Track Fitting for the BELLE II Experiment

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for the Collaboration

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Belle II

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EM calorimeter
CsI(Tl), waveform sampling electronics (barrel)
Pure CsI + waveform sampling (end-caps) later

K_L & μ Detector
Resistive Plate Counter (barrel outer layers),
Scintillator + WLSF + MPPC (end-caps, inner 2 barrel layers)

7.4 m

electrons (7 GeV)

Vertex Detector
PXD: 2 layers Si pixels (DEPFET),
SVD: 4 layers double sided Si strips (DSSD)

5.0 m

positrons (4 GeV)

Central Drift Chamber
He(50%):C_2H_6(50%),
smaller cell size,
longer lever arm,
fast electronics

Particle Identification
Time-of-Propagation counter (barrel),
Proximity focusing Aerogel Cherenkov Ring Imaging detector (forward)

CDC Legendre

CDC Cellular Automaton

CDC Merging

SVD Standalone

CKF SVD → CKF Merging

CKF PXD

DAF Track Fit

TRACK FINDING

CKF: Combinatorial Kalman Filter
DAF: Deterministic Annealing Filter

In this Talk

GENFIT: Generic Track Reconstruction Toolkit

Open Source C++ Modular track-fitting framework

Several implemented algorithms inside (DAF is used in our case)

- Not homogeneous Magnetic Field
- Energy loss (different for each particle)
- Different detector hits:
  - ☆ CDC: wire + drift time (L/R ambiguity)
  - ☆ SVD: position along strips
  - ☆ PXD: planar hits (XY)

B Field [T]
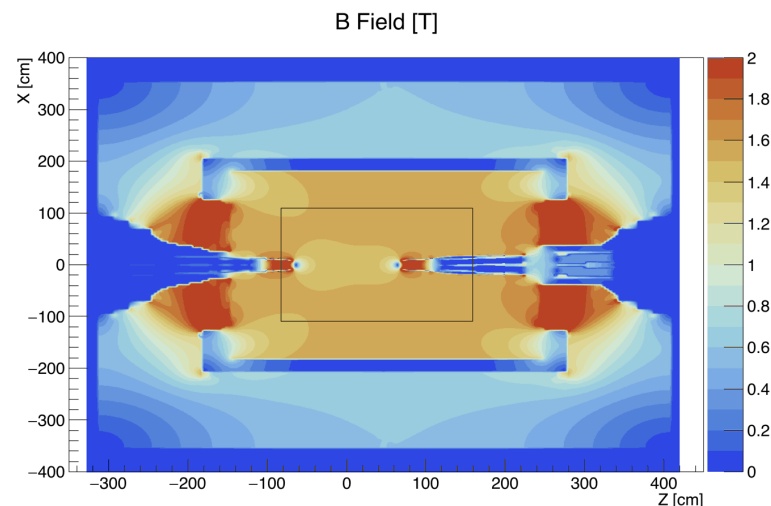
- Originally developed inside PandaRoot framework at TUM
- Major update (GENFIT2) based on acquired experience with Belle II
- Now used by large community (Belle II, PANDA, GEM-TPC, FOPI, SHiP)
- Nucl. Instr. Meth. A 620 (2010) 518-525 – J. Phys.: Conf. Ser. 608 (2015) 012042

- ❖ Different particles, different energy loss
- ❖ Different particles, different time of flight, different drift time in CDC
- ❖ At high momentum not large differences
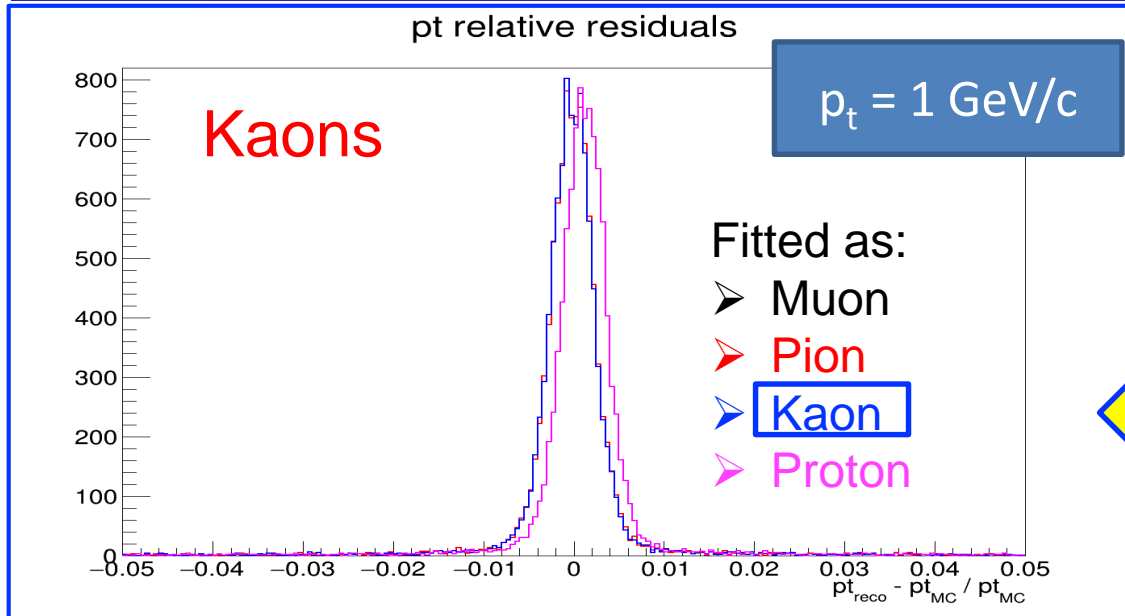- ❖ At low momentum, wrong mass hypothesis can lead to wrong results

