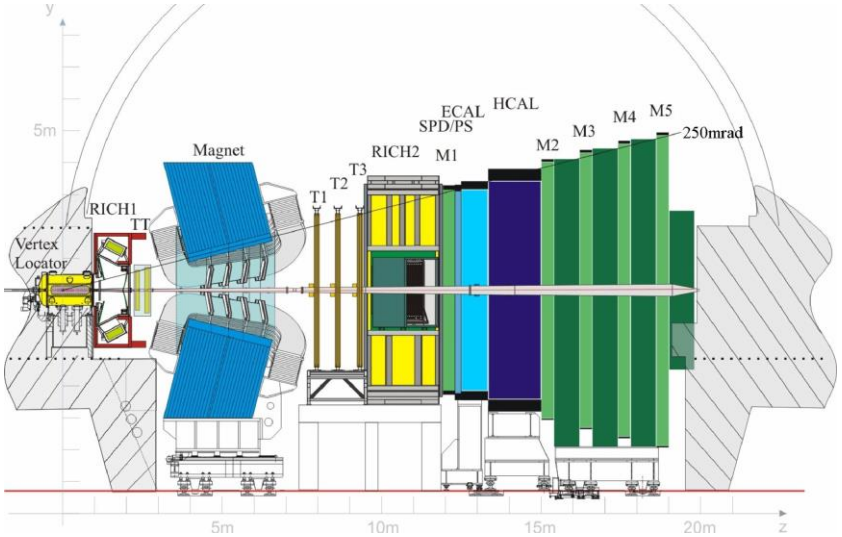
Add RICH information for T-track reconstruction

2022/09/28

Mengzhen Wang (INFN di Milano)
on behalf of T-Track Performance Task Force team

The LHCb detector

- Originally designed for b, c physics



Single-arm & forward spectrometer

Good tracking/PID/trigger performance for **particles originating around collision point**

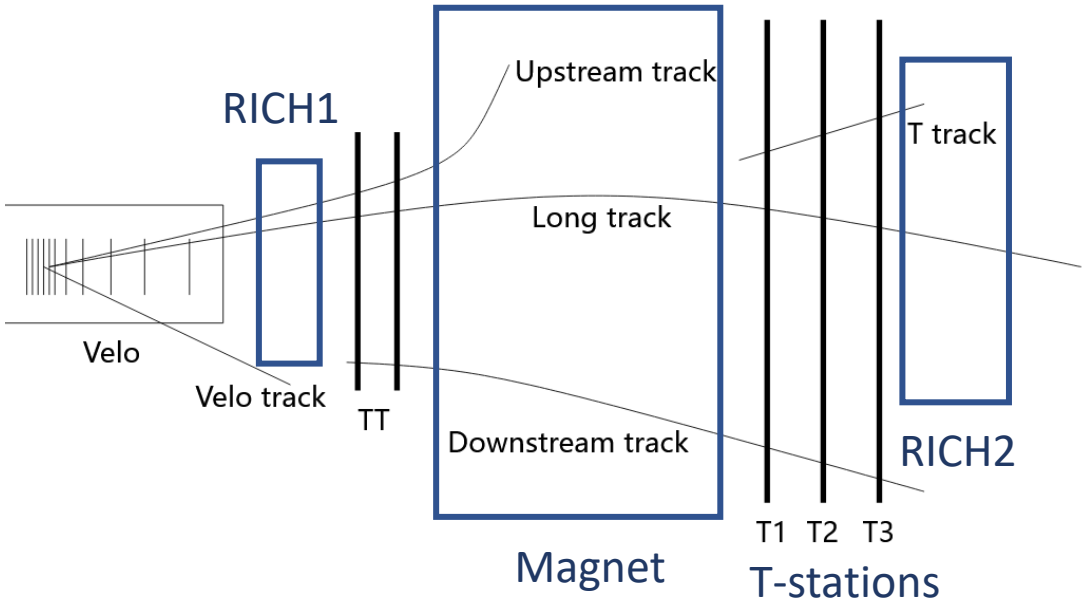
JINST 3 (2008) S08005 Int.J.Mod.Phys.A 30 (2015) 07, 1530022

- Now developed as a general-purpose experiment
  - Arising interests on **long-lived particles**
  - Λ EDM, MDM; BSM particle searches…

Example: arXiv 2101.00928

- A good-performance track reco. using downstream trackers becomes crucial

LHCb track categories



Long & Downstream track:

Most widely used for physics analysis

Good spatial & momentum resolution:

Enough hits from 3(2) trackers

Pass central region of $\vec{B}$ field

Cherenkov-based PID info for BKG subtraction

- T-track: essential input for long-lifetime particle studies

BSM particles decaying after TT; Λ decaying after magnet (EDM, MDM effect visible)

- Poor track momentum resolution
  - $\frac{\delta p}{p} = (10\sim30)\%$ [LHCb unofficial] (Long-track @ 1% level)
- No PID information in default LHCb algorithm

How to improve ?
(Menu of today)

By Mengzhen Wang et. al.

RICH information for T-track momentum reconstruction

θ_C: Cherenkov angle

Motivation

- Cherenkov-based PID:
  - Velocity measurement: $\beta = \frac{1}{n \cos\theta_C}$
  - Momentum from tracking system

} Estimation of mass (PID)

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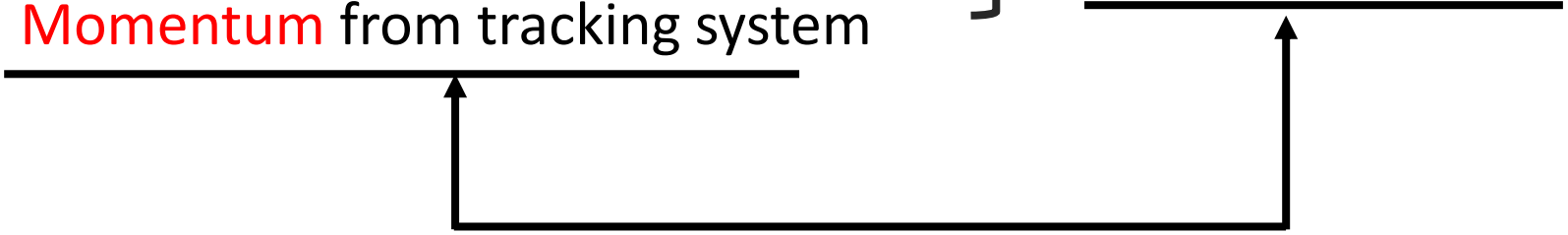

Exchange the input & output ?

