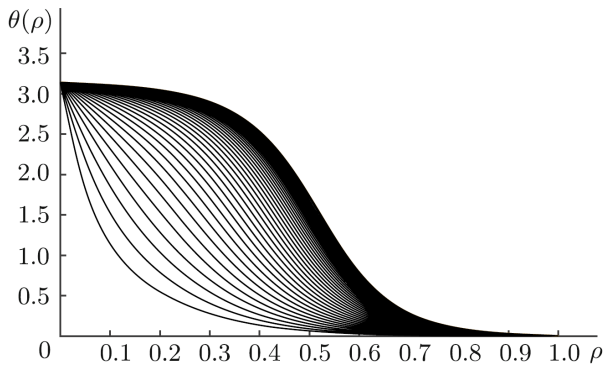
Skyrmions 1

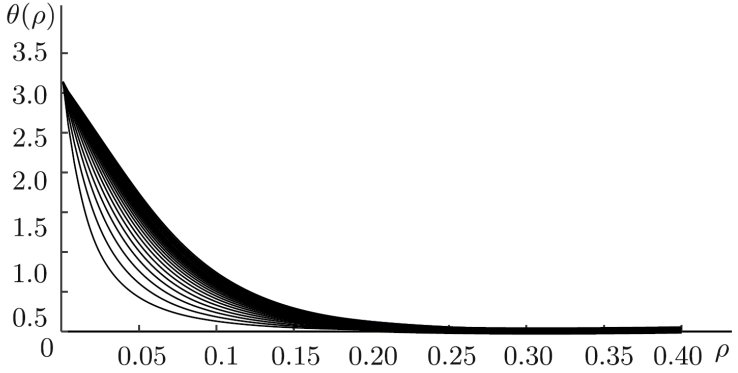
$$\frac{\partial^2\theta}{\partial z^2} + \frac{\partial^2\theta}{\partial \rho^2} + \frac{1}{\rho}\frac{\partial\theta}{\partial\rho} - \frac{1}{\rho^2}\sin\theta\cos\theta \mp \frac{4\pi}{\rho}\sin^2\theta - \pi^4\left(\frac{E}{E_0}\right)^2\sin\theta\cos\theta = 0,$$

$$\theta(0,z) = \pi, \qquad \theta(\infty,z) = 0,$$

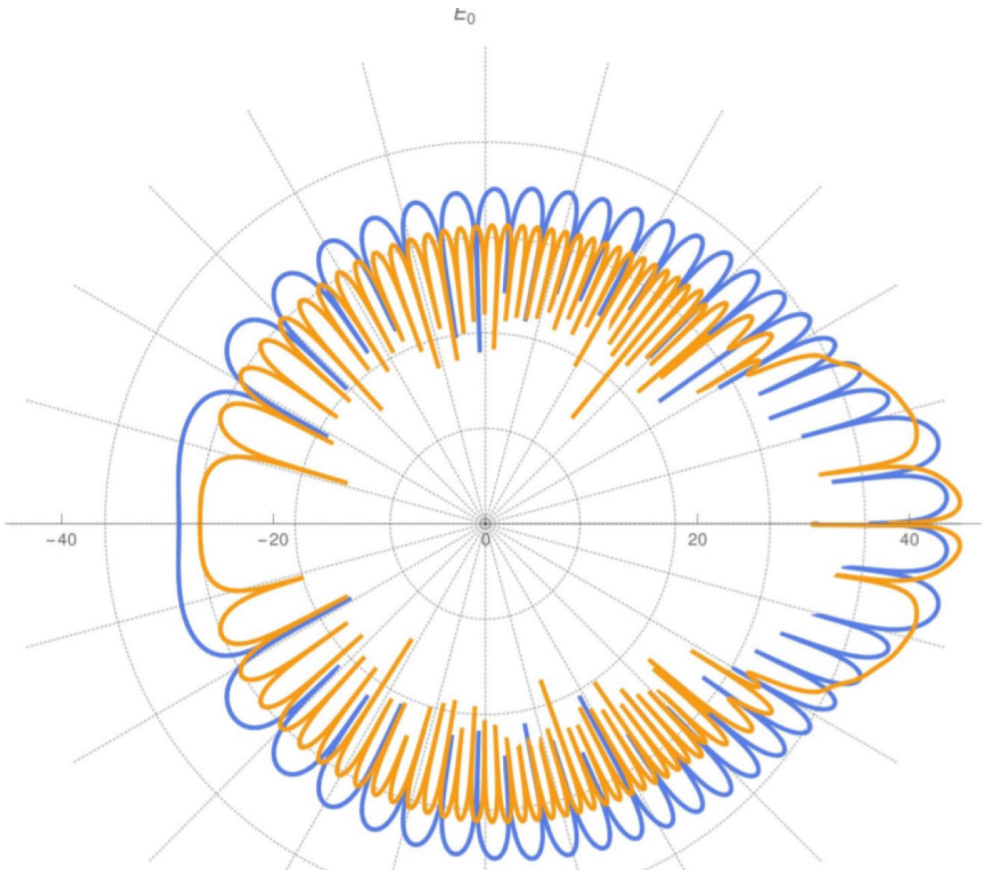
$$\partial_z\theta\left(\rho,\pm\frac{\nu}{2}\right) = \mp 2\pi k_{\mathrm{s}}\sin\theta\left(\rho,\pm\frac{\nu}{2}\right)\cos\theta\left(\rho,\pm\frac{\nu}{2}\right),$$

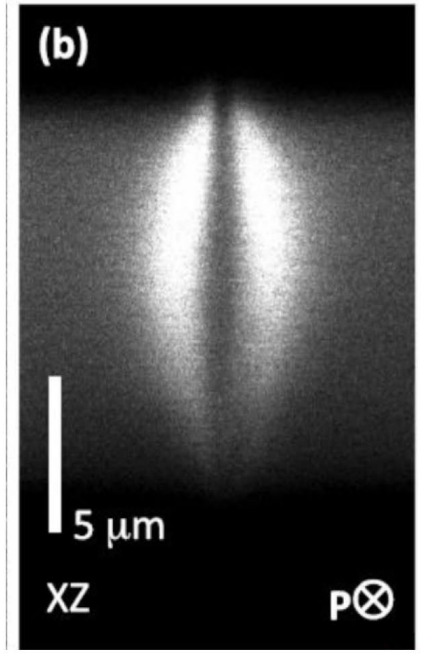






Skyrmions 2





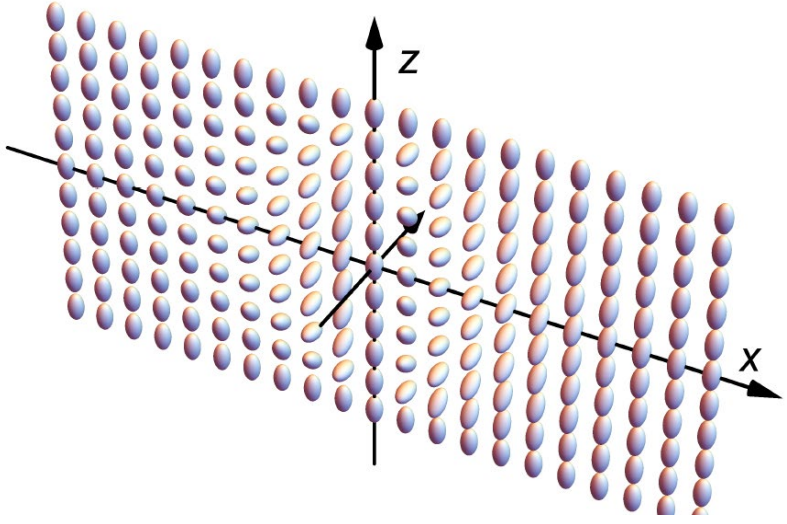
PHYS. REV. E 90, 012505 (2014)

