Likelihood Method for mRICH PID

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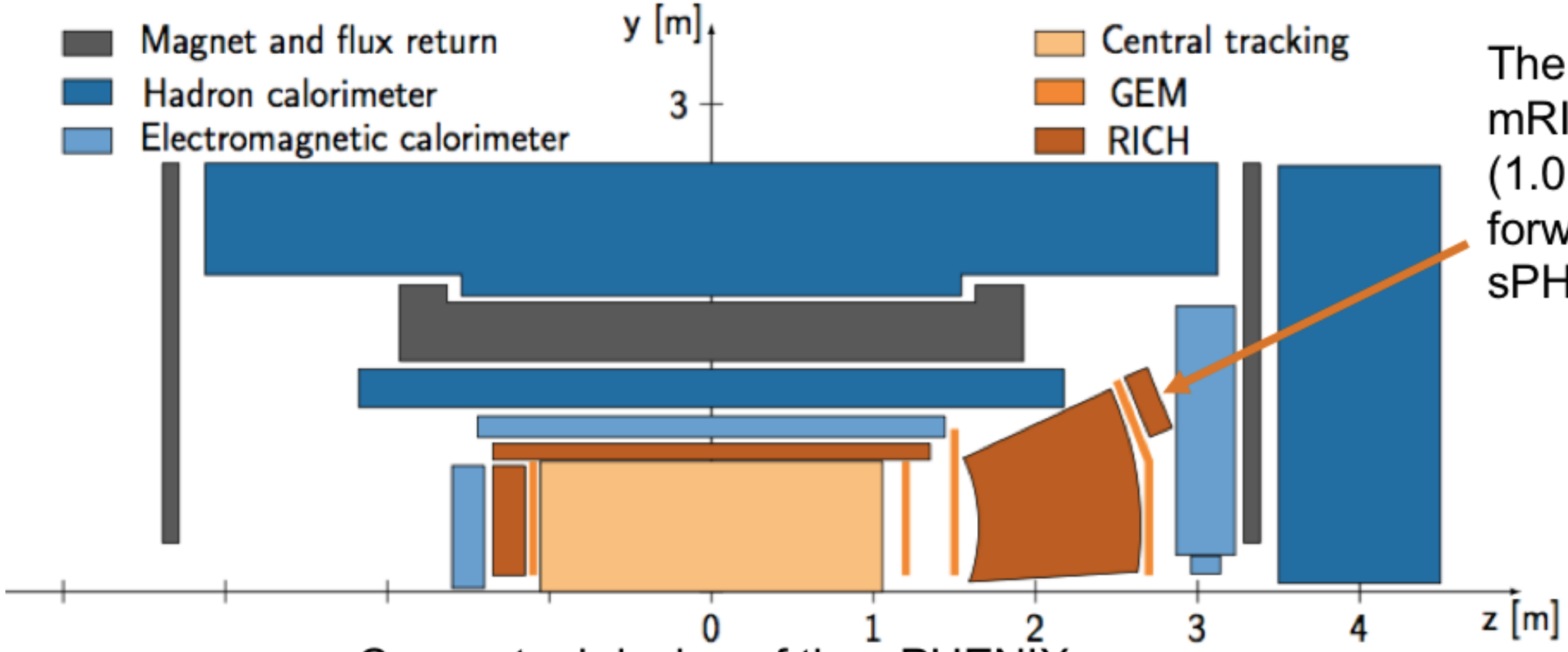
mRICH in Forward sPHENIX

An implementation of the mRICH detector concept in the Forward sPHENIX has been proposed in a Letter of Intent to BNL.

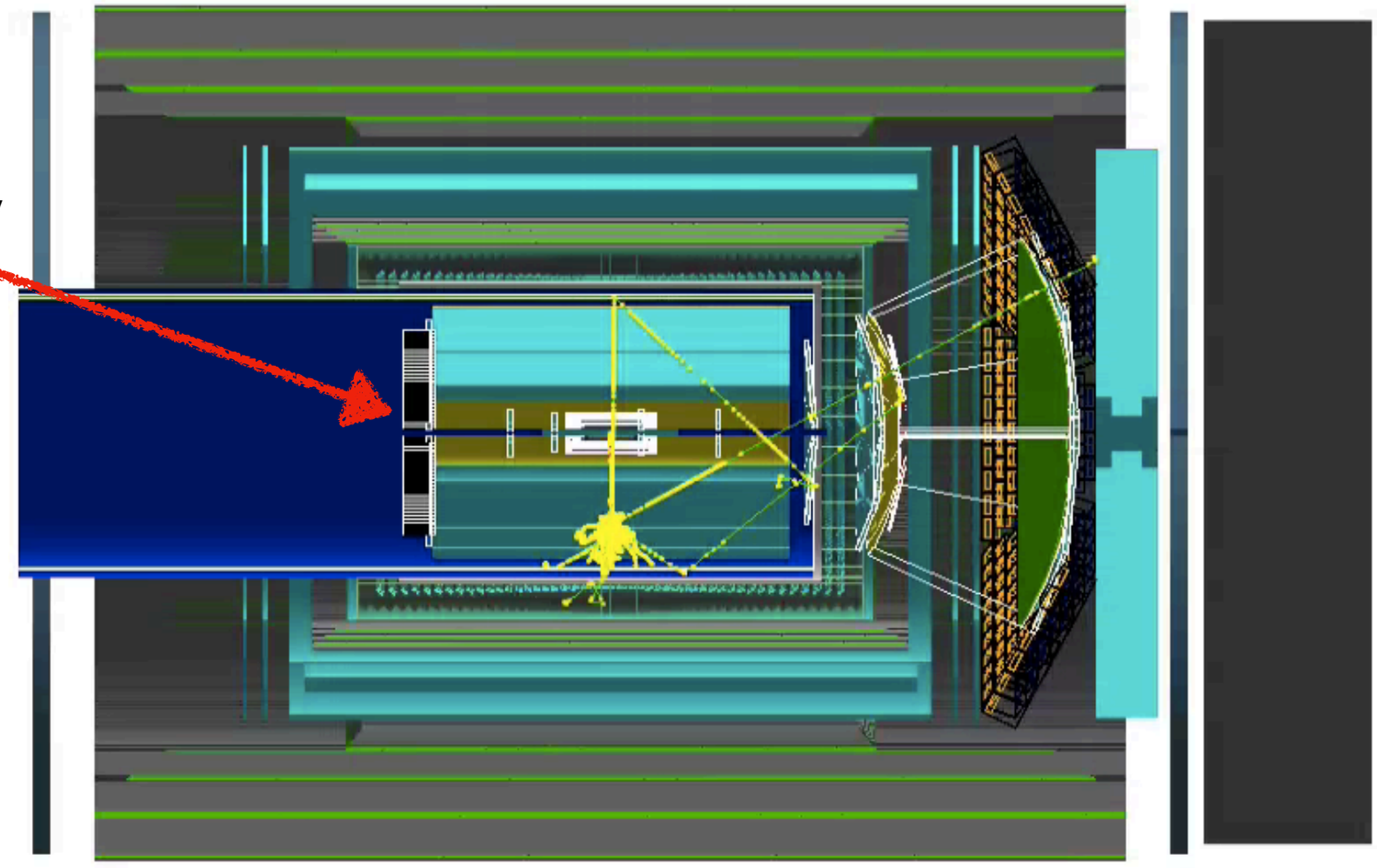
- Enhance of the physics capabilities of the sPHENIX experiment.
- Make the sPHENIX detector system a realist eRHIC detector for the future EIC experiments.
- Validate the mRICH detector PID performance in real experiments before EIC coming online.



The proposed mRICH coverage ($1.0 < y < 2.0$) in the forward region of sPHENIX.

Conceptual design of the sPHENIX

mRICH Simulation Updates



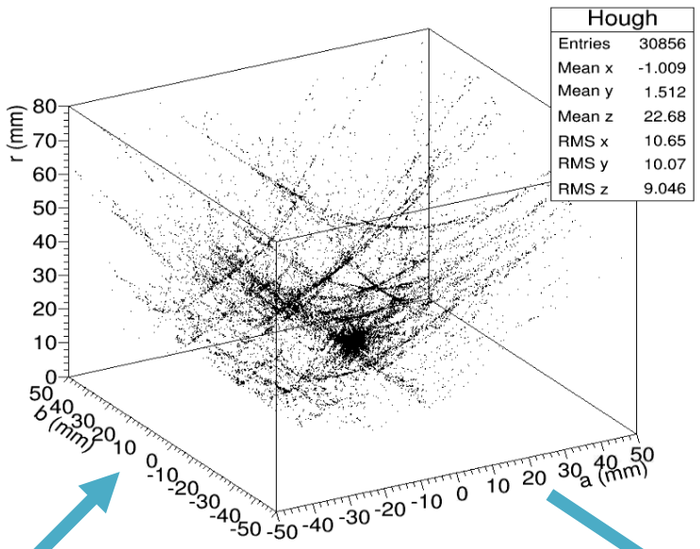
- https://github.com/sPHENIX-Collaboration/coresoftware.git <= PR #425 merged
- https://github.com/sPHENIX-Collaboration/calibrations.git <= PR #32 under preview
  - mRICH geometry
  - will add mRICH array on e-going side
- https://github.com/sPHENIX-Collaboration/macros.git <= PR #106 under preview
  - implementation into EIC detector
  - G4_Aerogel.C
  - overlap check is done for single mRICH