Y(4S) Montecarlo sample
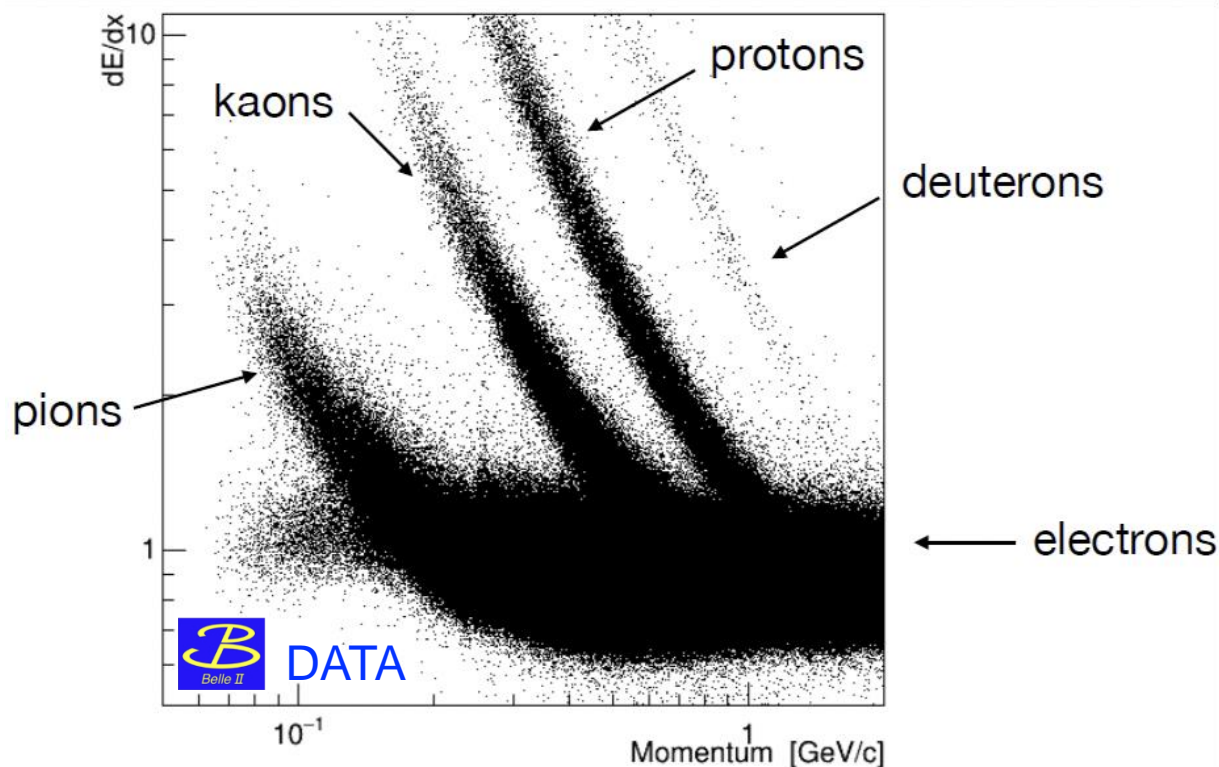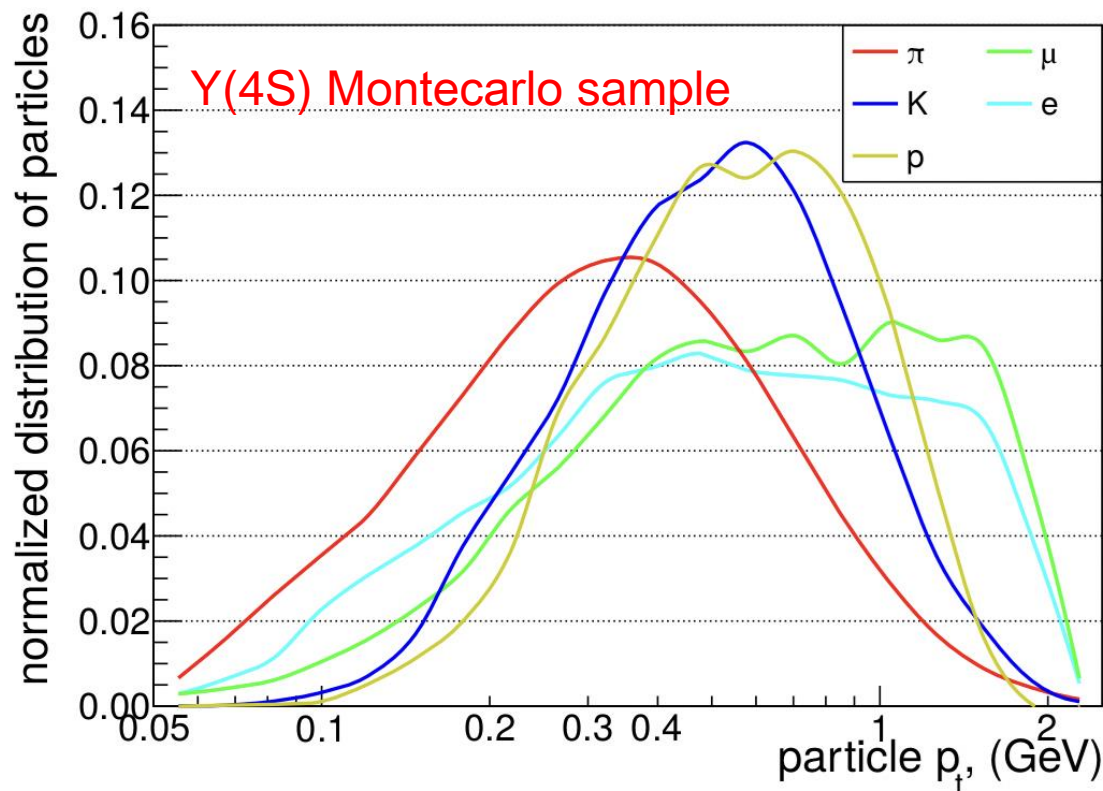
✓ Large fraction of pions
✓ Particles below 1 GeV/c (mostly)