Helicoids 1

$$\mathbf{n} = (0, -\sin\theta(x, z), \cos\theta(x, z)) \longrightarrow \partial_x^2\Theta + \partial_z^2\Theta = \Lambda^2 \sin\Theta, \quad \Theta = 2\theta, \quad \Lambda = \sqrt{\frac{\varepsilon}{K}}\mathrm{E}.$$

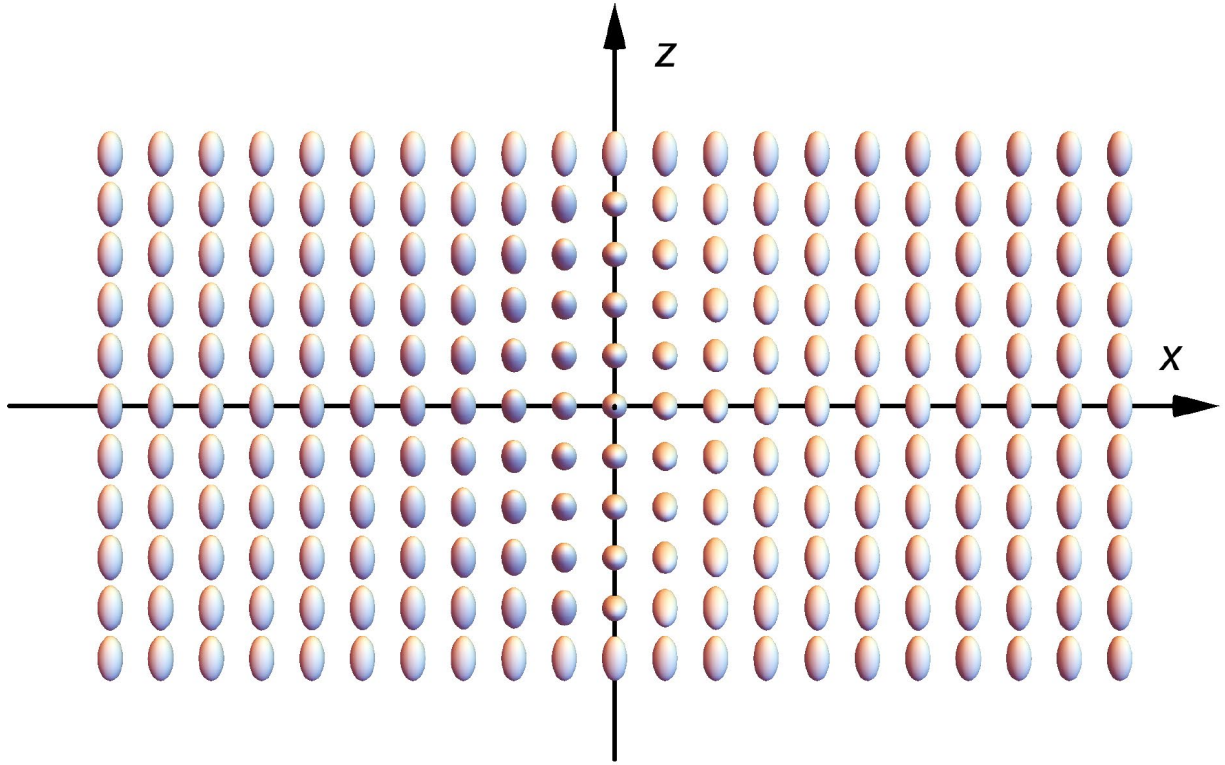
$$\theta_n = 2\arctan\left[\frac{c_n\,\ell}{\pi(1+2n)}\frac{\cos\left(\frac{\pi(1+2n)z}{L}\right)}{\sinh\left(c_n\,\ell\,\frac{x}{L}\right)}\right] - \mathrm{sign}[x]\pi$$

with $\ell = \Lambda L$, $c_n = \left[1 + \frac{(1+2n)^2\pi^2}{\ell^2}\right]^{1/2}$.



Helicoids 2

$$\theta_+(x,z) = 2\sum_{k=0}^{+\infty} \frac{(-1)^k}{2k+1} e^{-\frac{x\sqrt{\pi^2(2k+1)^2+\ell^2}}{L}} \cos\left(\frac{\pi(2k+1)z}{L}\right)$$

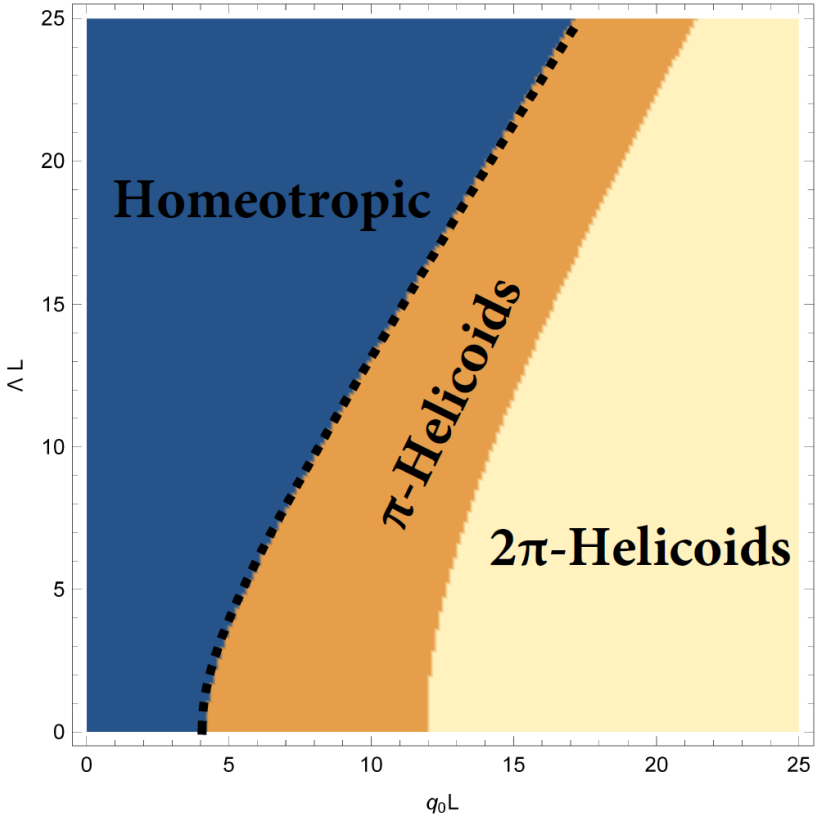


Helicoids 3

$$\Lambda_c L = \sqrt{\frac{2\gamma^2 qL\left(qL - \frac{2}{\gamma}\right)}{1 - \frac{\left(1 - e^{-\gamma qL}\right)}{\gamma qL}}} \quad \text{with } \gamma \equiv K_2/K = 1.054,\ qL = -\frac{1}{\gamma} W_{-1}\left(-\frac{\gamma L}{2a} e^{-1-q_0 L\gamma}\right)$$

$\downarrow$

Lee, Allender 1992 (dotted line)



$$a = 10^{-2} L$$

And now?