mRICH Parameterization

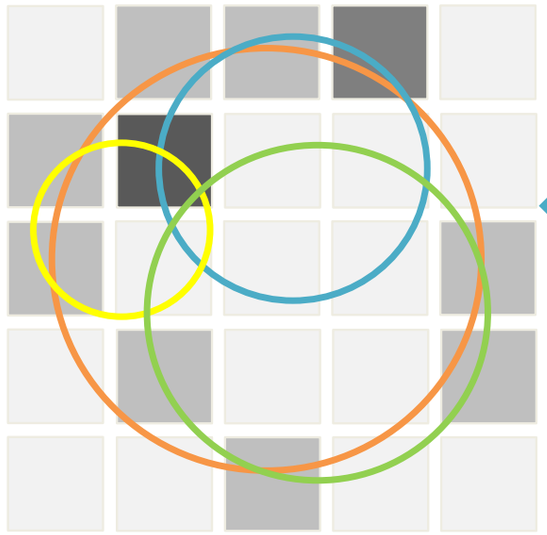
Ring Finder Algorithm

Ping's Master defense

Hough Transform Algorithm

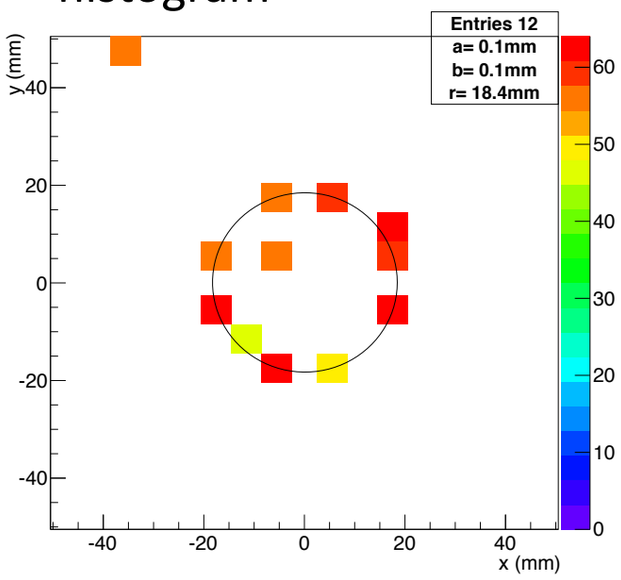


Find all possible rings in an event



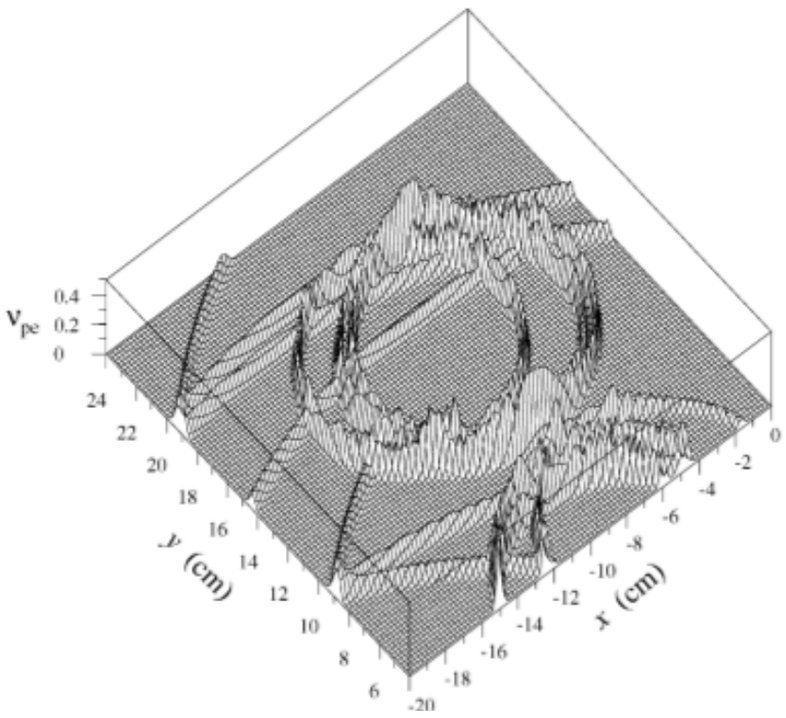
Fill possible rings' r, (a,b) in a probability density histogram

The most possible ring is the densest bin in the probability density histogram

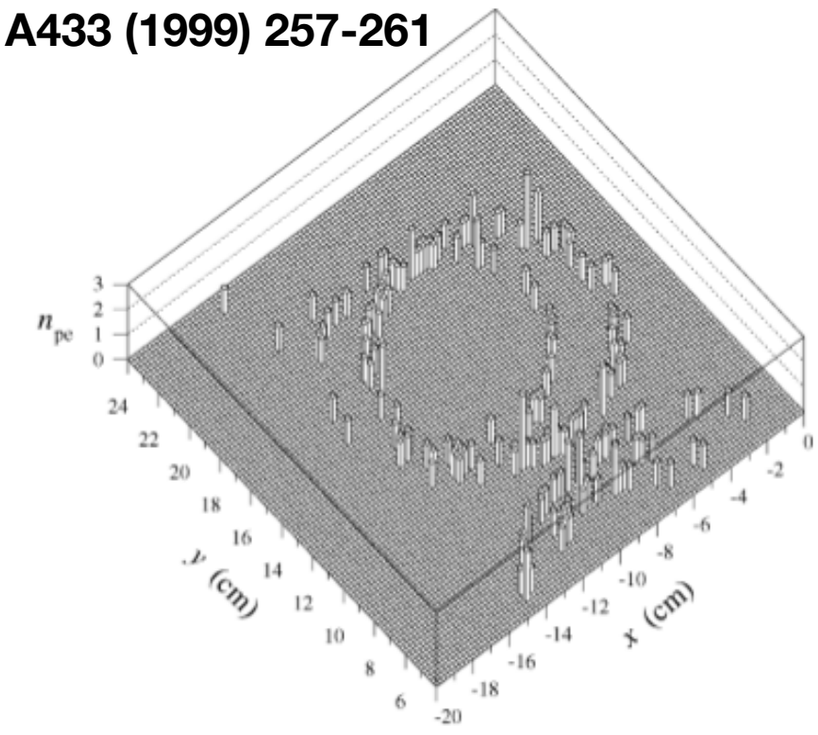


https://en.wikipedia.org/wiki/Hough_transform

mRICH Parameterization Maximum Likelihood



NIM A433 (1999) 257-261



- simulate photoelectron distribution in sensor plane with different PID for certain momentum => PDF
- compare with measured photoelectron distribution
- calculate poisson likelihood $\mathscr{L} = \prod_{\text{pixels } i} \frac{e^{-\nu_i} \nu_i^{n_i}}{n_i!}$
- select set-of PID maximum the likelihood

Or:

$$P(M \mid \mathbf{E}) = \frac{P(\mathbf{E} \mid M)}{\sum_m P(\mathbf{E} \mid M_m) P(M_m)} \cdot P(M)$$

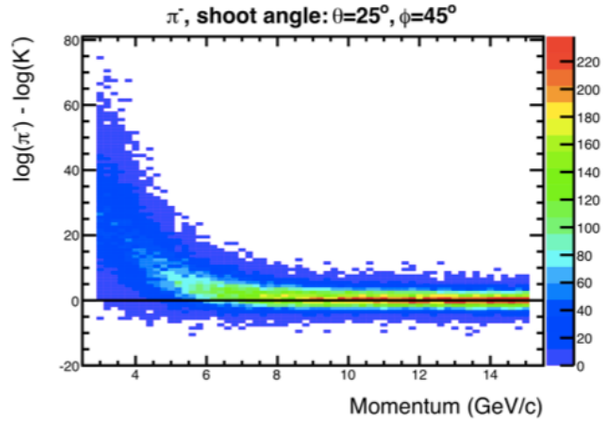
posterior probability — prior probability