Particle type	Average fraction
$\pi^{\pm}$	72.8%
$K^{\pm}$	14.9%
$e^{\pm}$	5.8%
$\mu^{\pm}$	4.7%
$p^{\pm}$	1.8%

WARNINGS
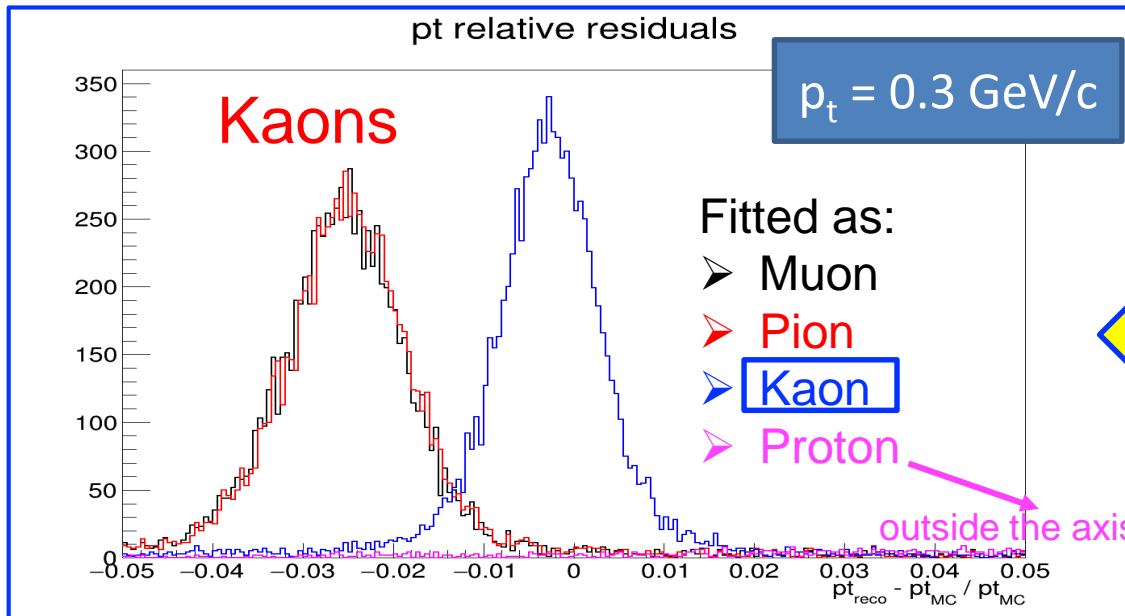
➢ Low multiplicity samples (e⁺e⁻, μ⁺μ⁻,…) reach larger momentum values
➢ Energy loss depends on total momentum (and not on p_t)