- Scattering of Light by Helicoids
- Lattices of Helicoids
- Numerical Minimization of free energy to obtain static and metastable equilibrium configurations starting from our continous solutions.
- Dozov-like Quartic free energy for the nematic twist-bend phase.

Thank you for your attention!

ESC Lightning Presentation

Valentin Volkl

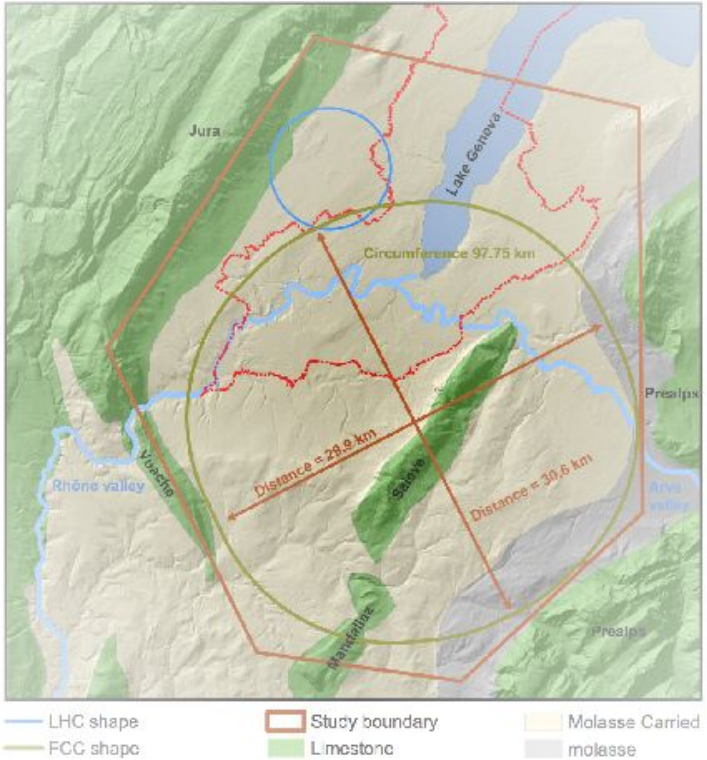
ESC 2019

Oct 17, 2019
Valentin Volkl
Univ. Innsbruck / CERN

About me

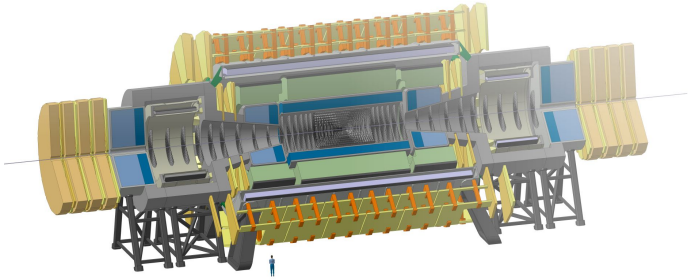
- Project Associate for the Future Circular Collider Design Study at CERN
- PhD Candidate at University of Innsbruck, Austria
-
- Was Doctoral Student in EP-SFT
  - Department developing ROOT, Geant4 ...

Future Circular Collider Design Study

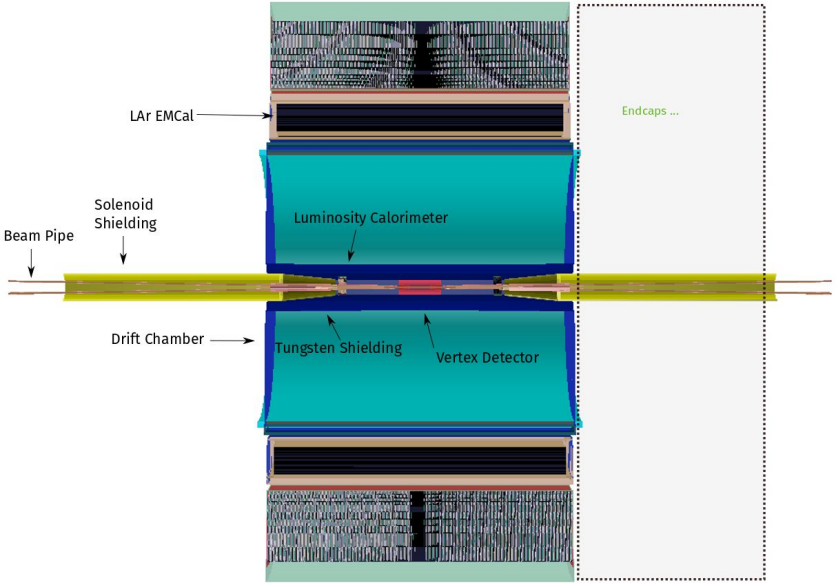


- FCC-ee
  - Lepton collider @ 90, 160, 240, 350 GeV
- FCC-hh
  - Super-LHC @ 100TeV
- FCC-eh