θ_C: Cherenkov angle

Motivation

- Cherenkov-based PID:
  - Velocity measurement: $\beta = \frac{1}{n\cos\theta_C}$
  - A pre-assigned mass hypothesis

} Estimation of momentum

- Resolution using this approach ?
  - $\delta\theta_C \sim 0.7$ mrad for RICH2

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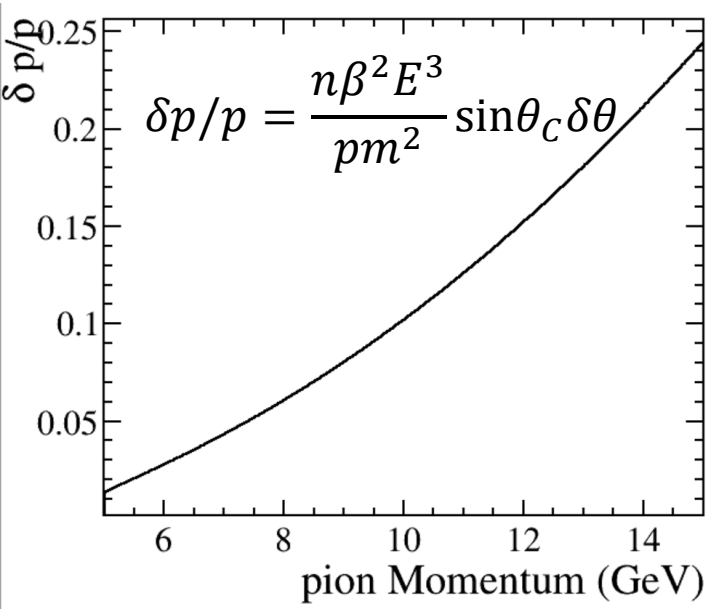
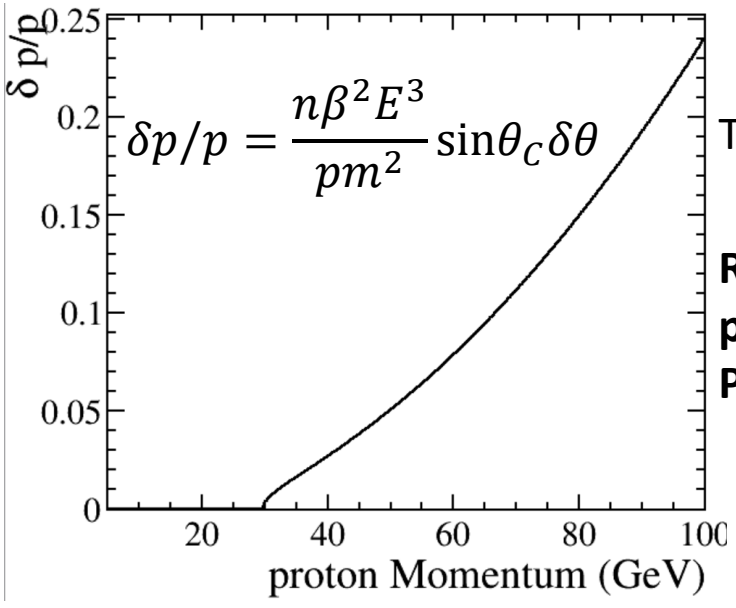