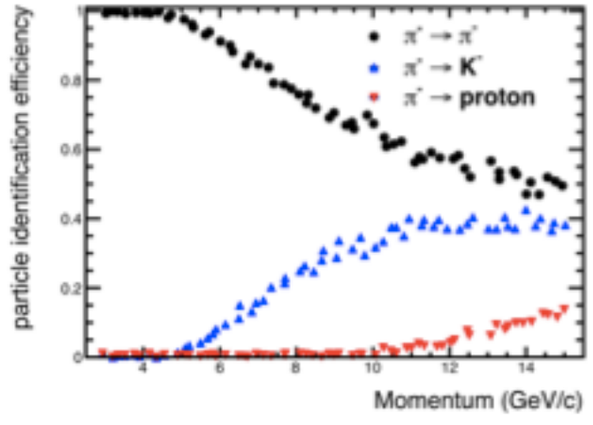
Bayesian inference

Where

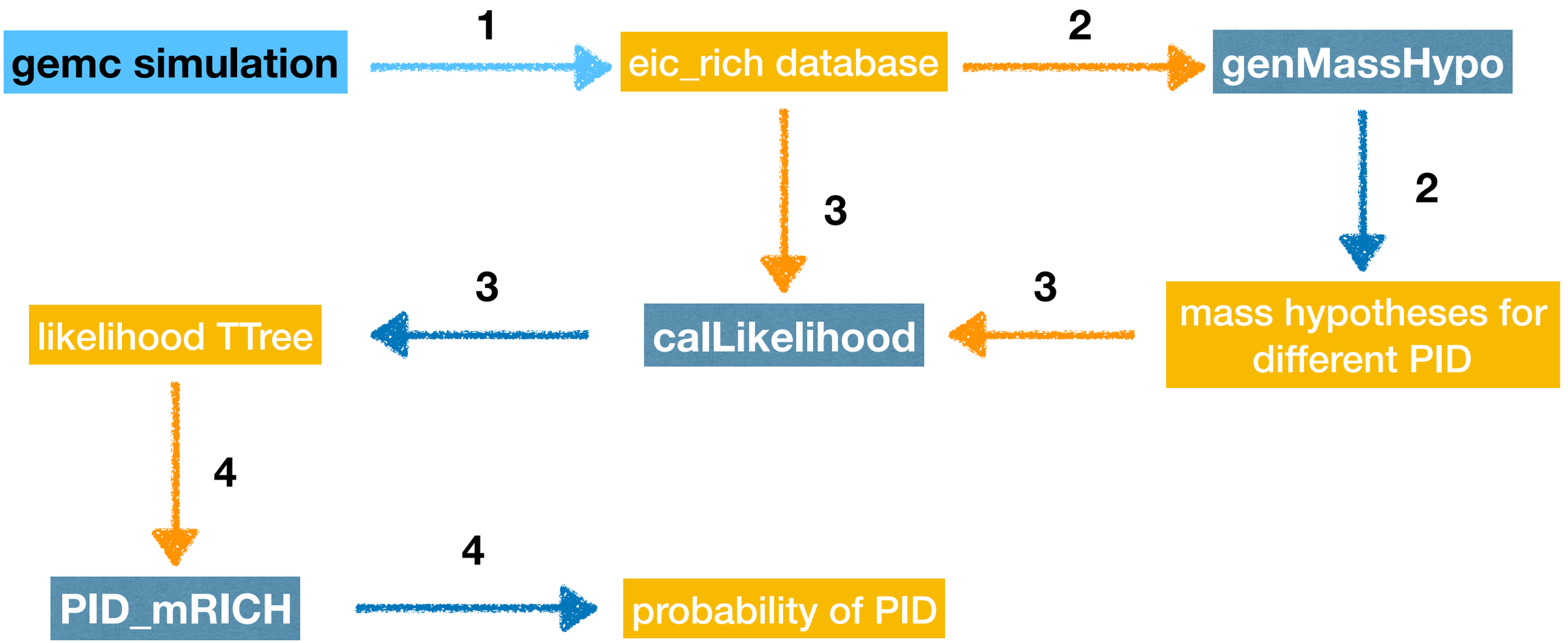
likelihood $P(\mathbf{E} \mid M) = \prod_k P(e_k \mid M).$

previous development





PID Code Chain

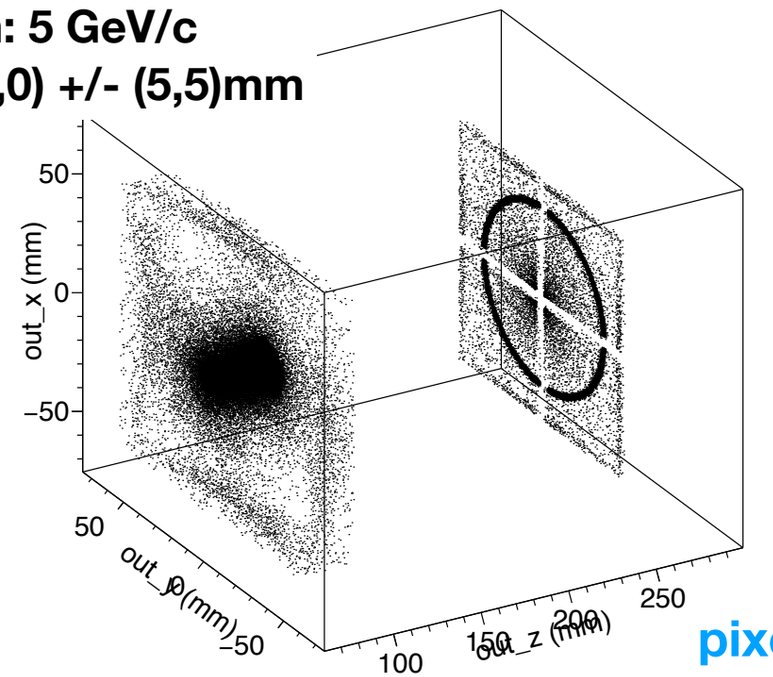


- **code is rewrote based on Liang and Ping's work**
- **https://github.com/sunxuhit/PID_mRICH.git**
- **major structure is done but still need a lot of polishing**
- **gemc simulation jobs are done at JLab ifarm**

Cherenkov Photons Distribution

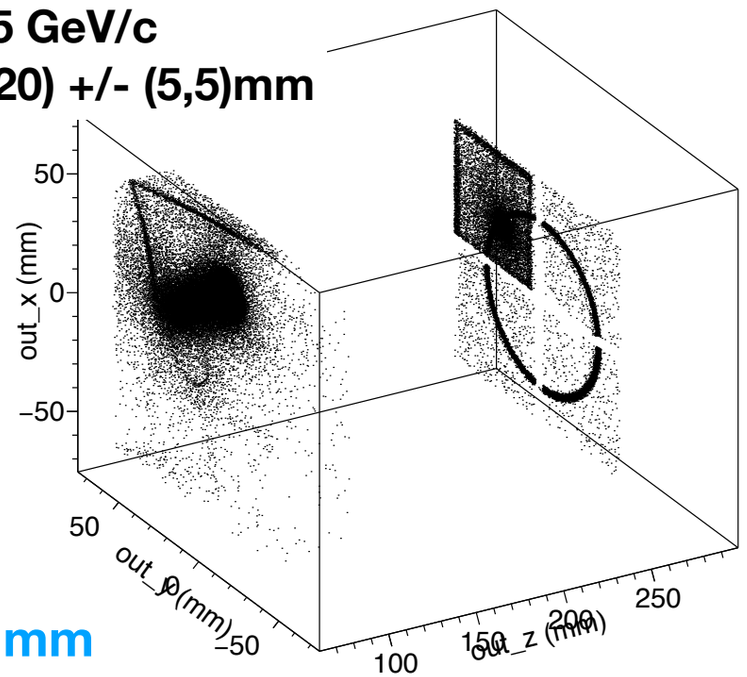
piplus

momentum: 5 GeV/c
position: (0,0) +/- (5,5)mm



kminus

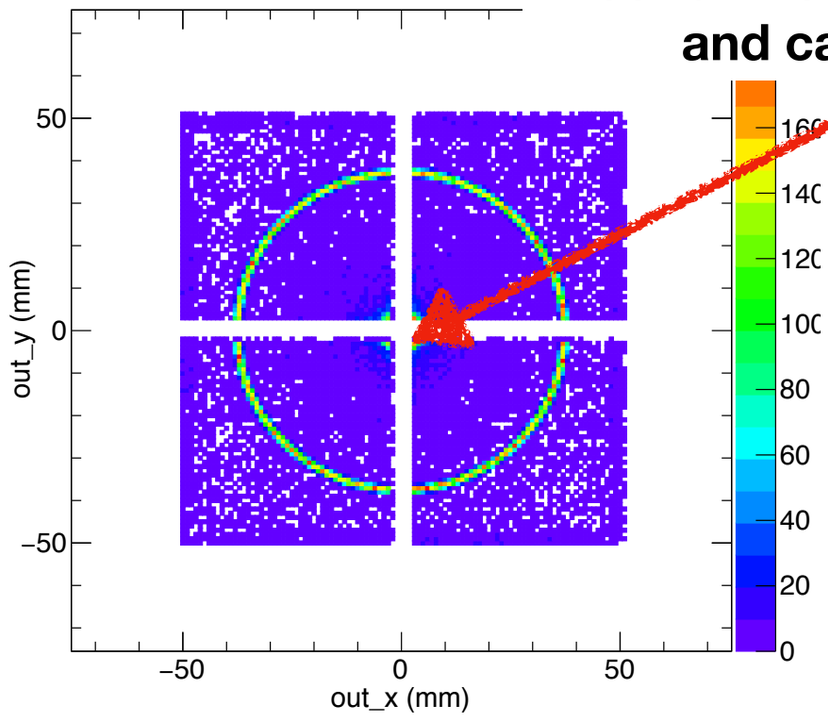
momentum: 5 GeV/c
position: (20,20) +/- (5,5)mm

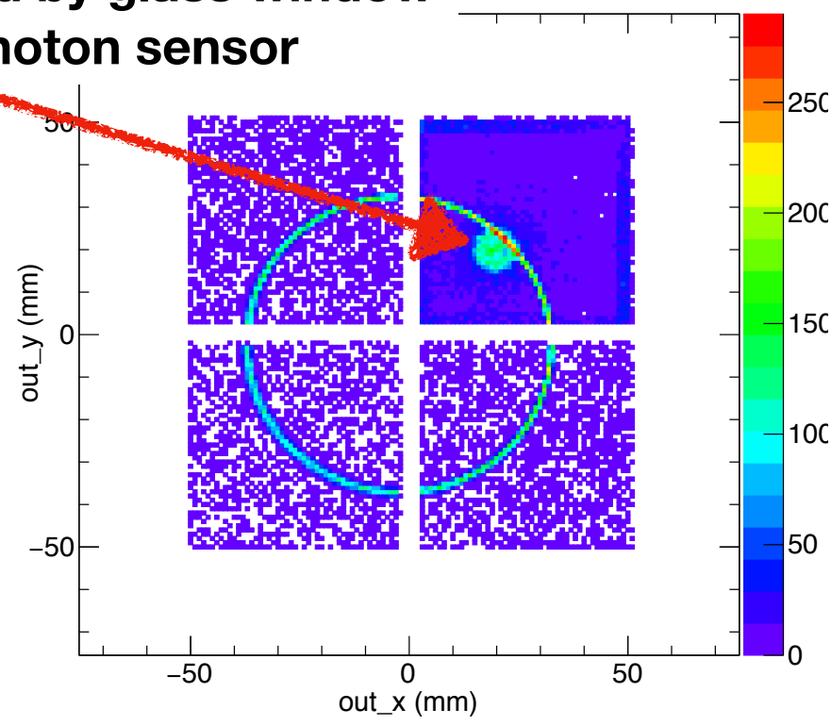


pixel size is 1mm*1mm

Cherenkov photons from glass window
most of them are reflected by glass window
and cannot reach photon sensor