Detector Design

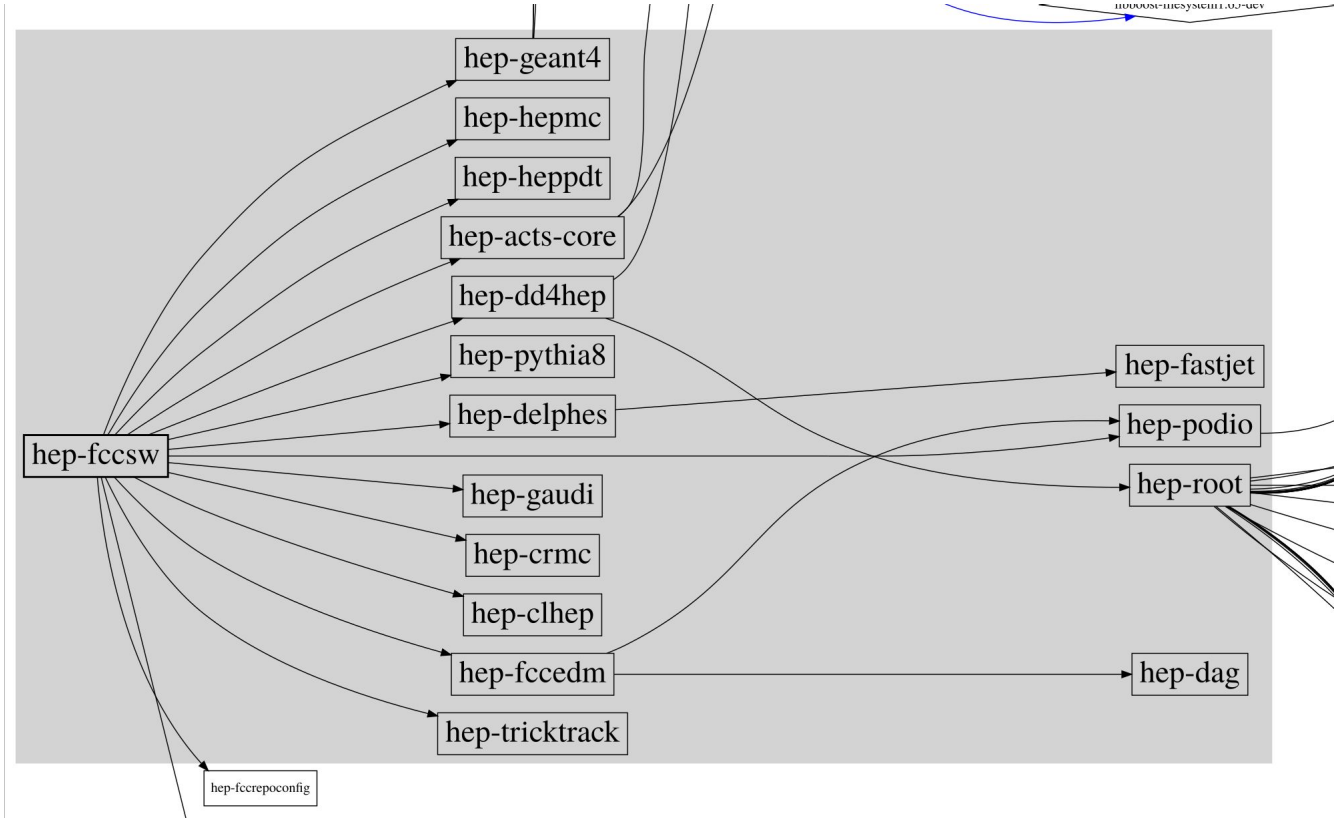


FCC-hh



FCC-ee IDEA

FCC Software



Software Collaboration

- Collaboration and synergies important for small venture like FCC
- High Energy Software Foundation is an ideal forum for this
- https://github.com/HSF/TrickTrack
  - CMS Track seeding code encapsulated
- https://github.com/HSF/EDM4HEP
  - Common Event Data Model for Future Collider Communities

I AM...

Katharina von Sturm

33 years old

german

PostDoc @ Physics Department
University of Padova

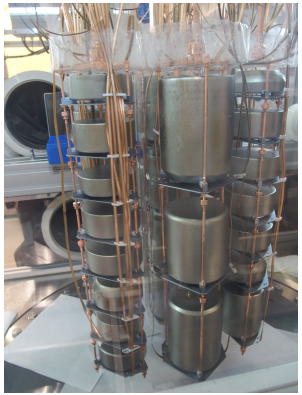
GERDA collaboration

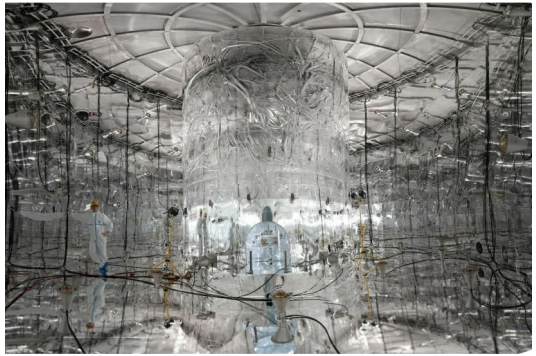
GERDA@LNGS

Search for neutrinoless-ββ decay using germanium diode detectors

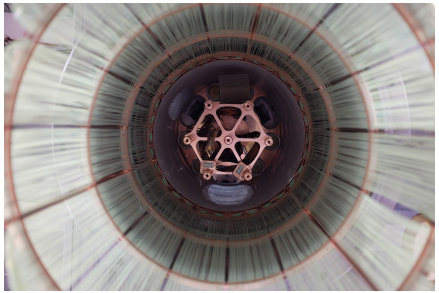
- exotic physics

Germanium detectors





collection of propaganda pictures



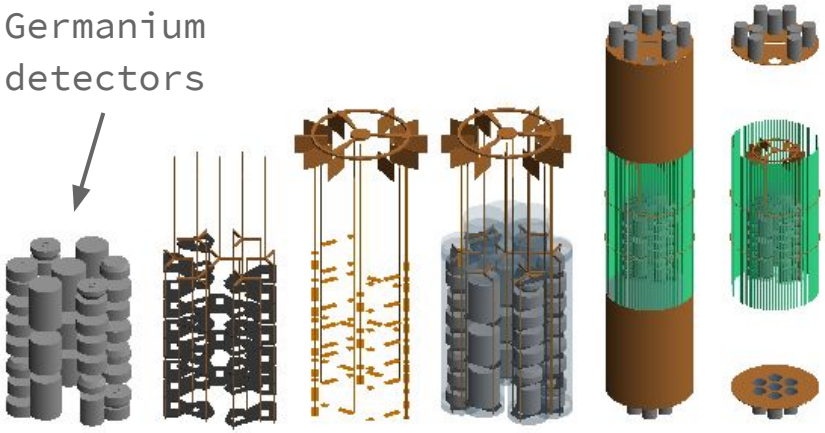
My research Activities

- Data analysis
  - digital signal processing of GERDA data
  - determination of detector properties
  - Background Modeling
- Geant4 based Monte Carlo simulation
  - Software development
  - Geometry implementation
  - Organization of simulations
  - Post processing

my daily life

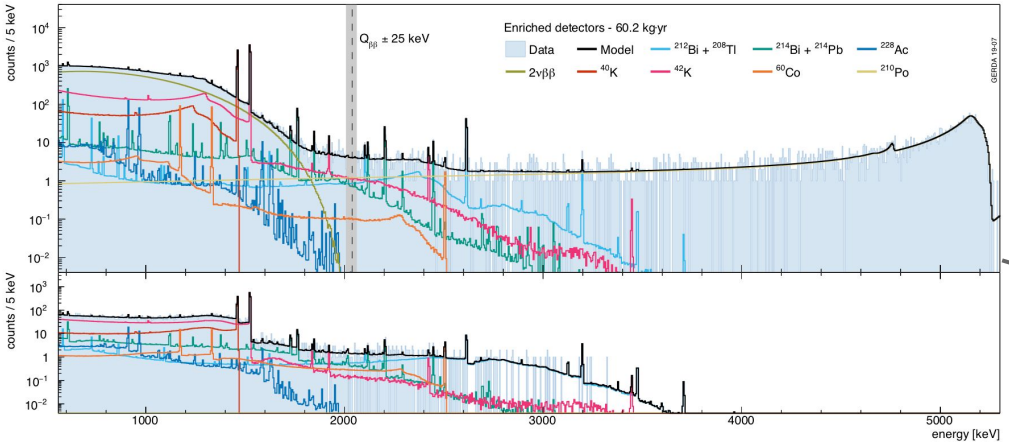
My research Activities

Germanium detectors



Background Modeling

- Reconstruct the experiment in a computer simulation
- Compare simulated and measured spectra