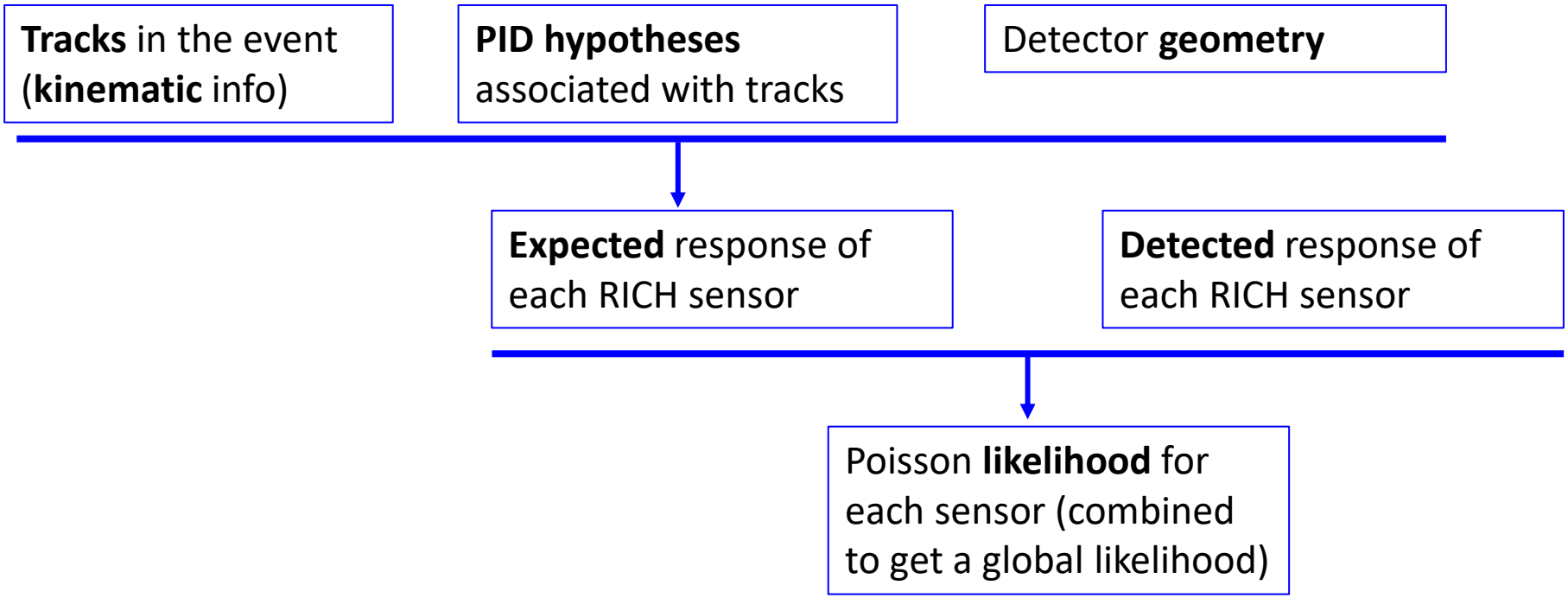


T-track $\frac{\delta p}{p} \sim 20\%$

RICH2 competitive for:
pions with $p \sim 10$GeV
Protons with $p \sim 60$GeV

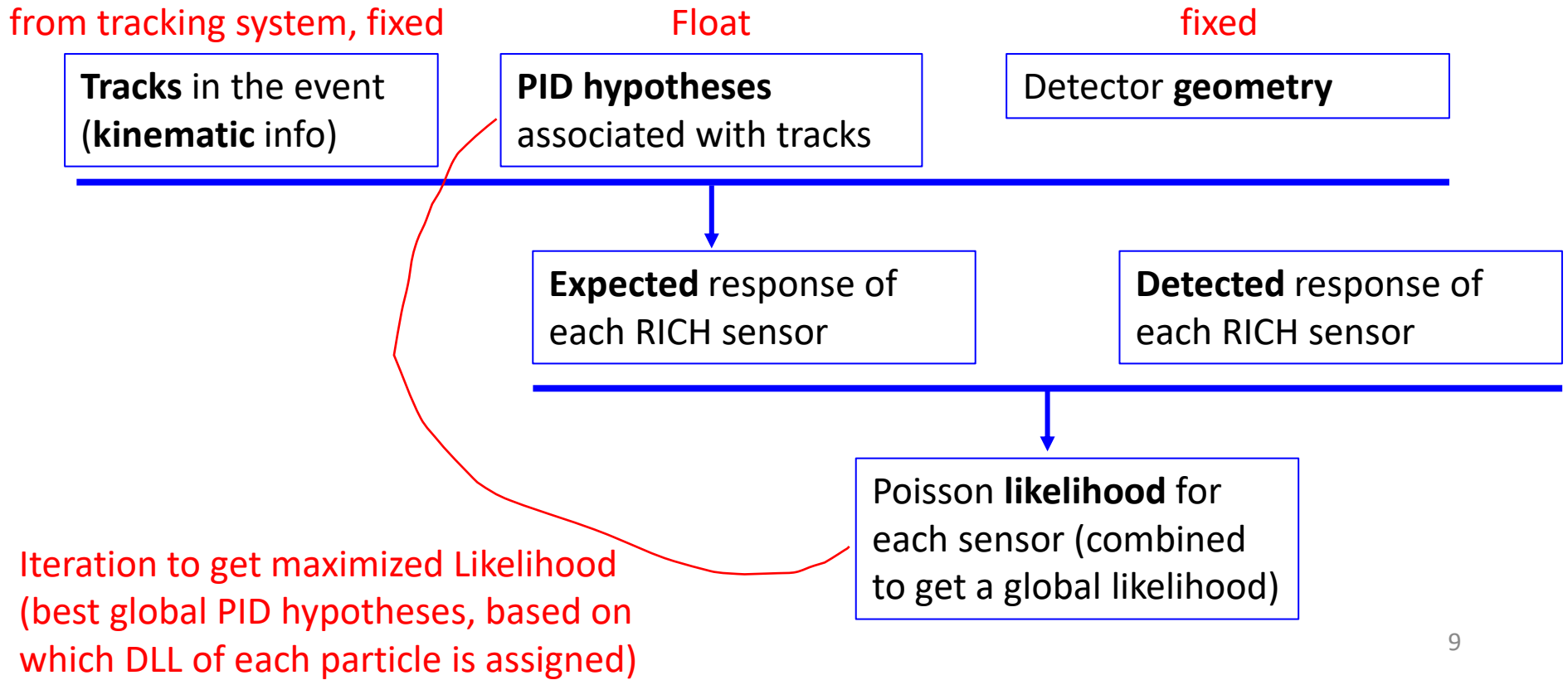
LHCb RICH reconstruction

- Basic idea:
  - Cannot naively obtain the θ_C value associated with each track, only global reconstruction & fits available



LHCb RICH reconstruction

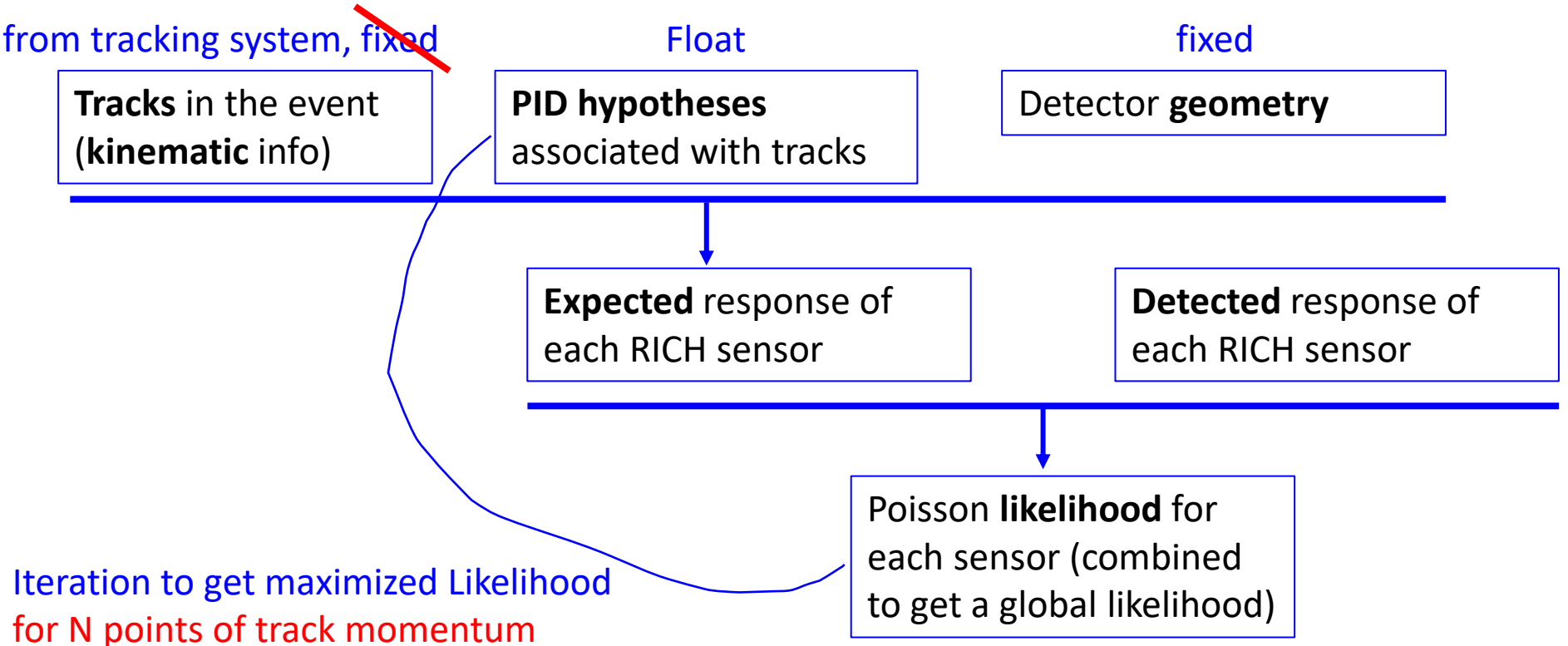
- The default PID assignment procedure
  - Float the PID hypotheses and find out the one resulting in the best global RICH likelihood



What we can do ? (W.I.P.)