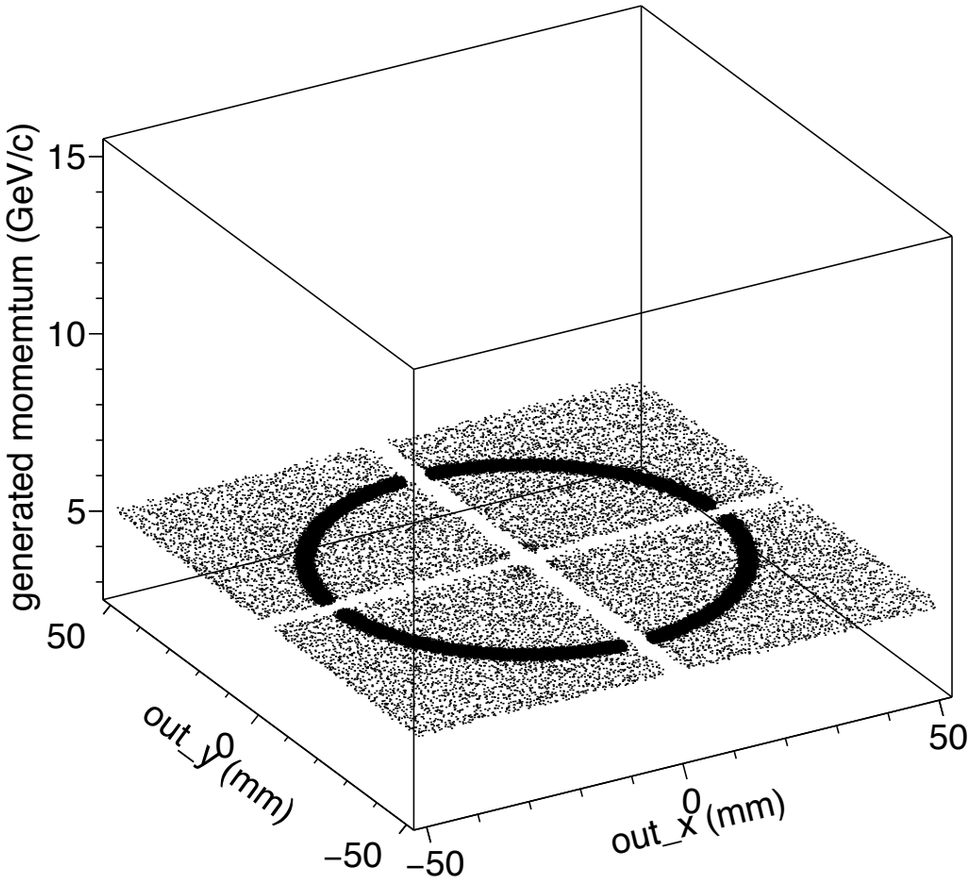
piplus



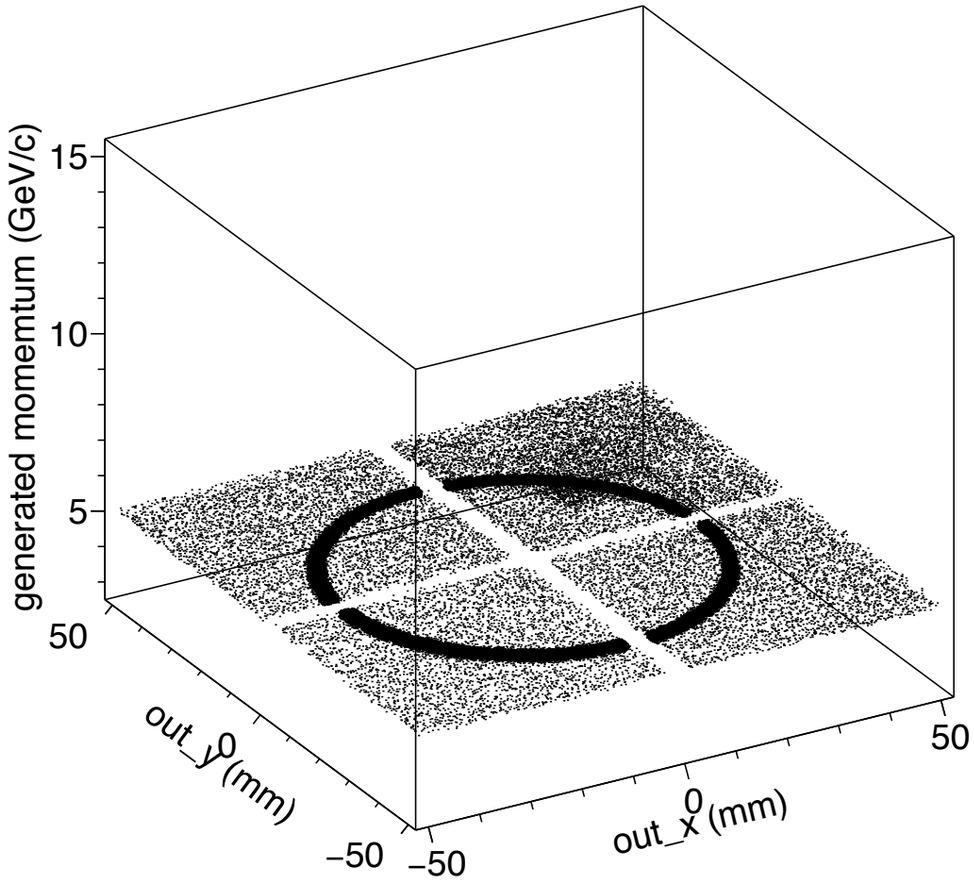


Mass Hypotheses

piplus

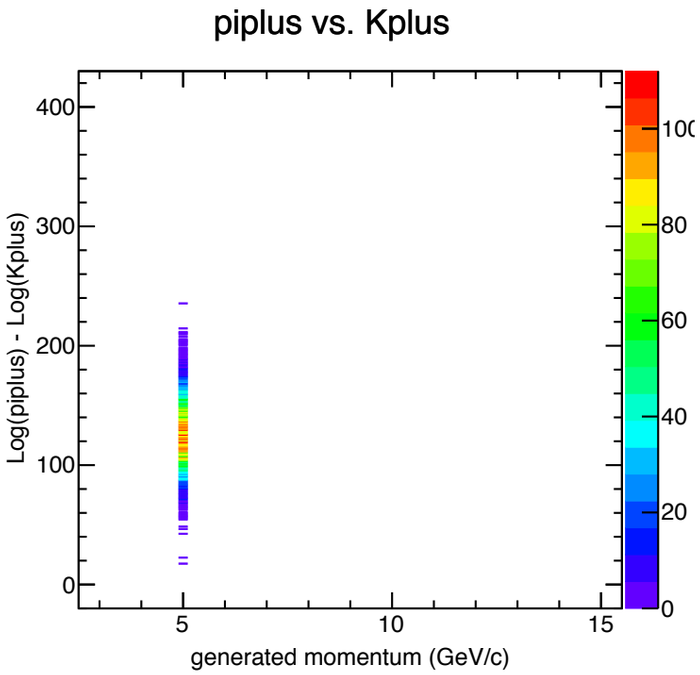


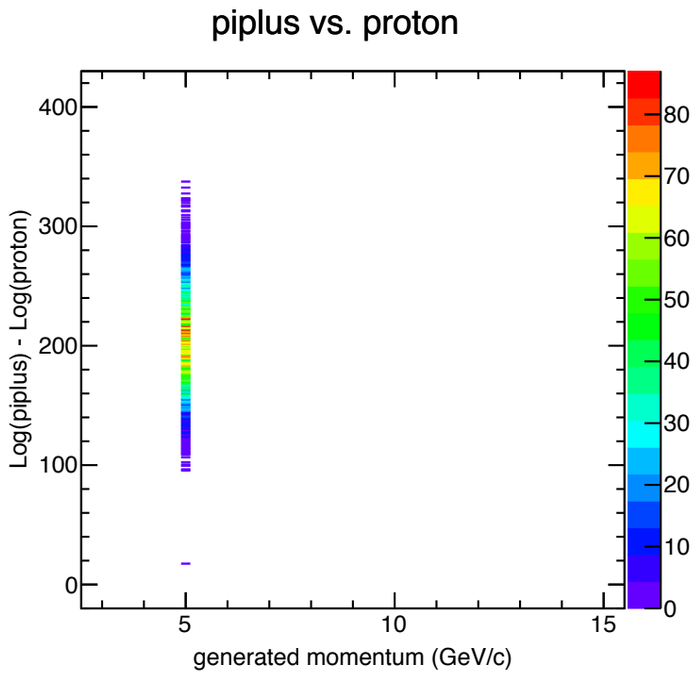
Kminus



- **less Cherenkov lights from glass window after photon cuts applied**
- **perfect detector for now**
- **generate particle with 5 GeV/c**