involves a lot of organization and automatization

- scripting
- containers

Search for exotic physics

FROM GERDA TO LEGEND

Large Enriched Germanium Experiment for Neutrinoless ββ Decay

- Gerda is about to reach design exposure
- Project post GERDA is called LEGEND
- 40kg -> 200kg of Germanium
- 40 detectors -> 150 detectors
- More and more complex data
- Processing and analysis will be more challenging
- More efficient computing methods are needed

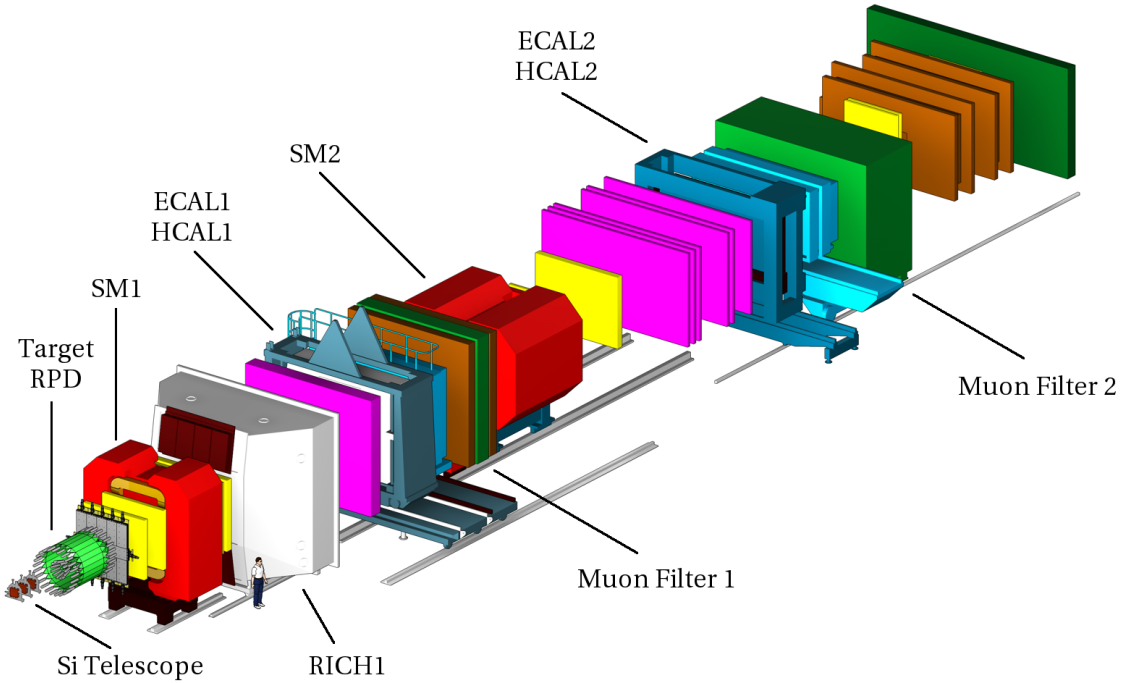
Investigation of the $a_1(1420)$-signal at the COMPASS experiment

Mathias Wagner, Mikhail Mikhasenko, Bernhard Ketzer

HISKP, Bonn University

October 21./22., 2019

- Analyzing data from COMPASS experiment
  - $\pi^- + p \quad \rightarrow \quad \pi^- + \pi^- + \pi^+ + p$
  - $E_{\text{beam}} = 190\,\text{GeV}$
  - Liquid hydrogen target (40 cm)
  - Data binned in 100 $m_{3\pi}$ and 11 $t' = |t| - |t_{\text{min}}|$ slices



[COMPASS, NIM A**779**, 69-115 (2015)]

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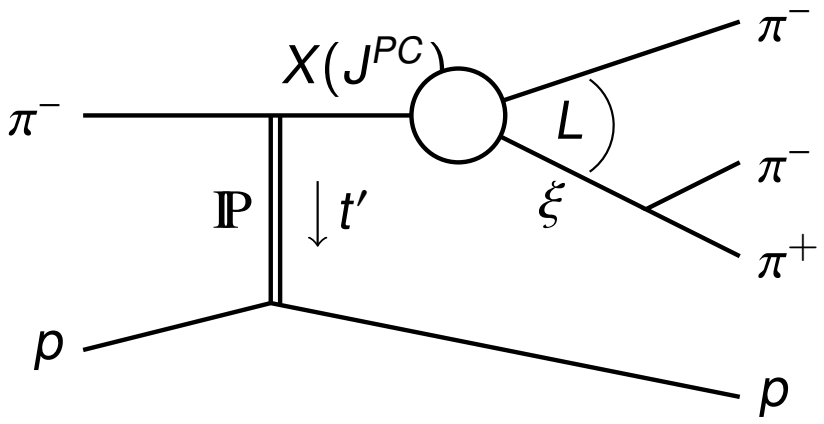
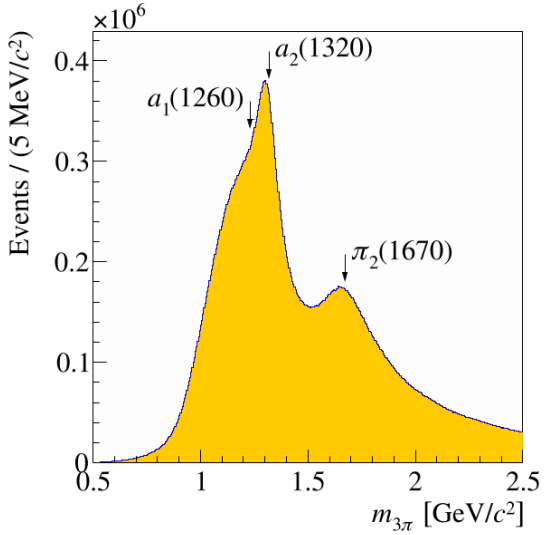
- PWA with 88 waves [COMPASS, PRD **95**, 032004 (2017)]





$\mathbb{P}$: Pomeron

X: Resonance, here $a_1(1260)$ ($J^{PC} = 1^{++}$) and $a_2(1320)$ (2^{++})