Different Particle Hypotheses Fit

pt relative residuals

Kaons

$p_t = 1$ GeV/c

Fitted as:
- ➤ Muon
- ➤ Pion
- ➤ Kaon
- ➤ Proton

$pt_{reco} - pt_{MC} / pt_{MC}$

pt relative residuals

Kaons

$p_t = 0.3$ GeV/c

Fitted as:
- ➤ Muon
- ➤ Pion
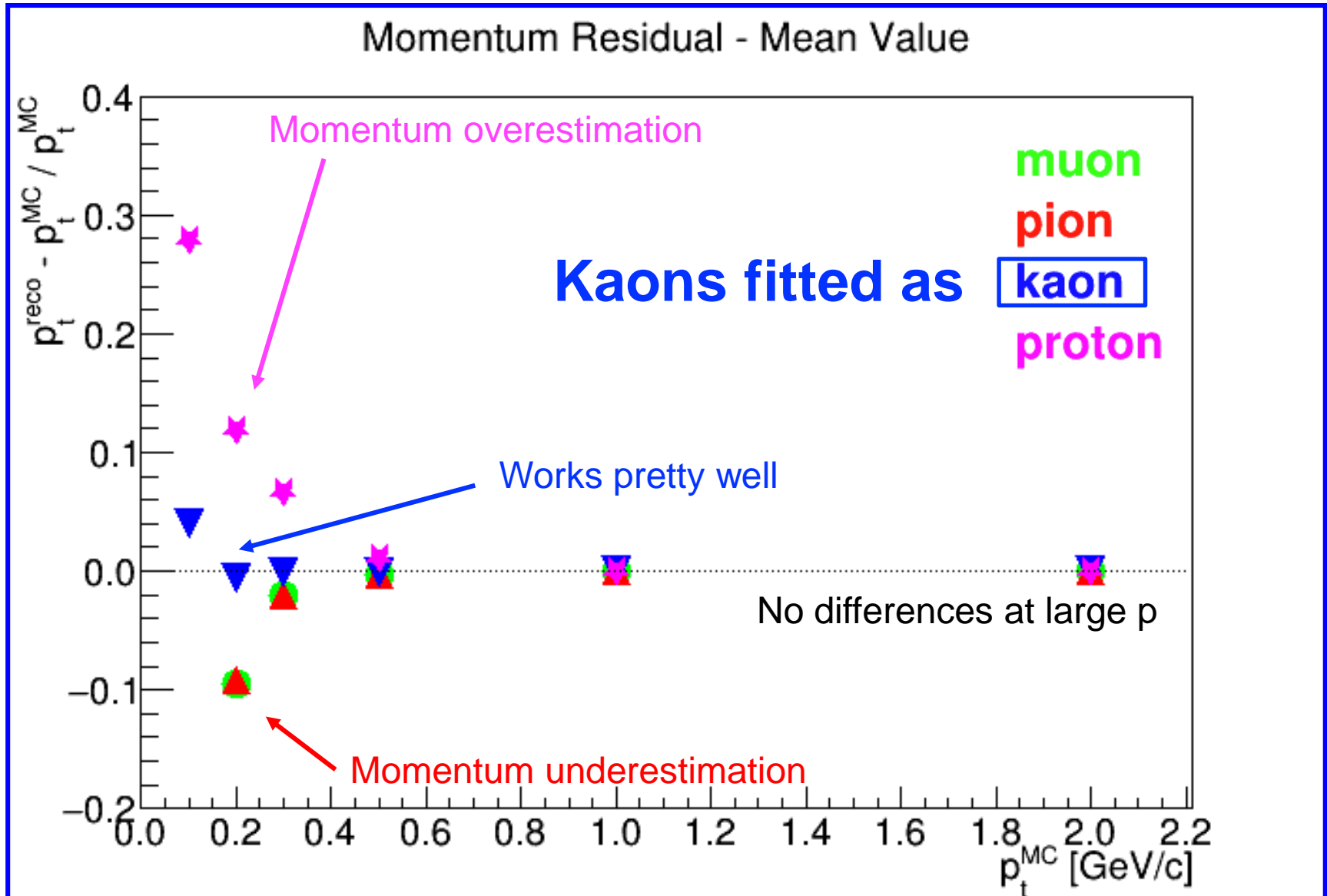- ➤ Kaon
- ➤ Proton

outside the axis

$pt_{reco} - pt_{MC} / pt_{MC}$

Kaons at θ = 60˚

MC particle gun
fixed momentum

at high momentum
different hypotheses provide
similar results

at low momentum
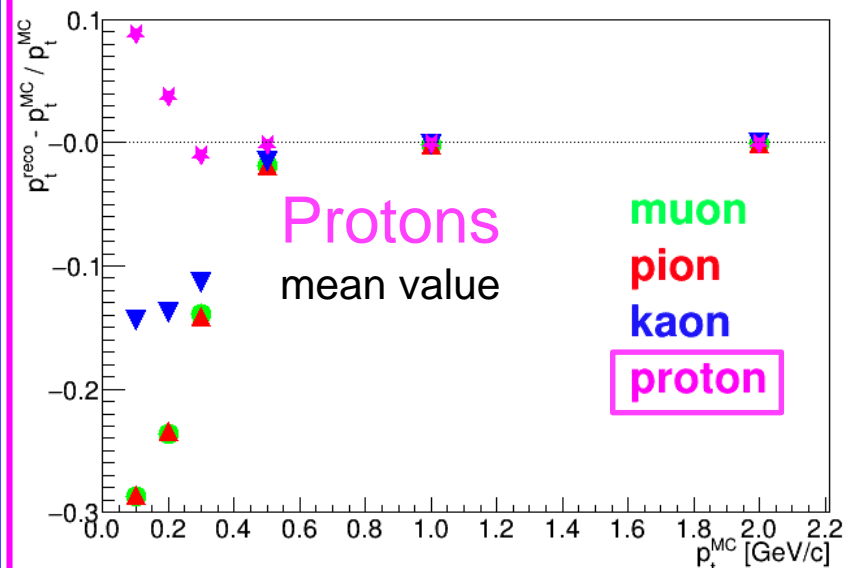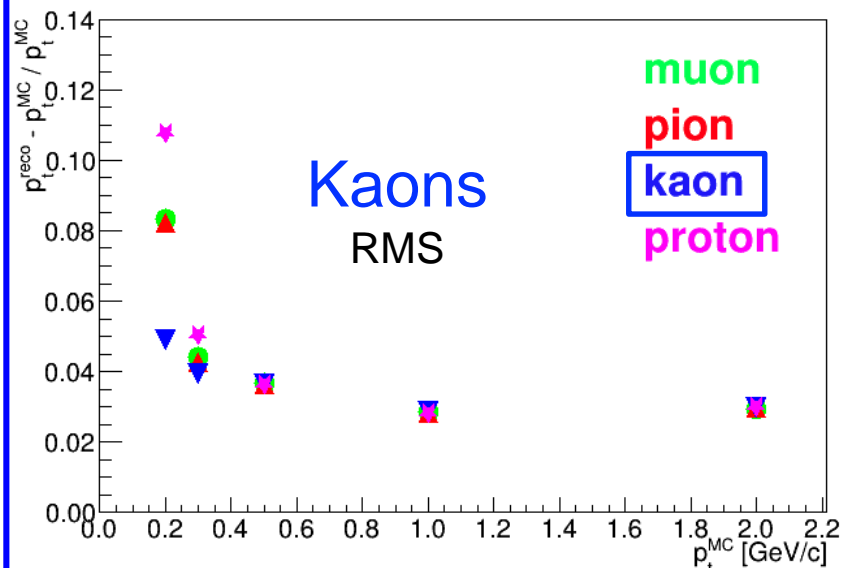wrong hypotheses provide
large bias in momentum