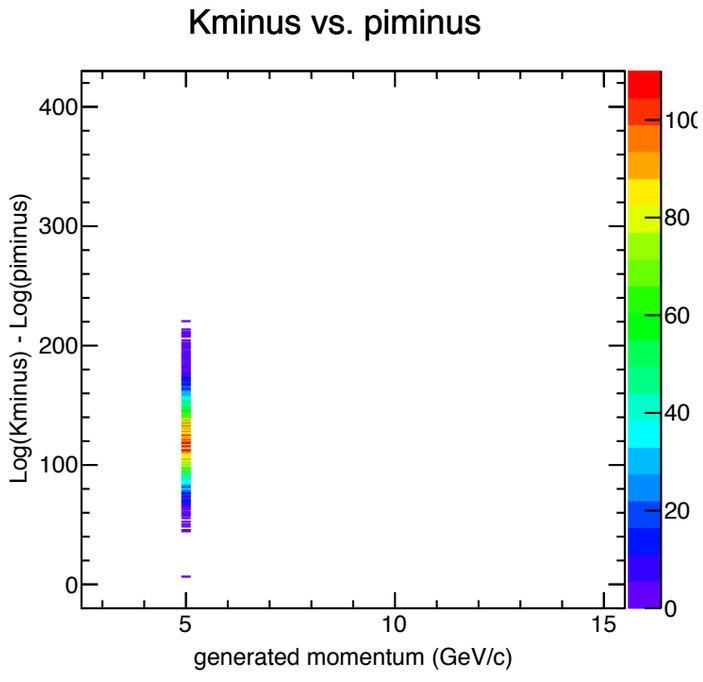
Log Likelihood Difference

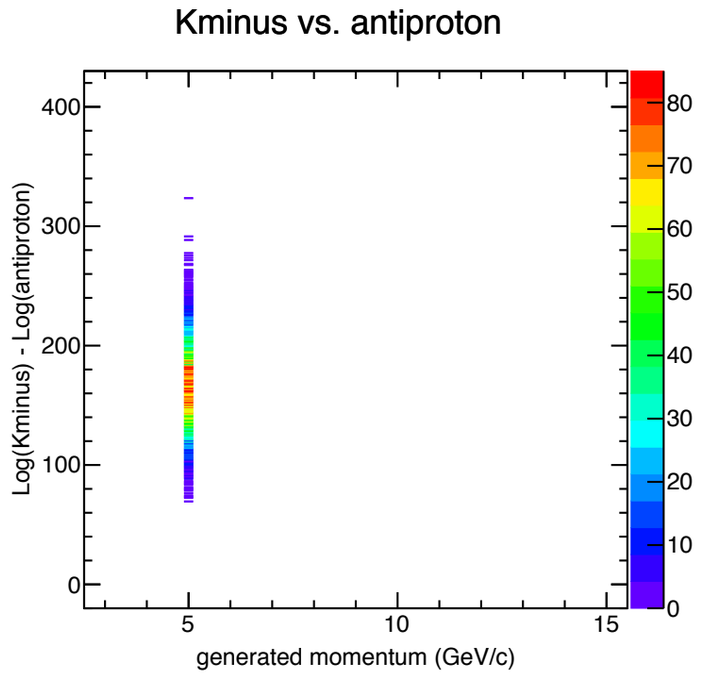




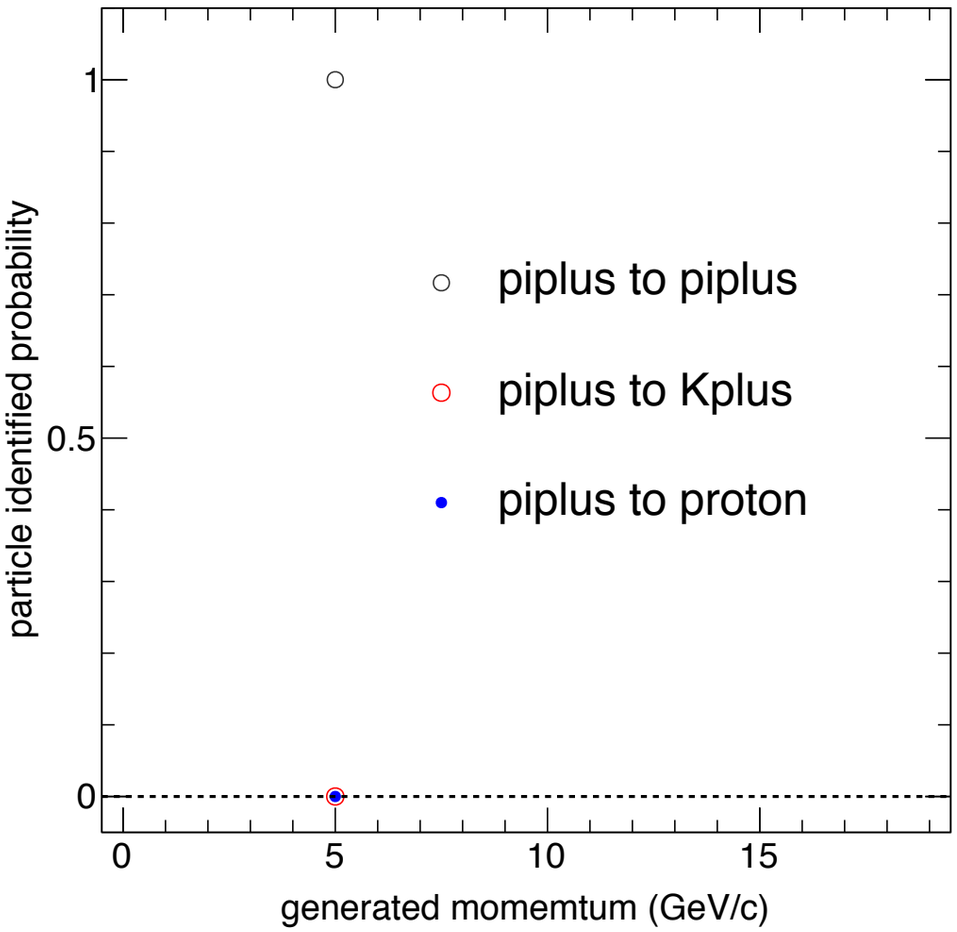
- **difference of log likelihood for different PID configuration**
- **difference is alway larger than 0 because pi, K and proton are launched at different location in this test**

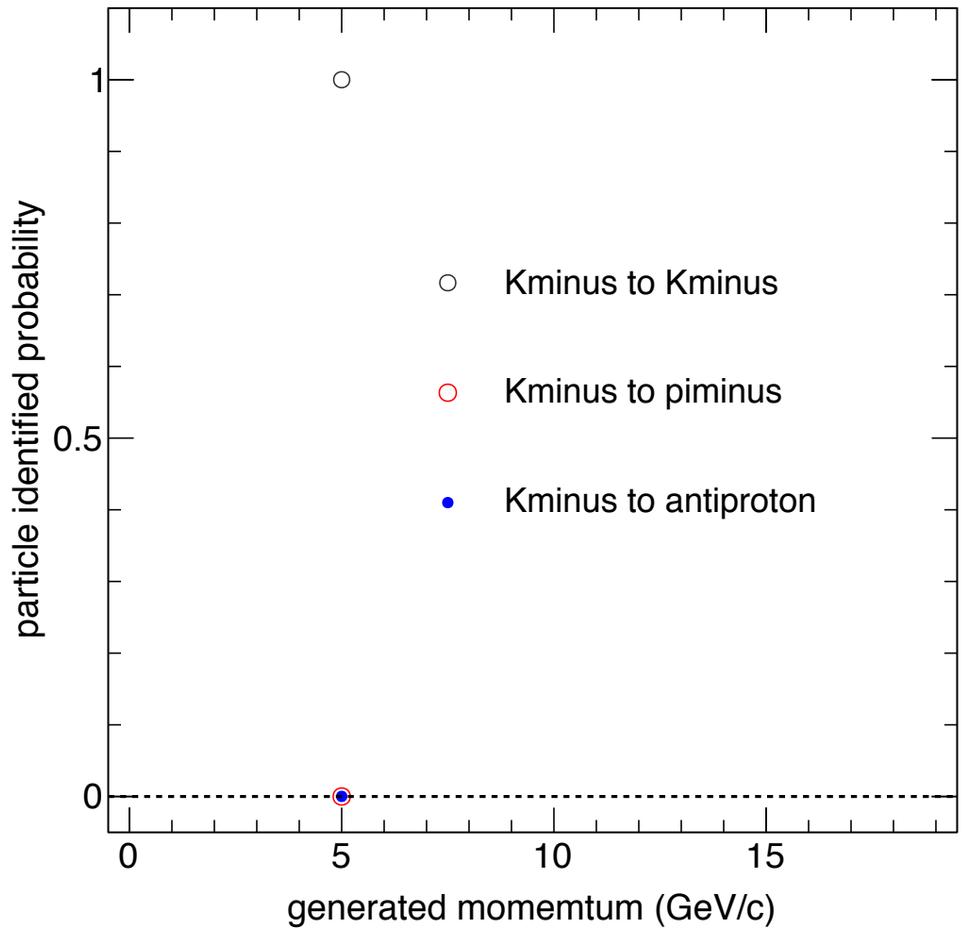
- **piplus => piplus, Kplus and proton**
- **Kminus => piminus, Kminus and antiproton**