ξ: Isobar, here $\rho(770)$ and $f_0(980)$

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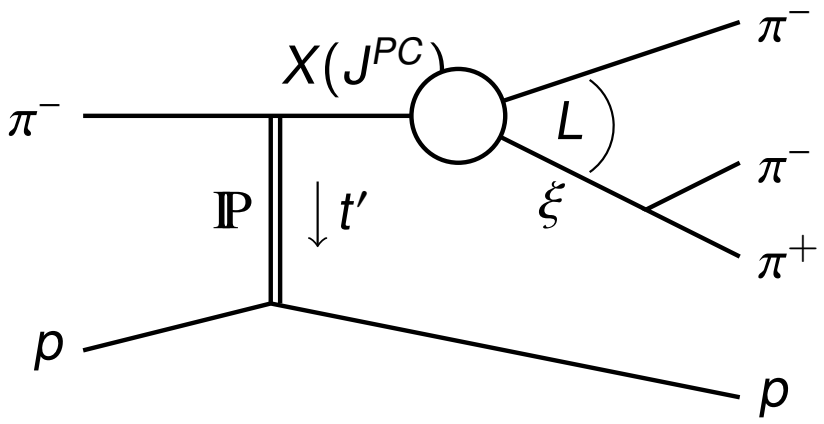

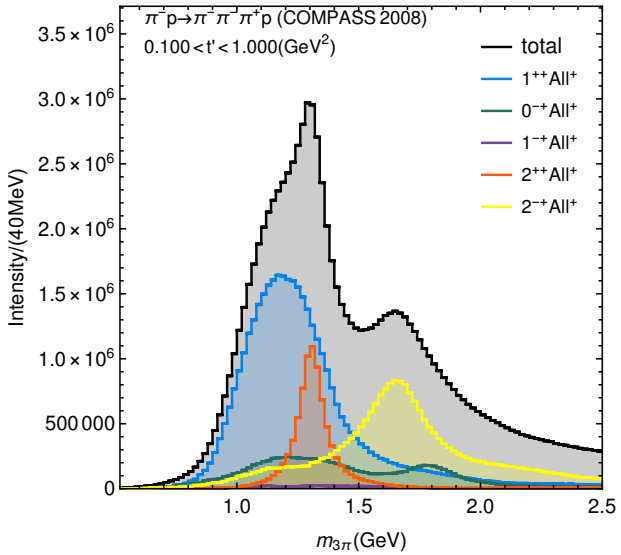

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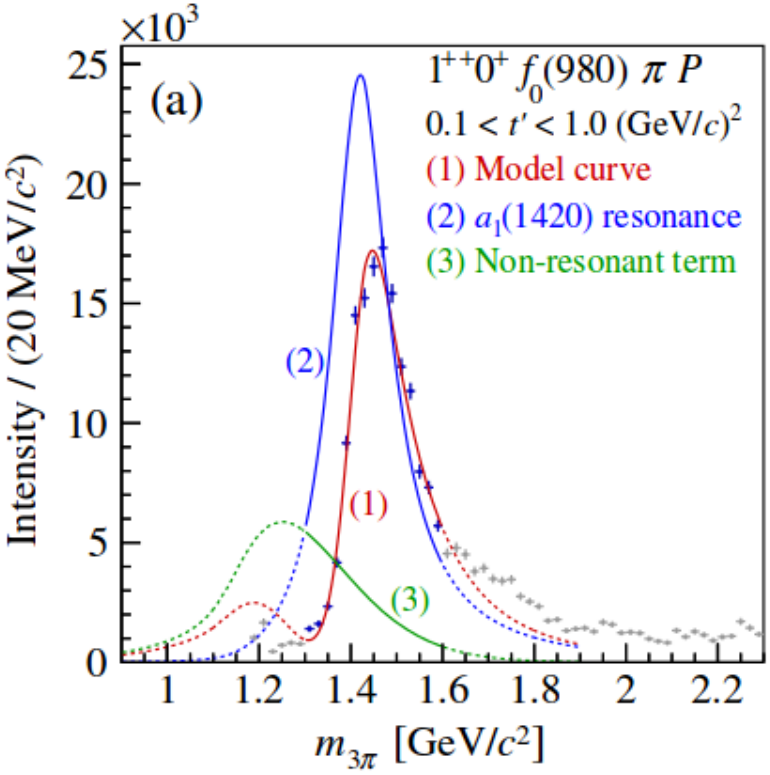
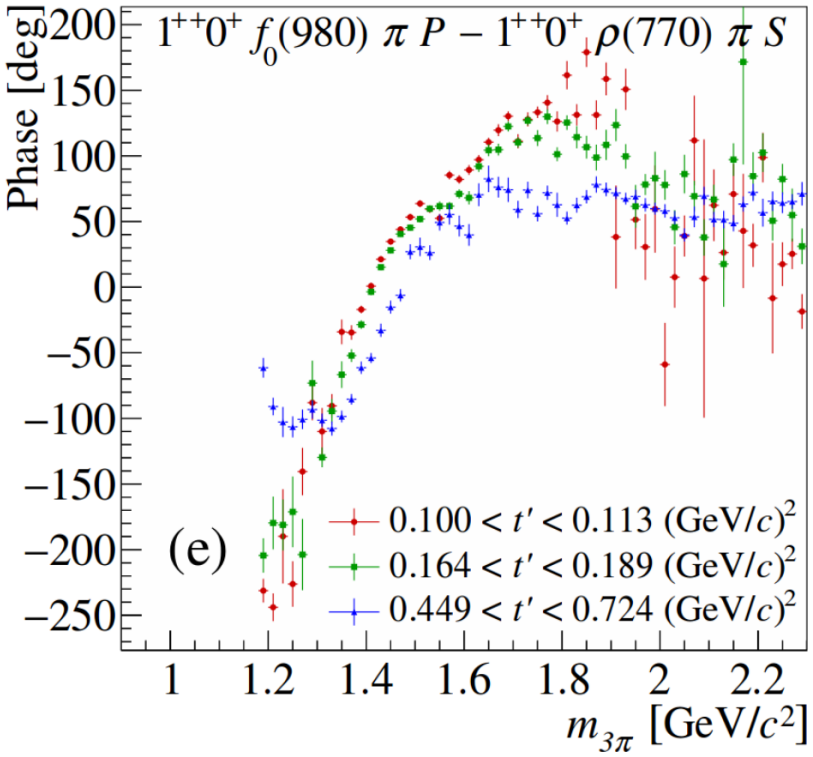
recent $a_1(1420)$ resonance-like signal in 1^{++} partial wave





BW-fit [COMPASS, PRL **115**, 082001 (2015)]