Belle II Experiment

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Momentum Residual - Mean Value

Momentum overestimation

muon
pion

Kaons fitted as kaon

proton

Works pretty well

No differences at large p

Momentum underestimation

$p_t^{reco} - p_t^{MC} / p_t^{MC}$

p_t^{MC} [GeV/c]

Comparison between different hypotheses
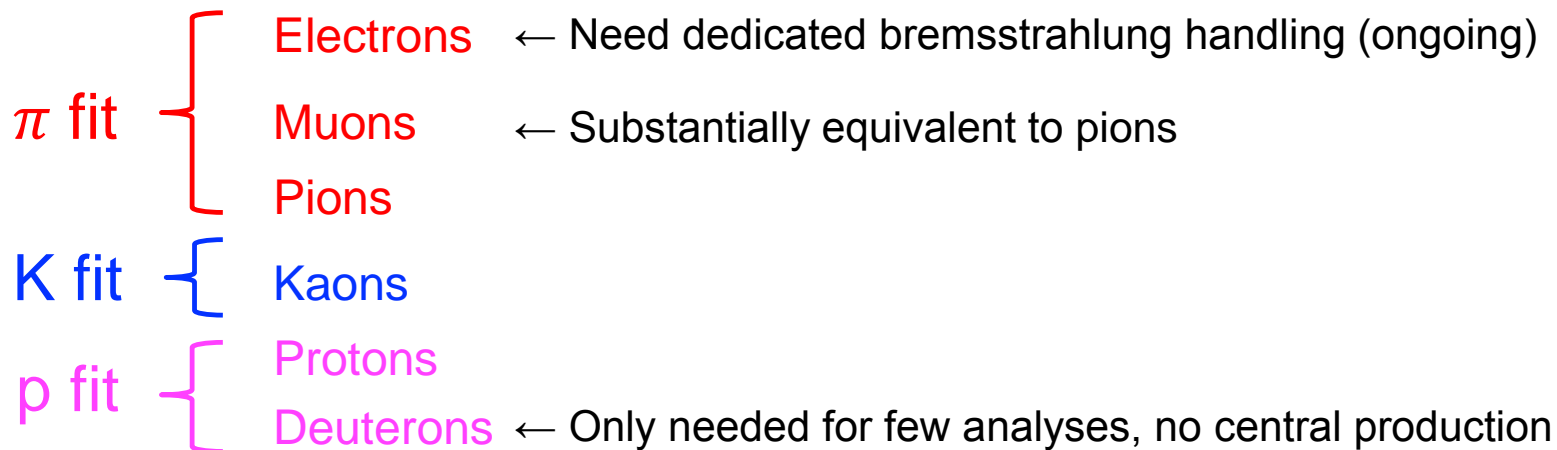

Momentum Residual - Mean Value

Kaons — mean value

muon, pion, kaon, proton

Momentum Residual - Mean Value

Protons — mean value

muon, pion, kaon, proton

Momentum Residual - RMS

Kaons — RMS

muon, pion, kaon, proton

Momentum Residual - RMS

Protons — RMS

muon, pion, kaon, proton
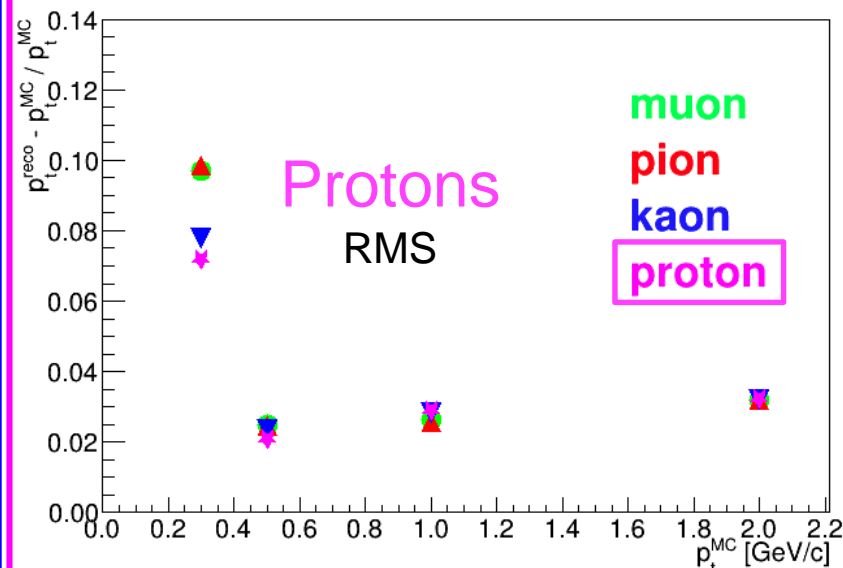
Determinist Annealing Filter - 3 hypotheses in parallel

π fit
- Electrons ← Need dedicated bremsstrahlung handling (ongoing)
- Muons ← Substantially equivalent to pions
- Pions

K fit
- Kaons

p fit
- Protons
- Deuterons ← Only needed for few analyses, no central production

Resources with 3 (π, K, p) and 4 (π, K, p, d) hypotheses
compared to only π hypothesis

	Disk Space Ratio		CPU Time Ratio	
	3/1 hyp	4/1 hyp	3/1 hyp	4/1 hyp
Track Fitting	2.59	3.12	2.89	3.75
Global mDST	1.17	1.22	1.07	1.09