- Scan the momentum value for tracks we have interest (T-tracks tagged as LLP decaying products)

$p = p_{rec}$ for most tracks; $p = p_{rec} \pm i\sigma$ for interesting tracks. Scan N points



Very simplified version, with many differences w.r.t. our target: based on long tracks; make use of both RICH1+2 info; et. al.

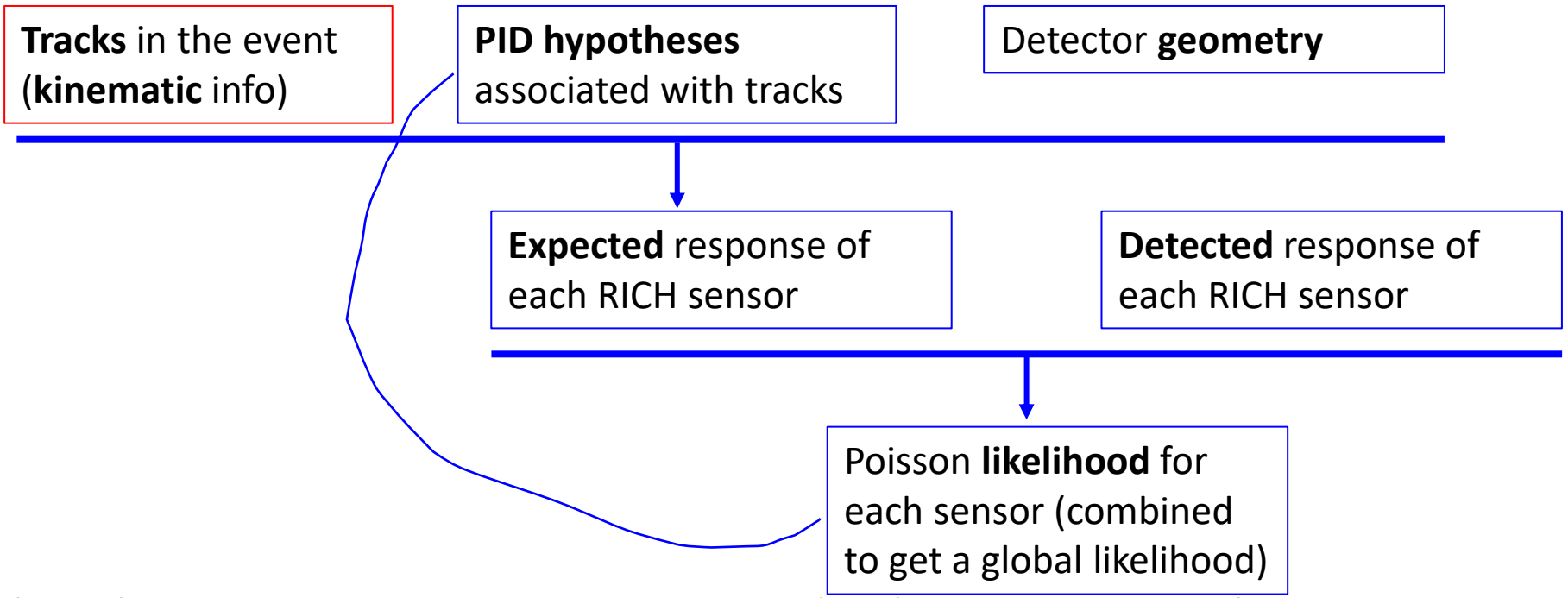
A simplified feasibility study

- MC sample: Run3, $\Lambda_c^+ \to pK\pi^-$, all raw banks persisted (XDIGI)

For most tracks, use reconstructed values

2 setting for Λ_c^+ decay products

a). Use true $\vec{p}$; b). $\vec{p} \times (1 + 0.2\mathrm{G})$, G: standard Gaussian

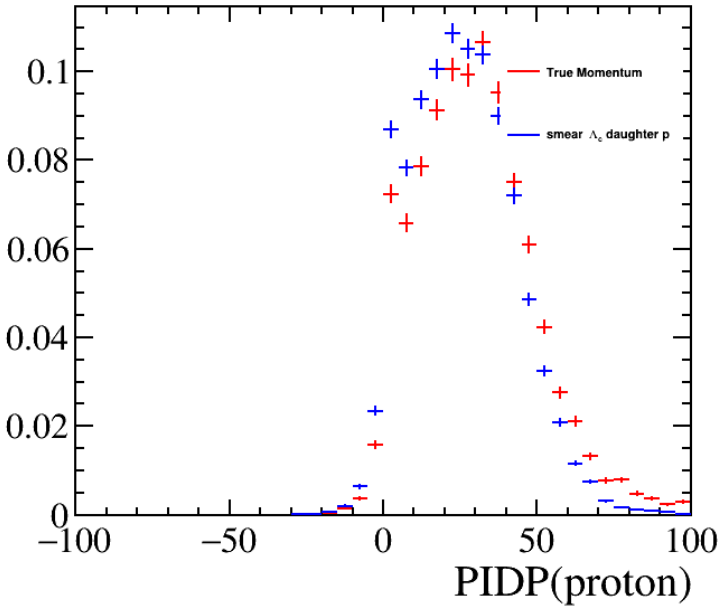


For a) and b), run separately rich reconstruction algorithm (run3), obtain global rich LL for each event, and DLL variables for Λ_c^+ decay products. Compare a) and b) distributions