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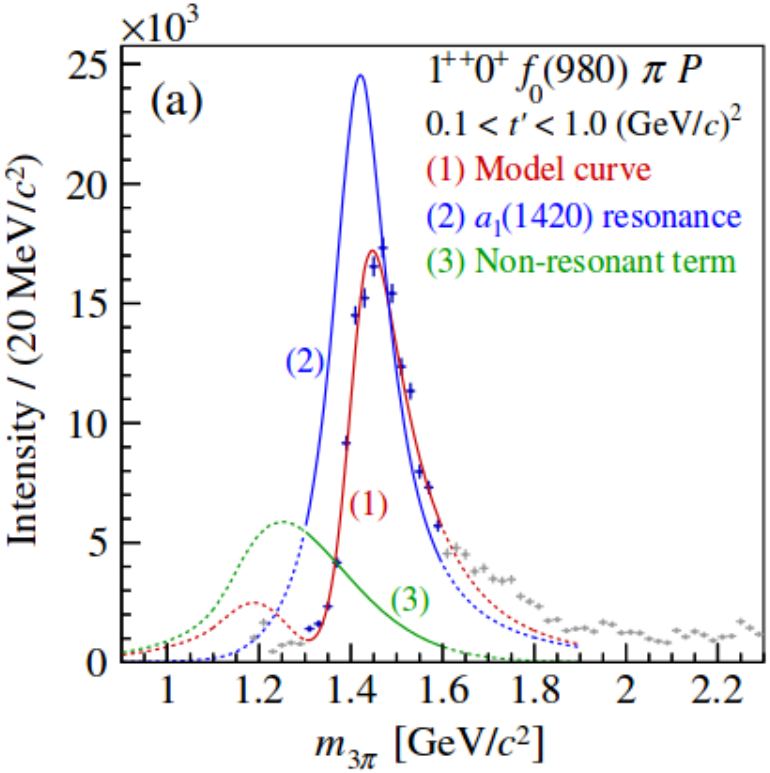
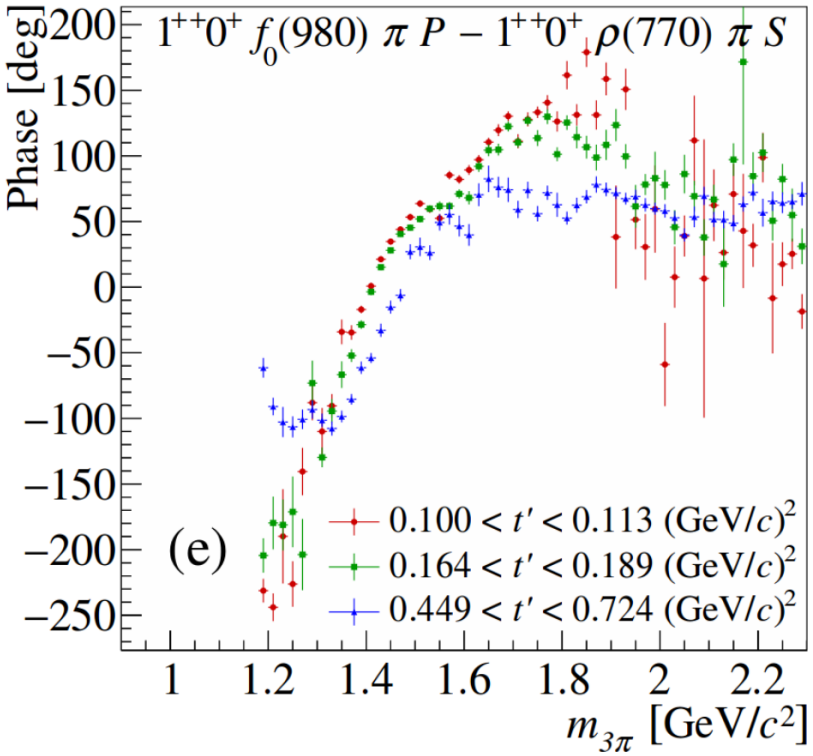


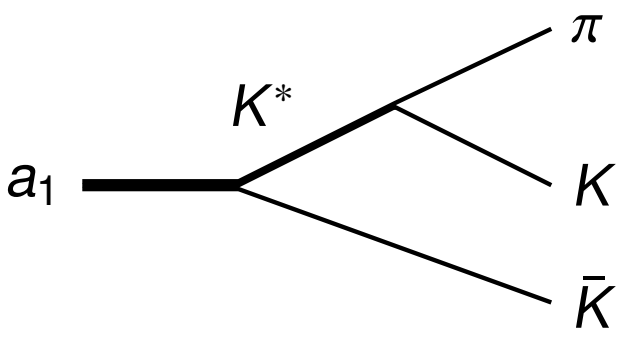


BW-fit [COMPASS, PRL **115**, 082001 (2015)]

- 4-quark state [Wang, arXiv:1401.1134]
- $K^* K$ molecule (similar to XYZ)
- Dynamic effect of interference with Deck-amplitude [Basdevant & Berger, PRL **114**, 192001 (2015)]
- **Triangle singularity** [Mikhasenko, PRD **91**, 094015 (2015)] [Aceti et al., PRD **94**, 096015 (2016)]

Include Spin via partial wave projection:

1. Look at the partial wave for $a_1(1260) \to K\bar{K}\pi$ with isobar K^*



Include Spin via partial wave projection:

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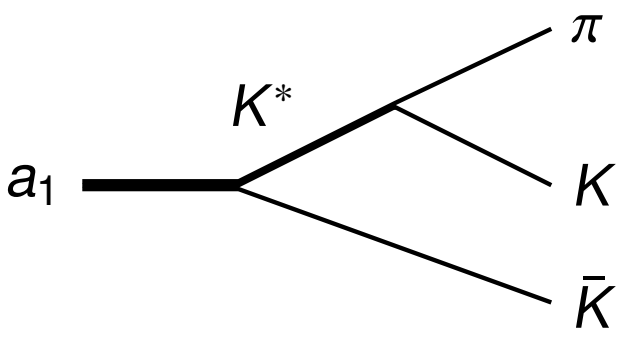
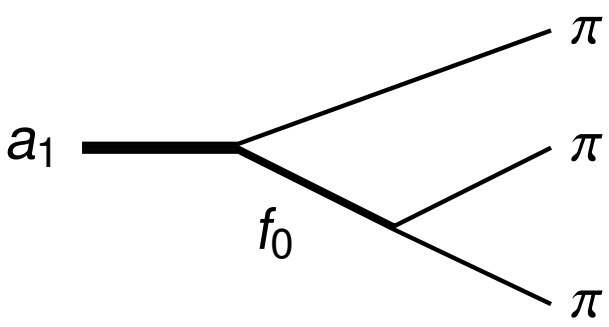
2. Project it onto the 3π final state with isobar $f_0(980)$