Particle Identification Probability

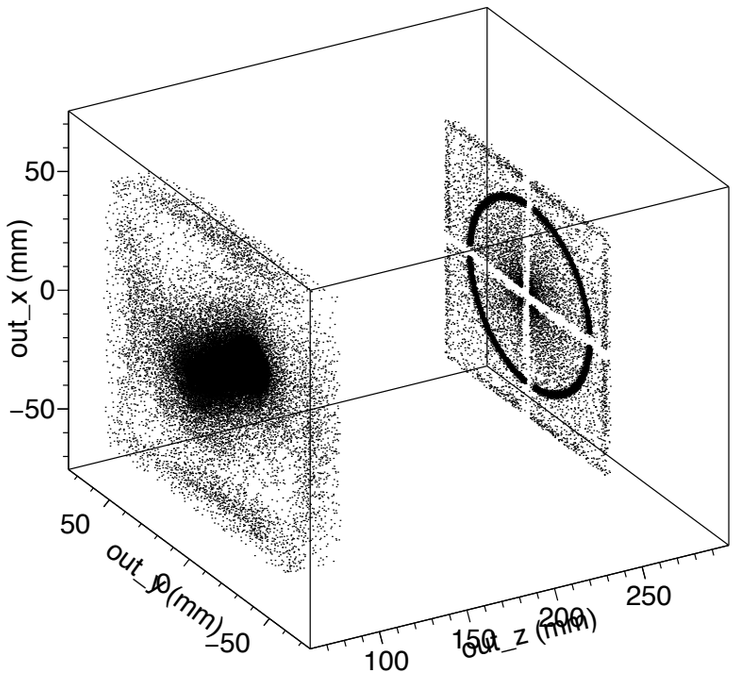




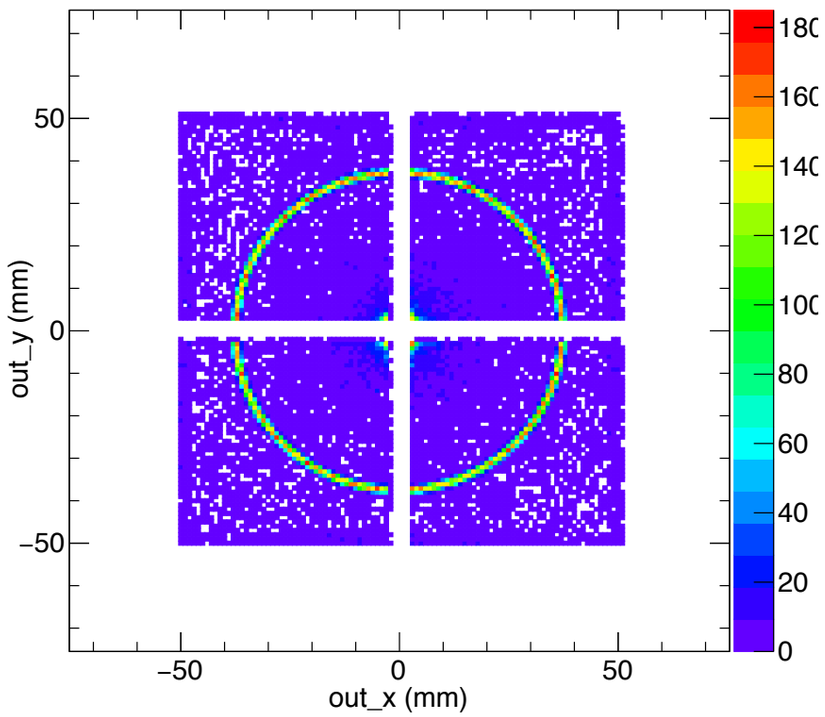
- **particle identification probability is almost 100% under perfect detector and different launching position**
- **momentum is 5 GeV/c for all 3 particle species**

Flat Distribution

piminus



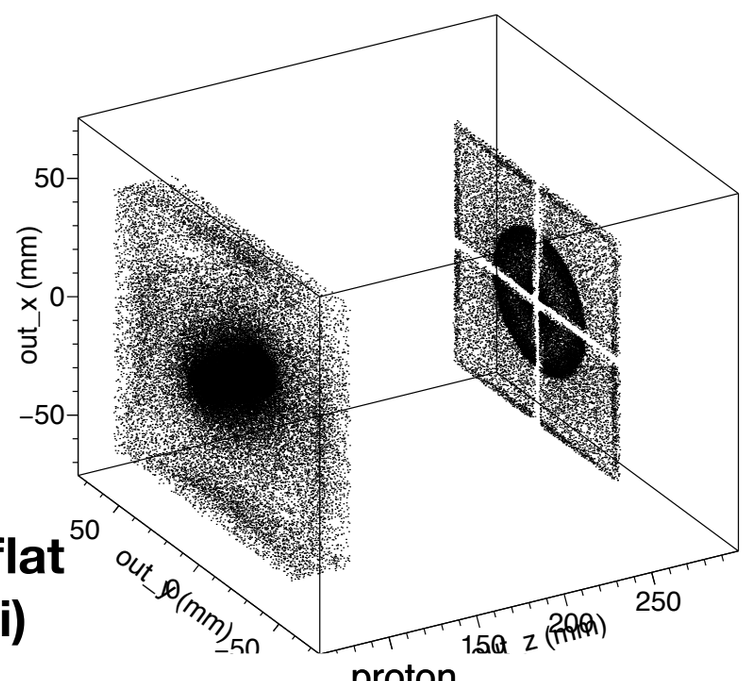
piminus



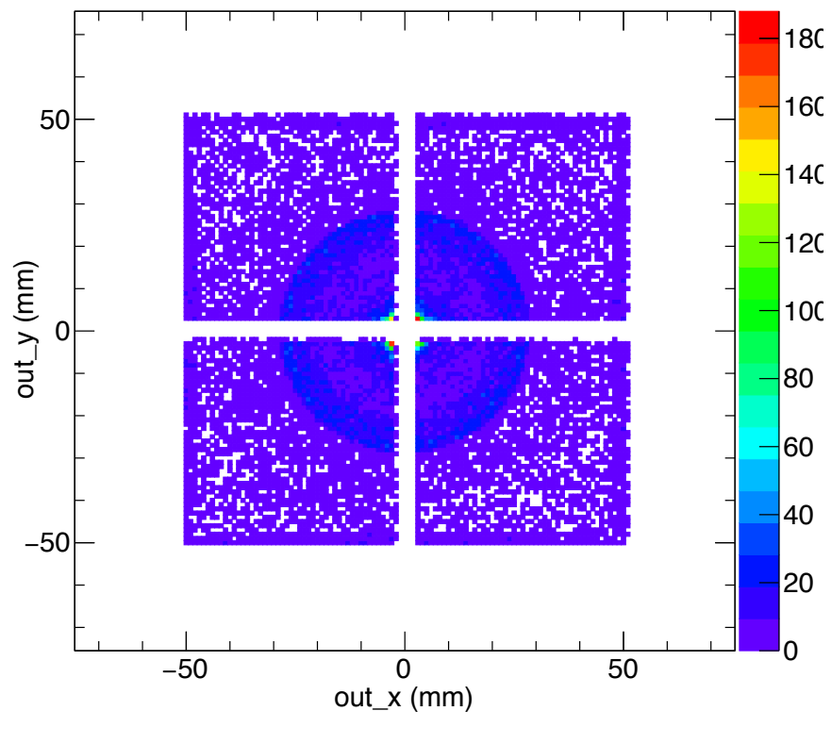
- **momentum: 5 +/-1 GeV/c**
- **position: (0,0) +/- (5,5)mm**
- **sampled inject particle with a flat distribution (vx, vy, p, theta, phi)**
- **binning can be decide with specific resolution**