⟹ Track Fitting values scale linearly with number of hypothesis

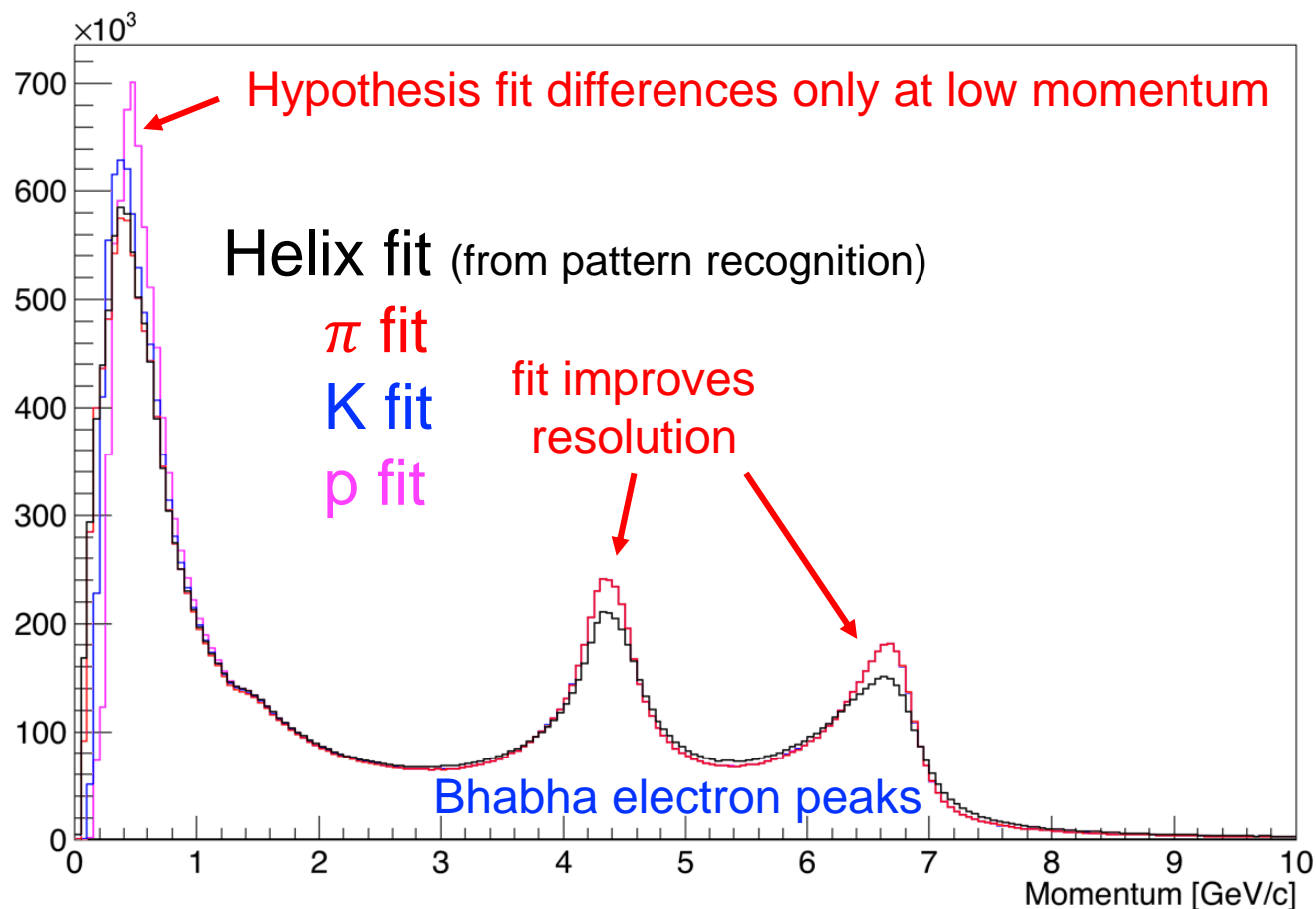⟹ Global increase of ~10% in CPU time and ~20% in disk space