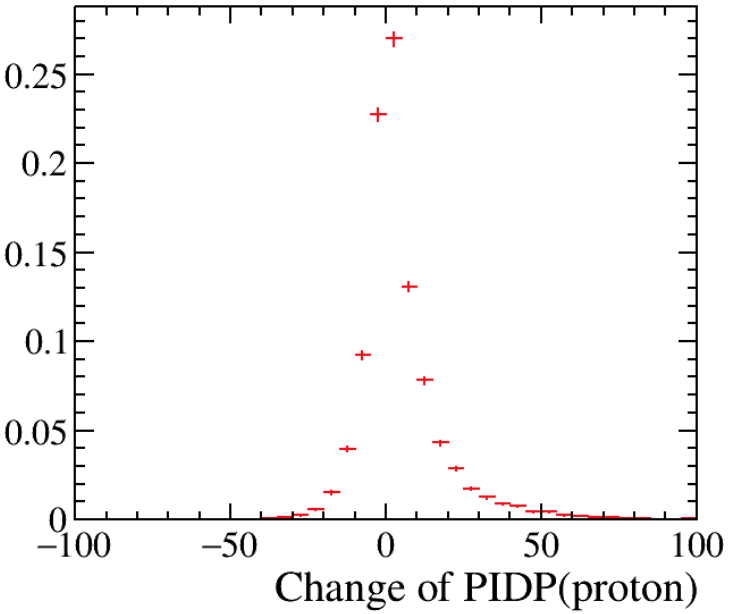
Some impact on ΔLL variables

- Proton sample:

Distributions when using settings a) or b)



Variation when changing from b) to a)



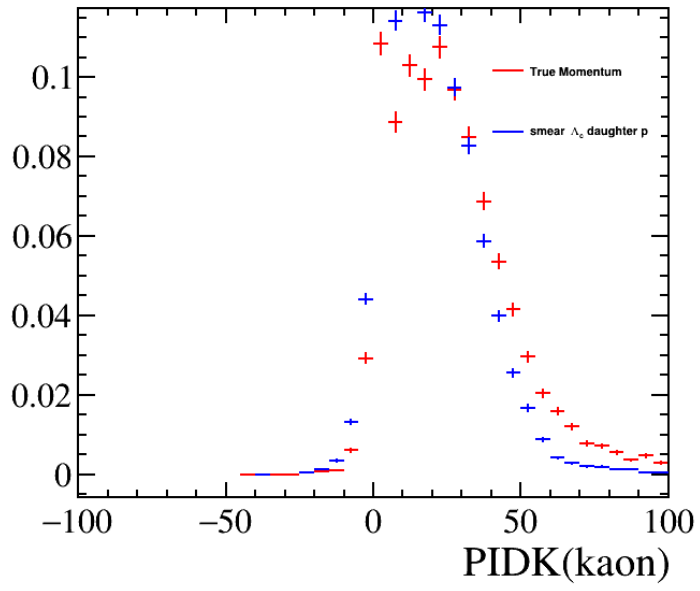
The true momentum is more likely to result in a larger PIDp variable

$$\mathrm{PID}p \equiv \mathrm{LL}_{\mathrm{RICH,\,global}}(p\ \mathrm{hypo}) - \mathrm{LL}_{\mathrm{RICH,\,global}}(\pi\ \mathrm{hypo})$$

Some impact on ΔLL variables

- Kaon sample:

Distributions when using settings a) or b)



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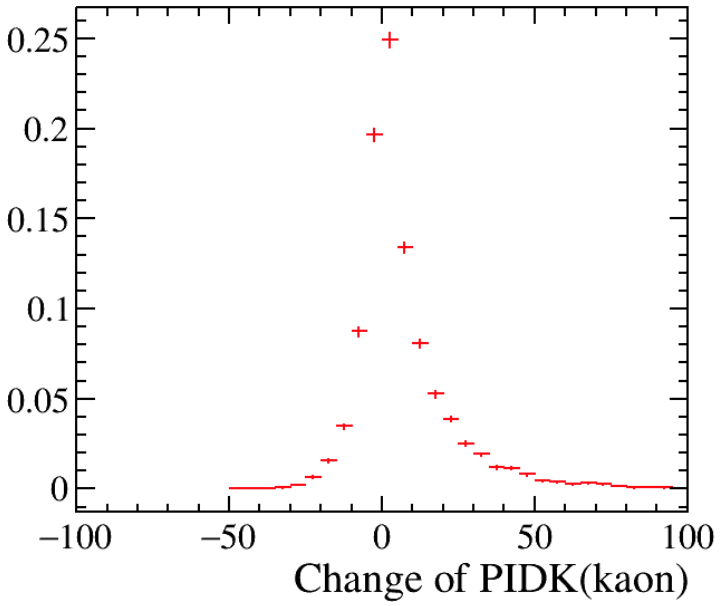


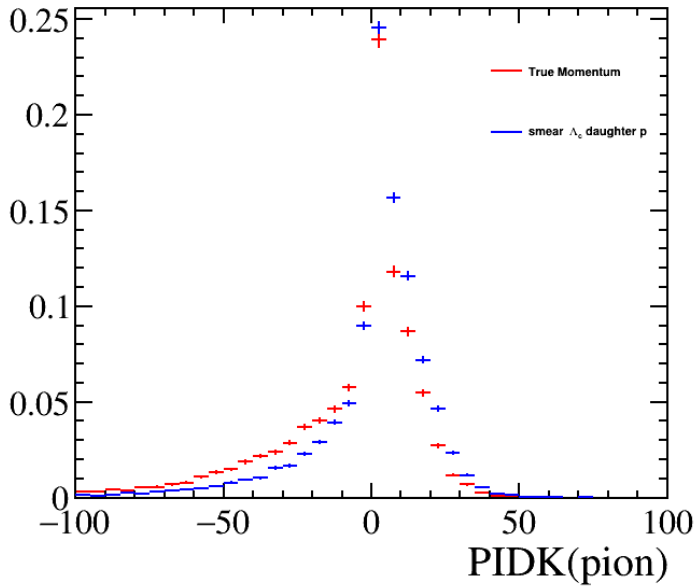
The true momentum is more likely to result in a larger PIDK variable

$$\mathrm{PID}K \equiv \mathrm{LL}_{\mathrm{RICH,\,global}}(K\ \mathrm{hypo}) - \mathrm{LL}_{\mathrm{RICH,\,global}}(\pi\ \mathrm{hypo})$$

Some impact on ΔLL variables

- Pion sample:

Distributions when using settings a) or b)