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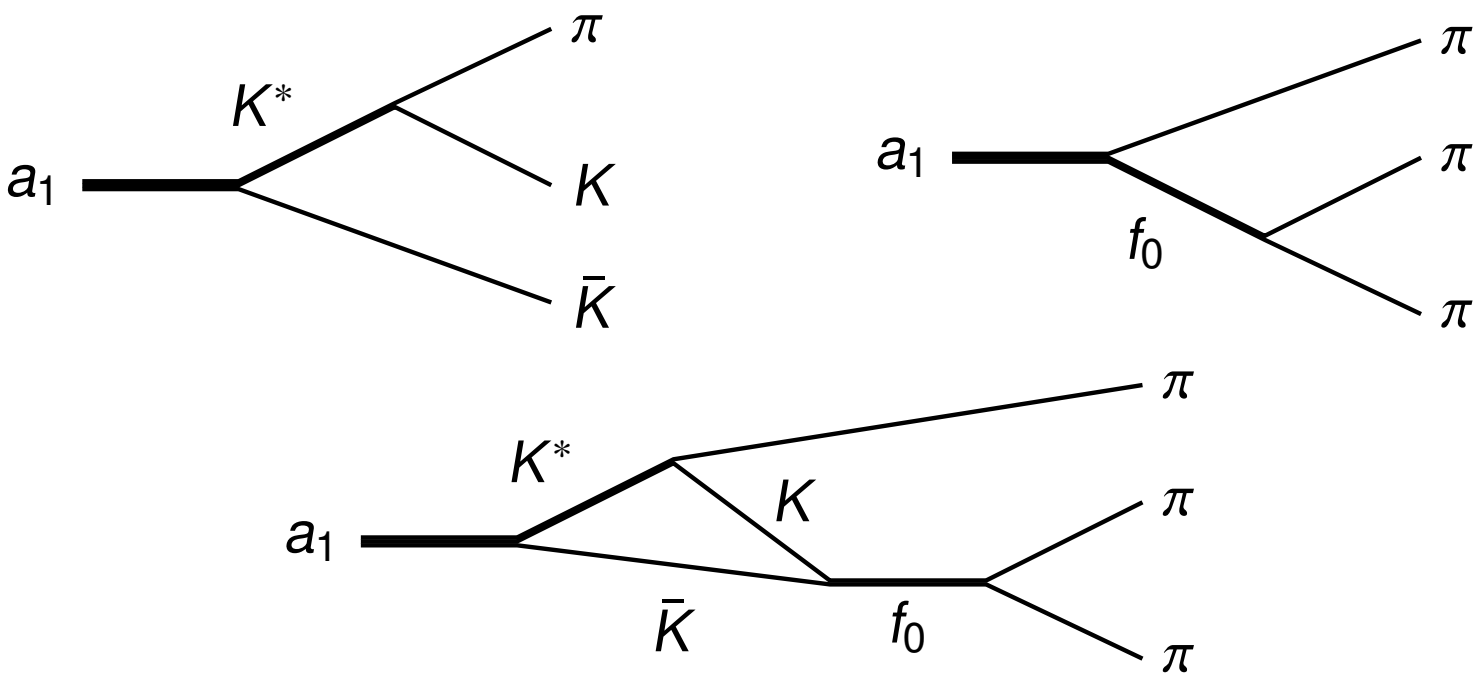
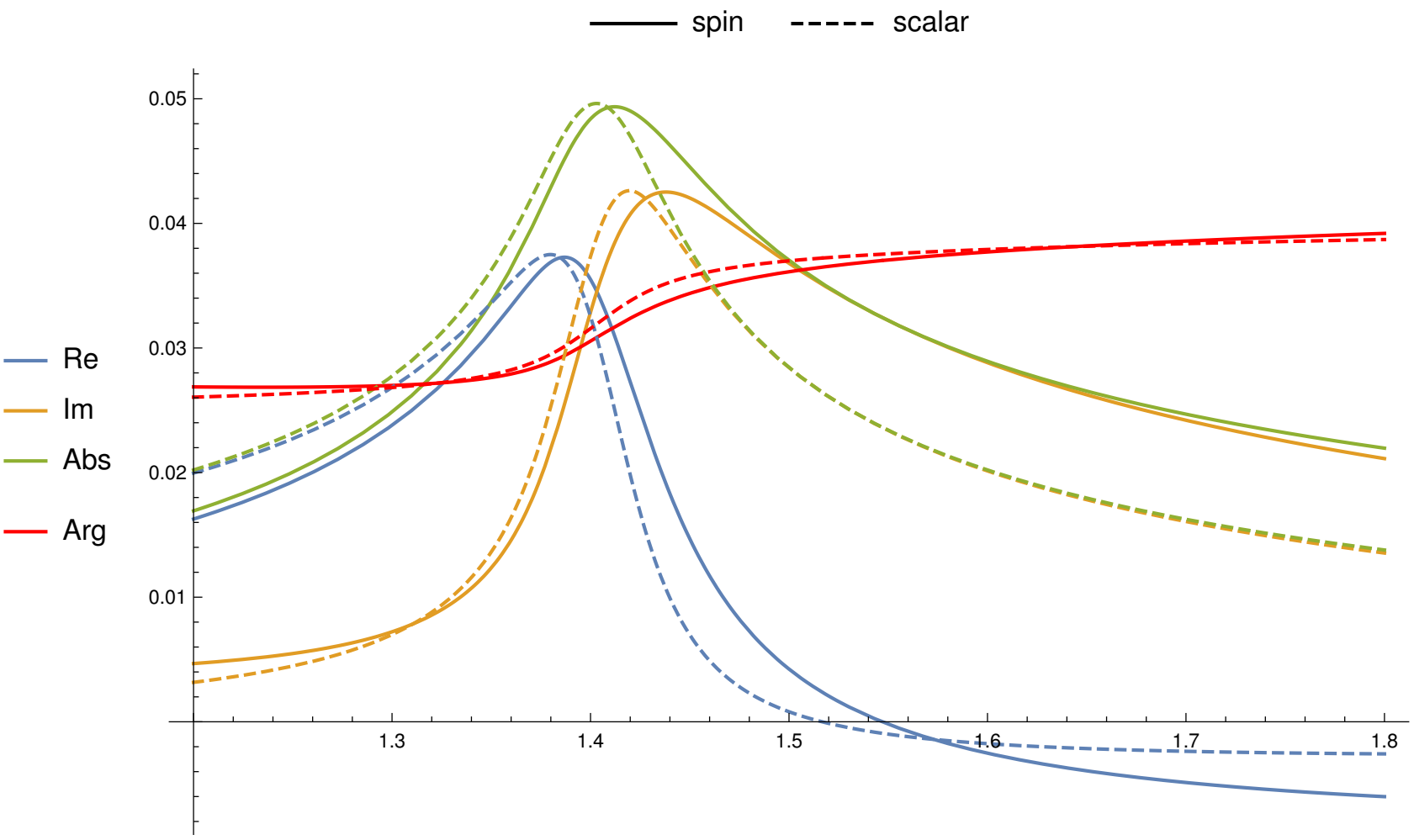
3. Obtain the first order approximation of the Khuri-Treiman approach




spin
scalar
Re
Im
Abs
Arg
0.05
0.04
0.03
0.02
0.01
1.3
1.4
1.5
1.6
1.7
1.8

Outlook

- Fit to data with new spin model
- Look for $a_1(1420)$ in the $K\bar{K}\pi$ final state
  - Event selection
  - MC studies
  - PWA
  - Fit