pixel size is 1mm*1mm

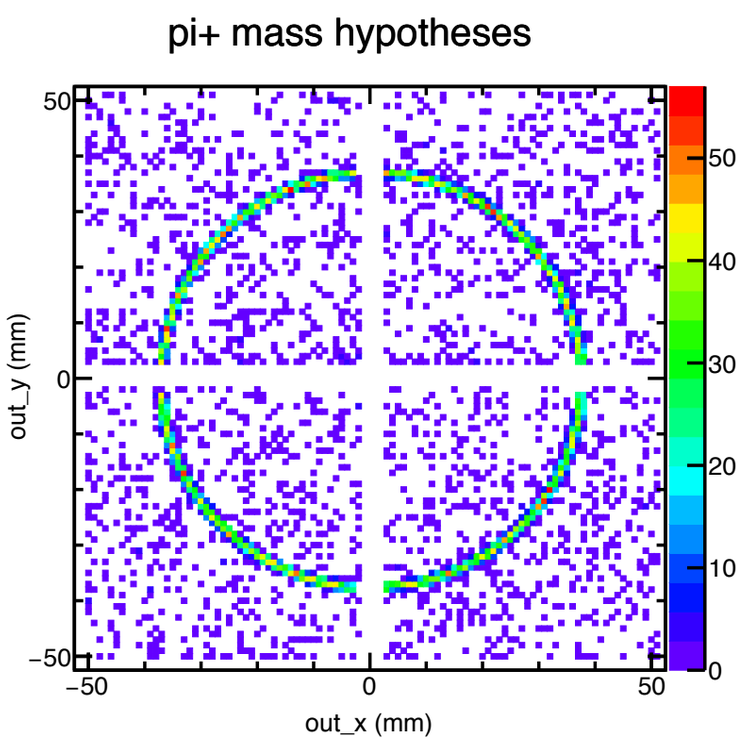
proton

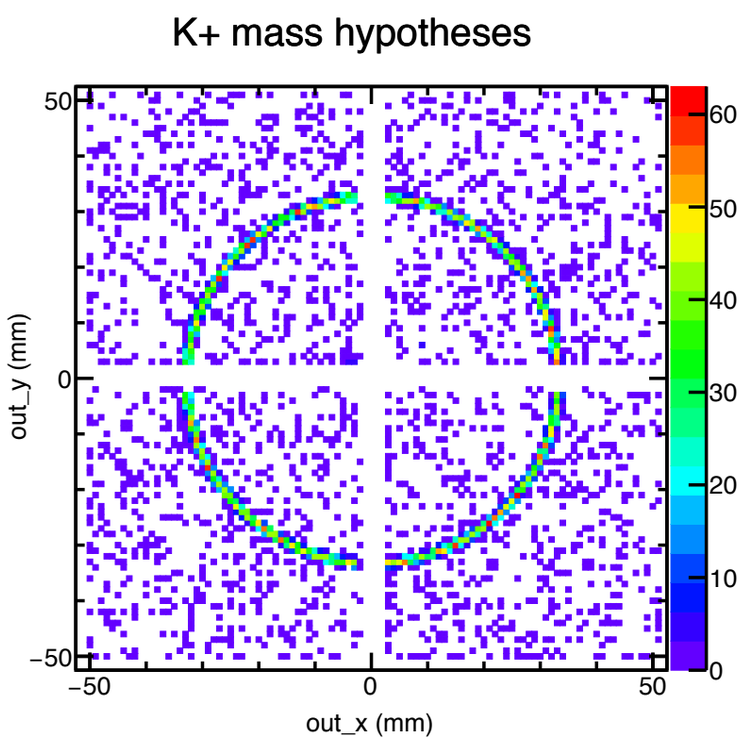


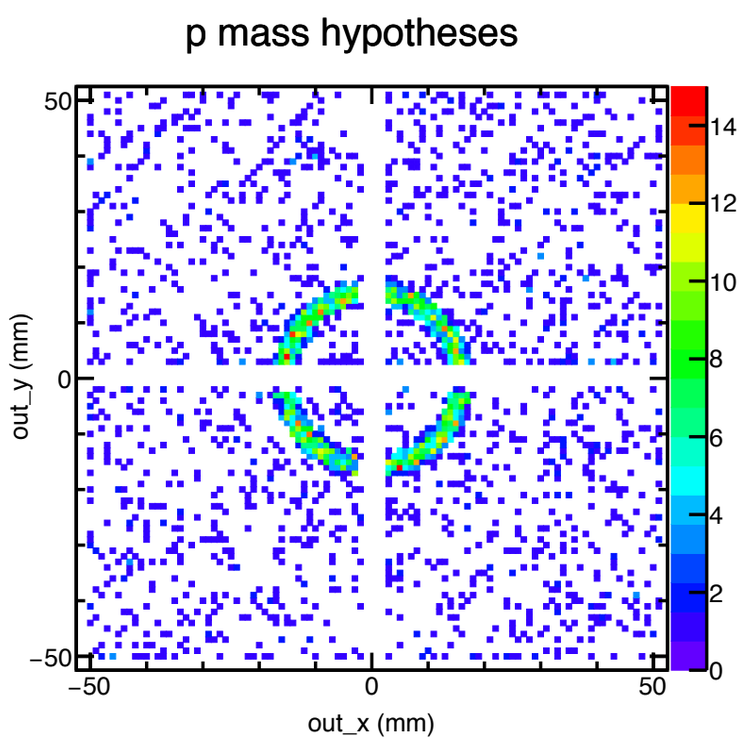
proton

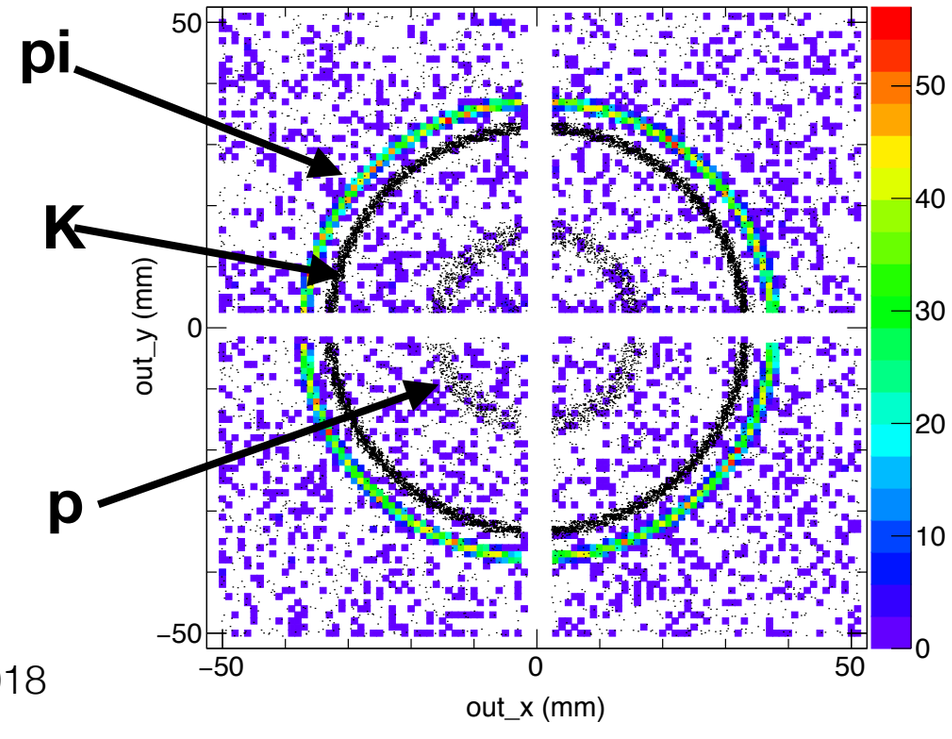


Mass Hypotheses



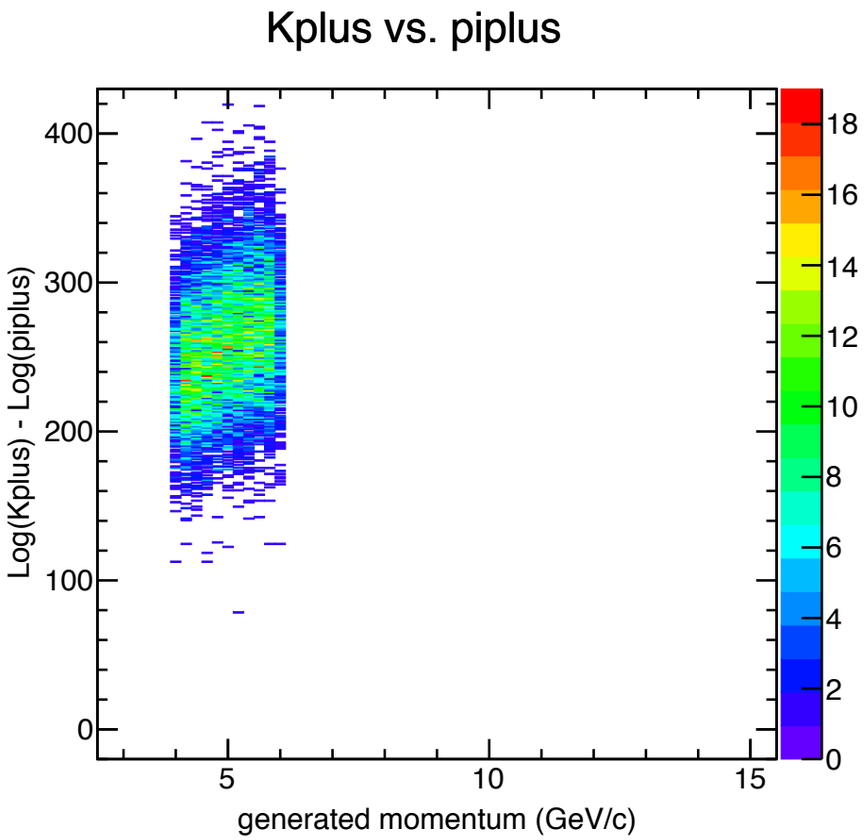


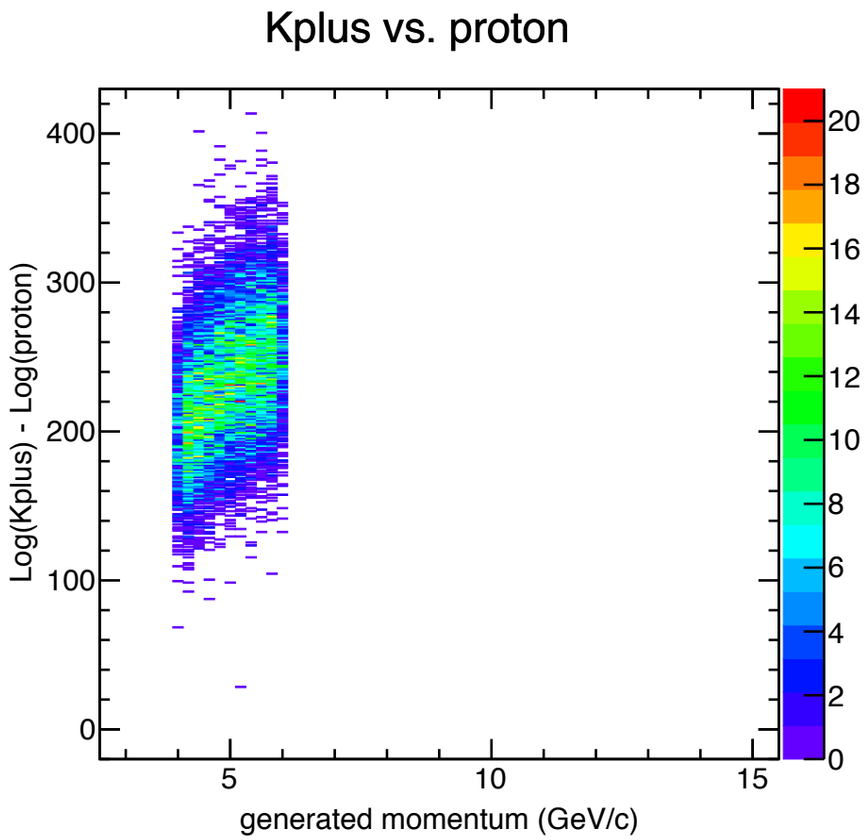


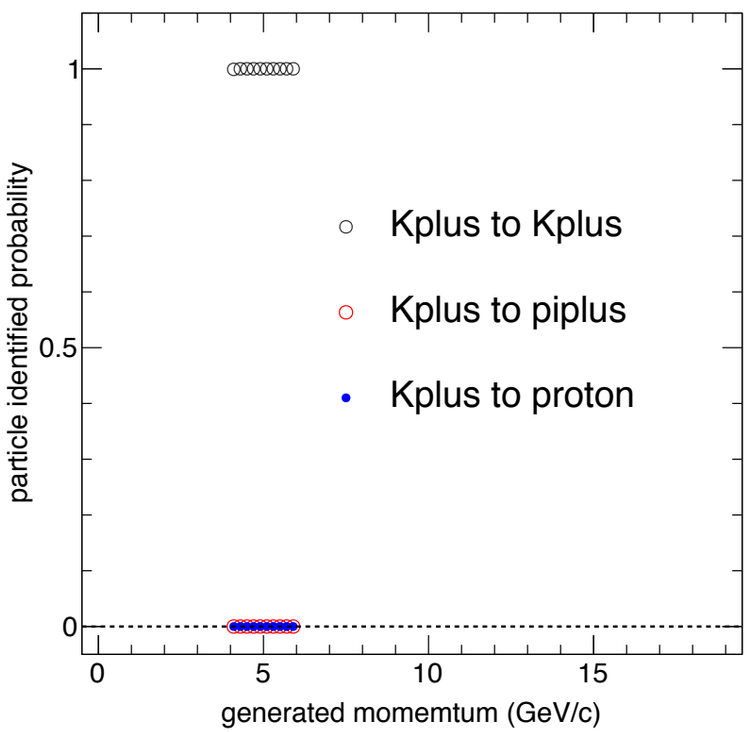