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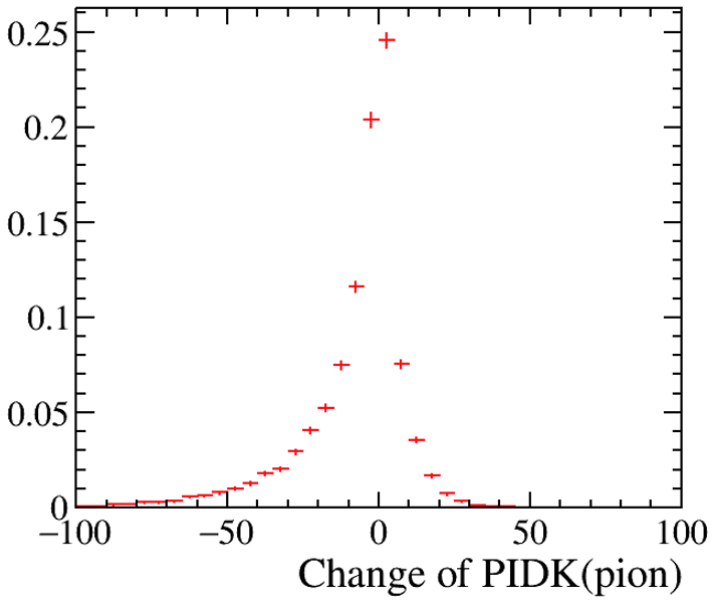

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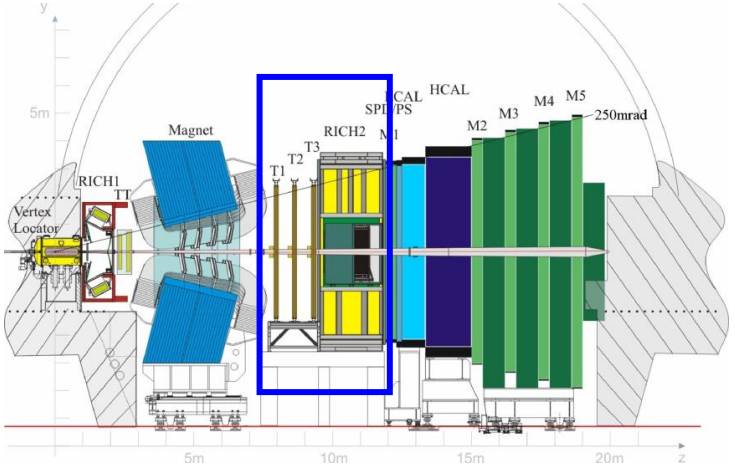
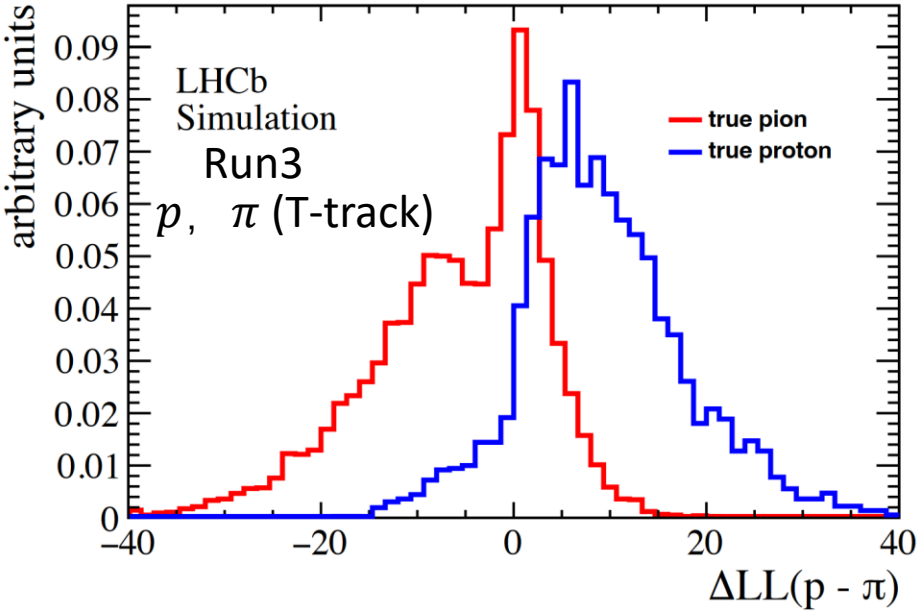
Activate **T-track PID** variables

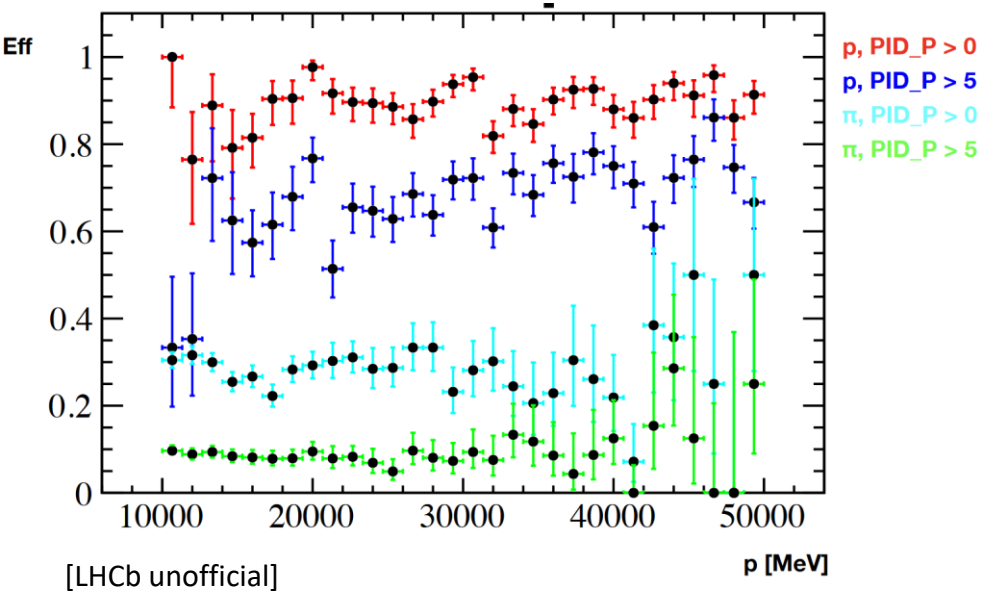
RICH2 is close to T-station



PID on T-tracks

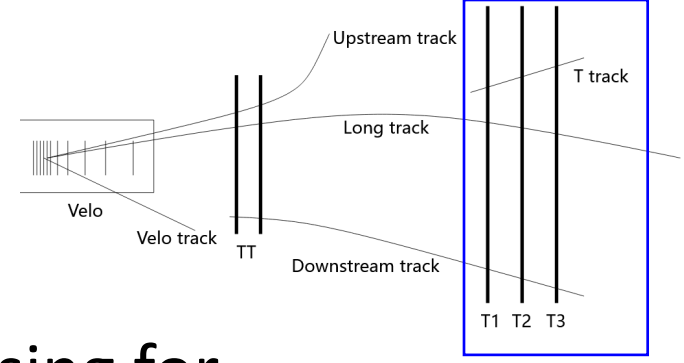
- Most T-tracks can also pass through RICH2 detector
- W.I.P. to enable RICH+Calo+Muon joint PID information for T-track prototype particles