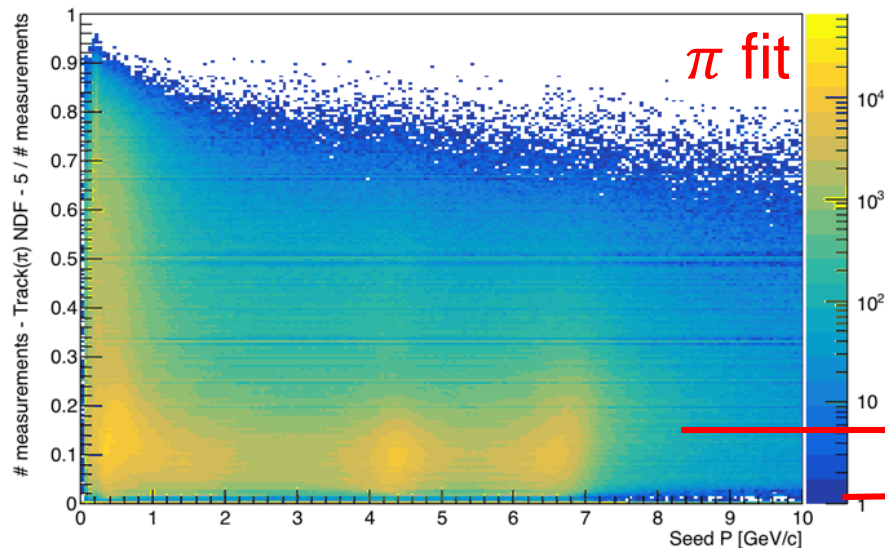Luminosity Run, 26th April 2018   First Hadronic Event
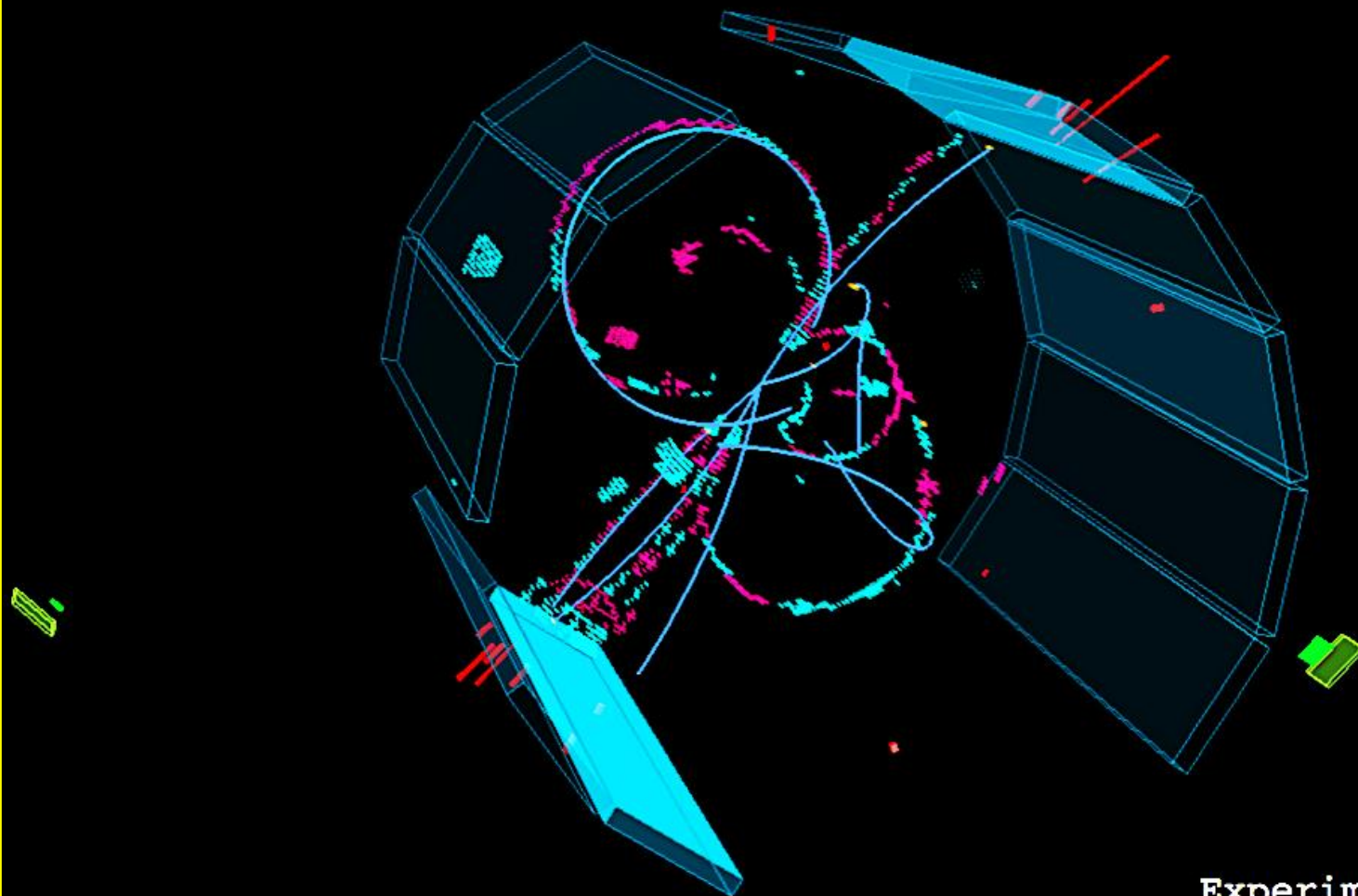
Experiment 3
Run 125
Event 223

note: vertex detector not shown

Non optimal beam profile, preliminary detector calibration, SVD+PXD only in a small acceptance, no Bhabha suppression on purpose
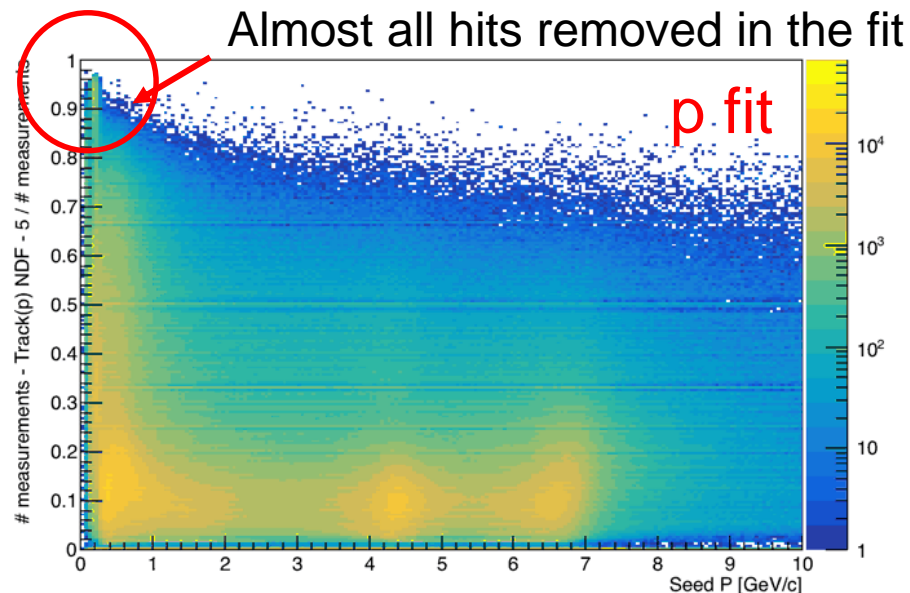
Hypothesis fit differences only at low momentum