[LHCb unofficial]

Summary



- Importance of T-tracks is arising for
  - Enable an efficient reconstruction on particles with **flying distance ~7 meters**
  - **Long-lived BSM** searches; **Λ EDM, MDM** measurement
- Efforts are ongoing to improve T-track performance
  - **Use RICH2 likelihood information to improve T-track momentum resolution**
    - A simplified feasibility study performed
    - Variation of p hypothesis do impact Rich likelihood
    - Next step: Implement the momentum scan and test the performance
  - **Activate PID information on T-tracks**
    - Preliminary draft ready for Run3 operation
    - Feasibility of implementing on Run1-2 under study

Stay tuned !

Thank you for your attention !

Any questions or comments ?

Back up

- Possibility of using RICH2 info as additional input for improved precision ?

LHCb-DP-2014-002

The values of $\sigma(\theta_C)$, extracted from a simple fit to the $\Delta\theta_C$ distributions, are determined to be 1.618 ± 0.002 mrad for RICH1 gas (C_4F_{10}) and 0.68 ± 0.02 mrad for RICH2 (CF_4),

$\Delta\theta_C$~0.7mrad using RICH2 ?

where the photon wavelength λ is in nm [104]. For C_4F_{10}, n=1.0014 and for CF_4, n=1.0005 at $\lambda = 400$ nm. The effective radiator lengths are about 95 cm in C_4F_{10} and 180 cm in CF_4. The

LHCb-DP-2008-001

6.1.2 RICH 2

The RICH 2 detector [91, 92] is located between the last tracking station and the first muon station, see figure 2.1. It contains a CF_4 gas radiator, providing PID from approximately 15 to $\geq$ 100 GeV/c for particles within the reduced polar angle acceptance of $\pm$120 mrad (horizontal) and $\pm$100 mrad

8 GeV pion	10 GeV pion	12 GeV pion	16 GeV pion	20 GeV pion	24 GeV pion
26.4 mrad	28.4 mrad	29.4 mrad	30.4 mrad	30.8 mrad	31.1 mrad

Δp~20%, $\Delta\theta_C$~1 mrad

Δp~20%, $\Delta\theta_C$~0.4 mrad

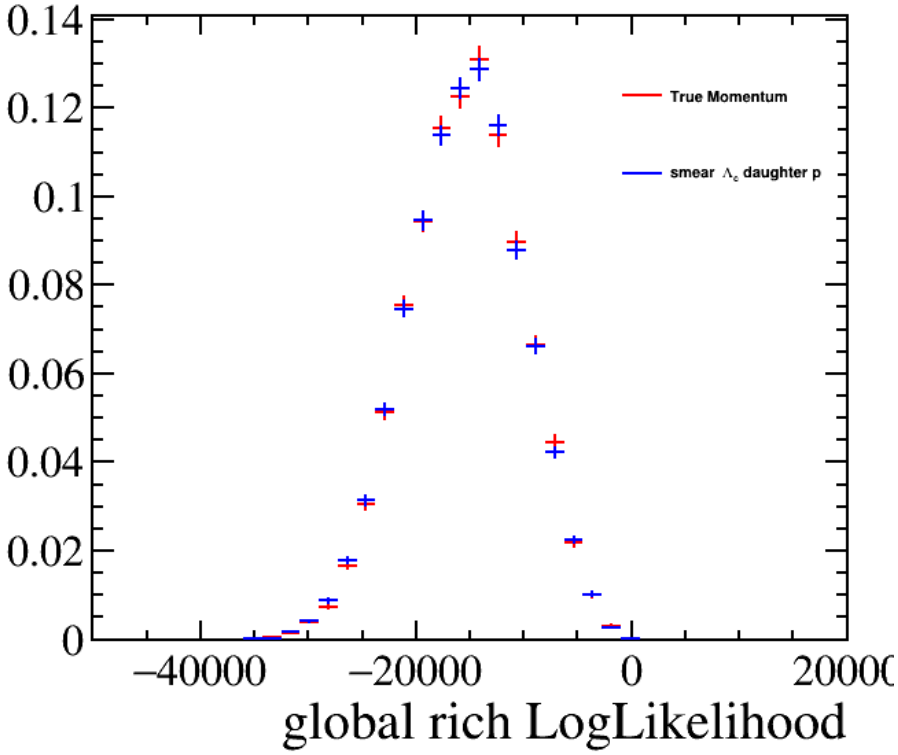
RICH2 info is promising to help improve T-track momentum resolution, at least in some kinematic regions (above RICH threshold but not too high)

Back up

- $\cos\theta_C = \frac{1}{n\beta}; \beta = \frac{p}{\sqrt{p^2+m^2}}$
- $\delta\theta \sin\theta_C = \frac{1}{n\beta^2}\delta\beta;\ \delta\beta = \frac{\delta p}{E} - \frac{p^2\delta p}{E^3} = \frac{m^2}{E^3}\delta p$
- $\delta\theta \sin\theta_C = \frac{1}{n\beta^2}\frac{m^2}{E^3}\delta p$
- $\delta p = \frac{n\beta^2 E^3}{m^2}\sin\theta_C\delta\theta$

No significant variation in Global RICH likelihood value

Distributions when using settings a) or b)



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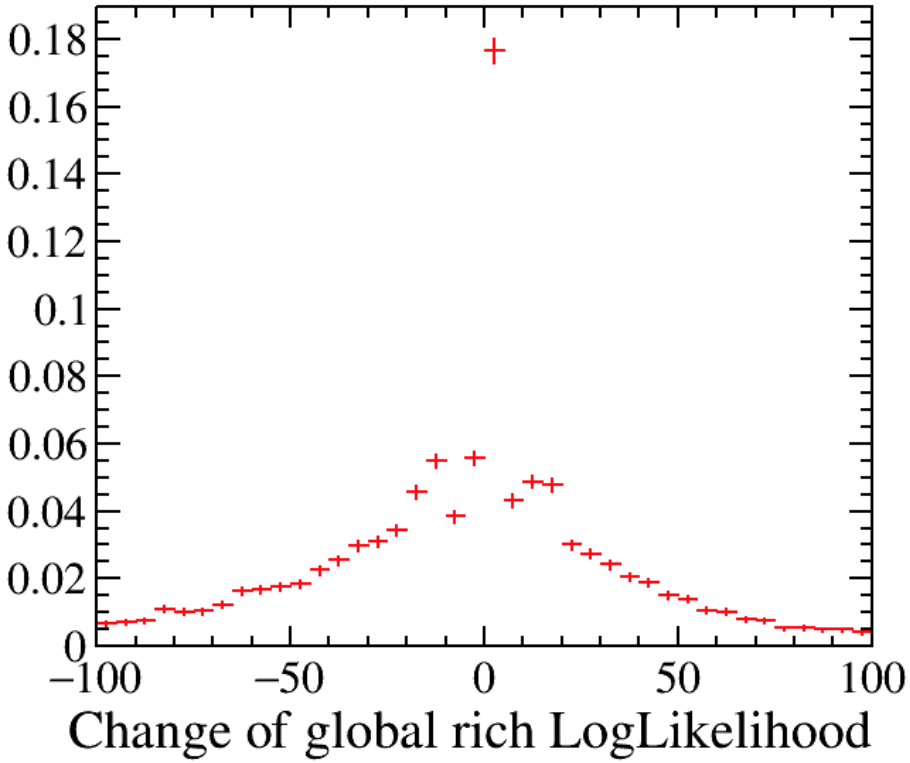
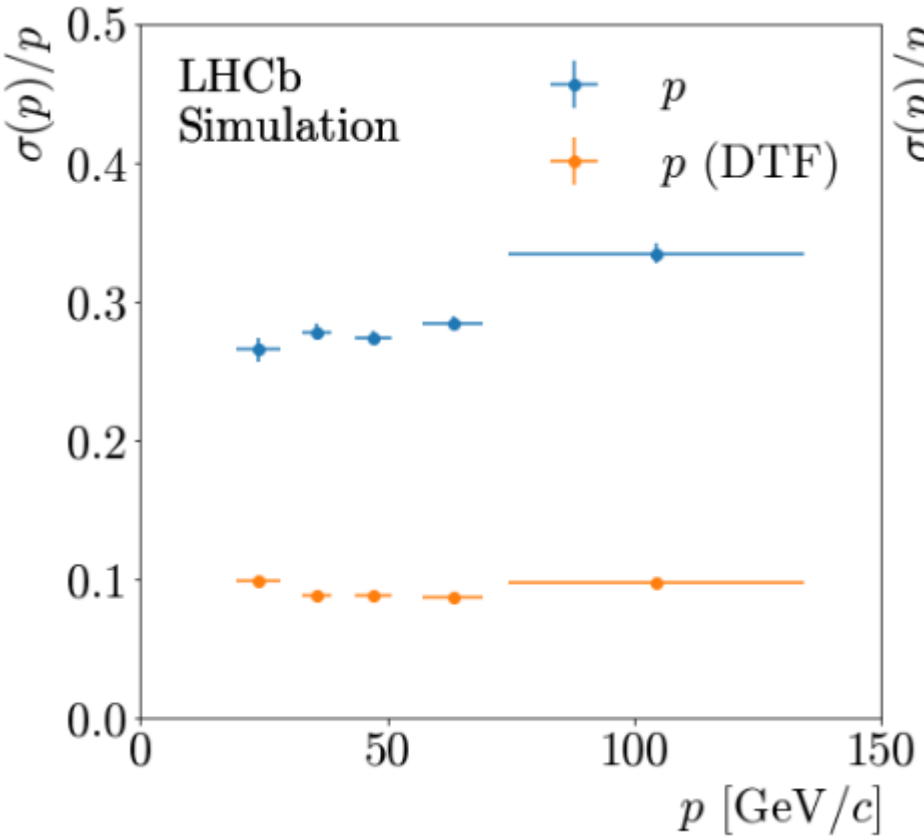
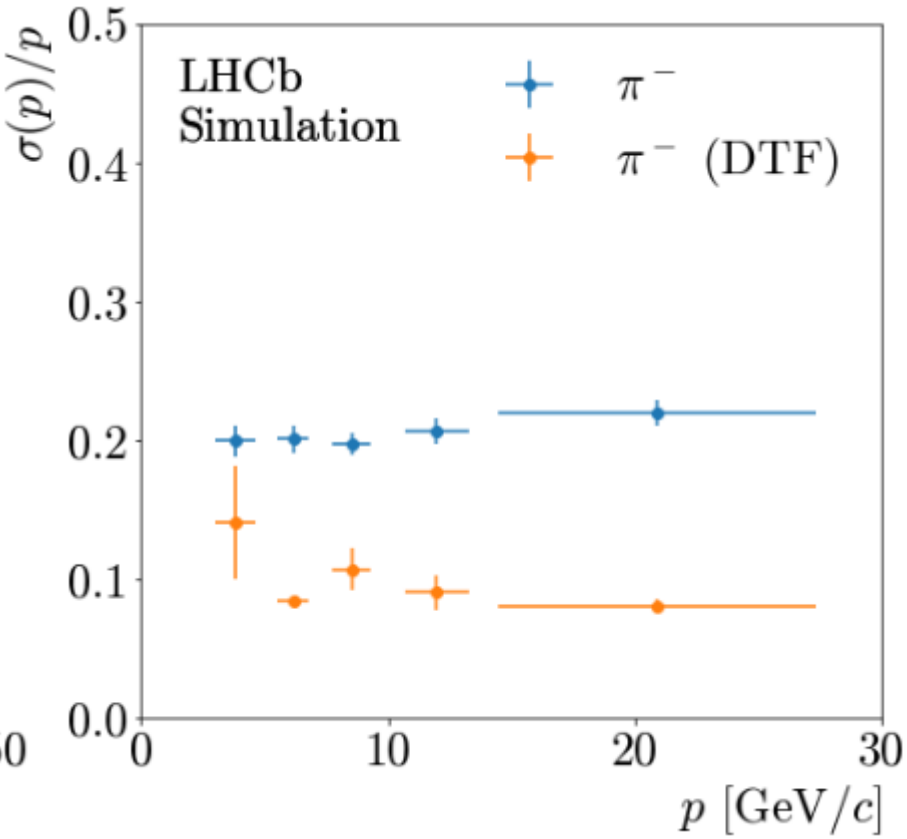


From Giorgia's talk





https://twiki.cern.ch/twiki/bin/view/LHCb/RICHPicturesAndFigures