Helix fit (from pattern recognition)

π fit

K fit

p fit

fit improves resolution

Bhabha electron peaks

π fit

Percentage of removed hits from DAF

measurements – weighted NDF – 5

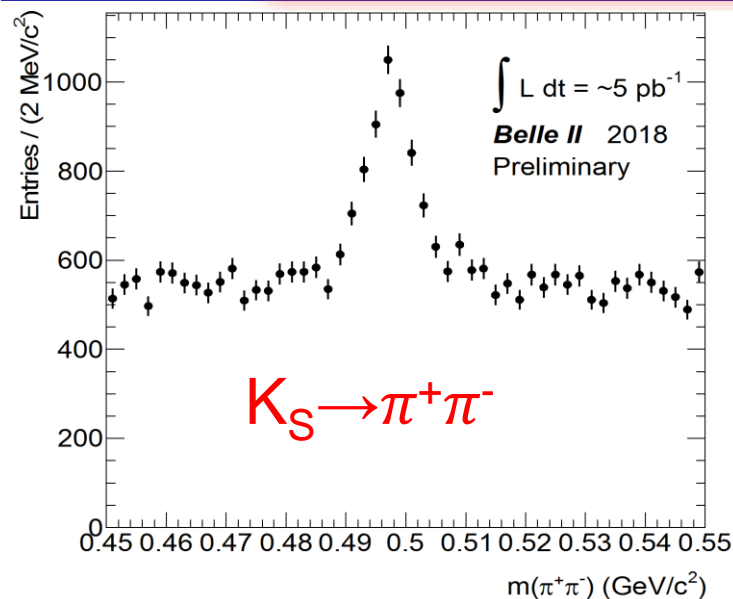→ ~10% hits are removed in the fit
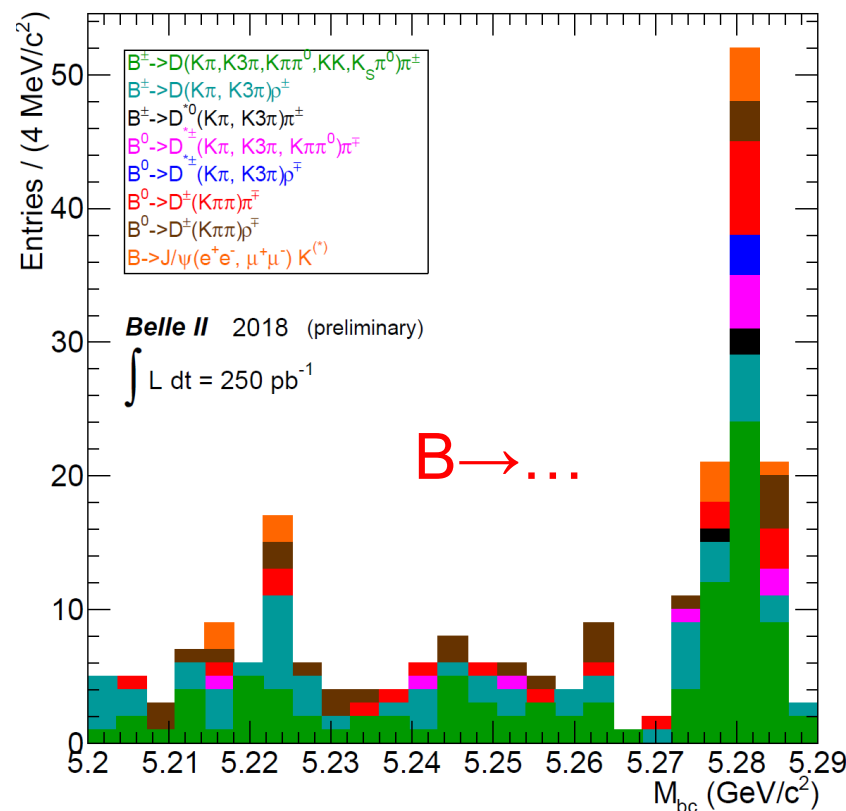
→ 0 → All measurements used in the fit

Almost all hits removed in the fit

p fit

➤ At very low momentum the proton hypothesis cannot fit the track (too much energy loss)

➤ DAF set a low weight to almost all the hits

Nice invariant mass peaks at the correct positions!

$K_S \rightarrow \pi^+\pi^-$

$\Lambda^0 \rightarrow p\pi$

$B \rightarrow \ldots$

Summary

In Belle II global tracking is performed my means of the GENFIT2 package

Track Fitting takes into account realistic magnetic field, different kind of detector hits, and energy loss for different particles

Tracks are fitted with three mass hypotheses (π, K, p), a compromise between performances and computing resource consumption

A momentum dependent mass hypothesis in the fit can reduce CPU time and disk usage, in particular for p >1 GeV/c tracks

Determinist Annealing Filter removes outliers and downweighs distant hits, possibility to detect wrong mass hypotheses

Ongoing studies on electron corrections
and optimization of the computing resources for fitting