- **vx > -5 && vx < 0mm**
- **vy > 0 && vy < 5mm**
- **p > 4.2 && p < 4.4 GeV/c**
- **theta = 0 deg**
- **phi = 0 deg**

Particle Identification Probability

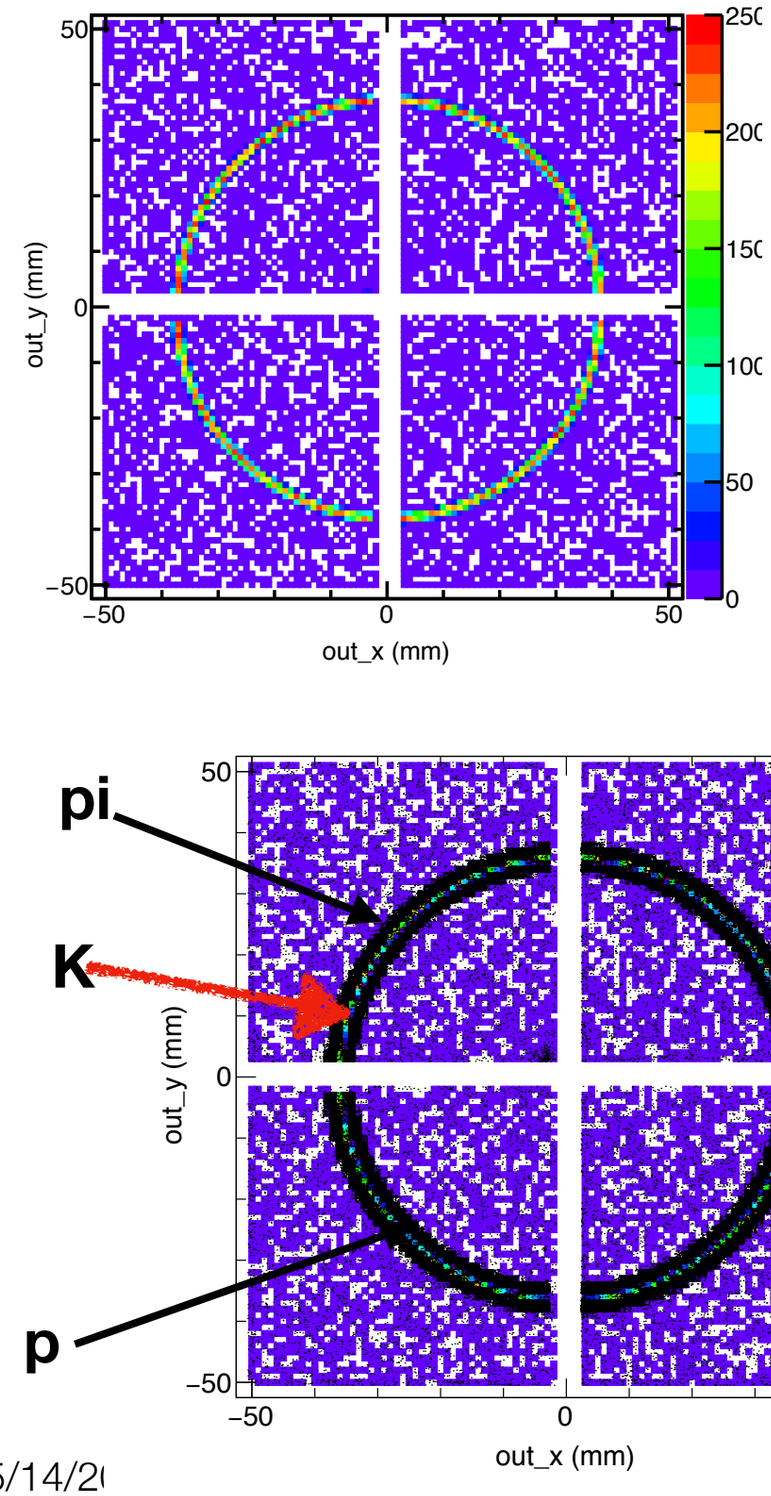






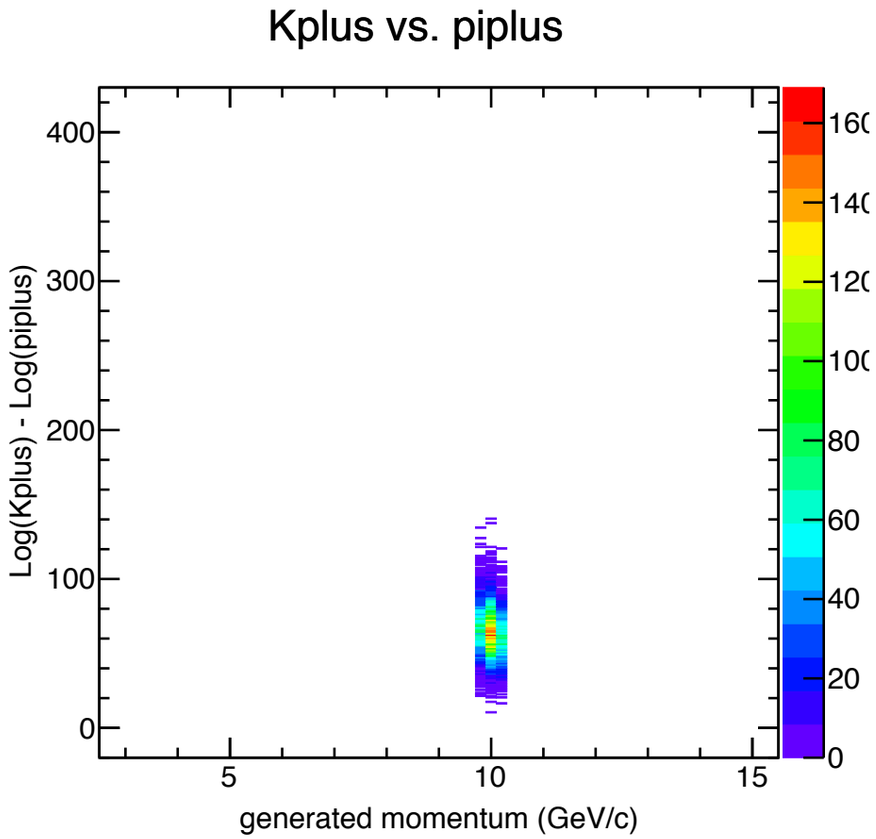
- **perfect detector**
- **1mm*1mm pixel size**
- **full separation at 4-6 GeV/c**

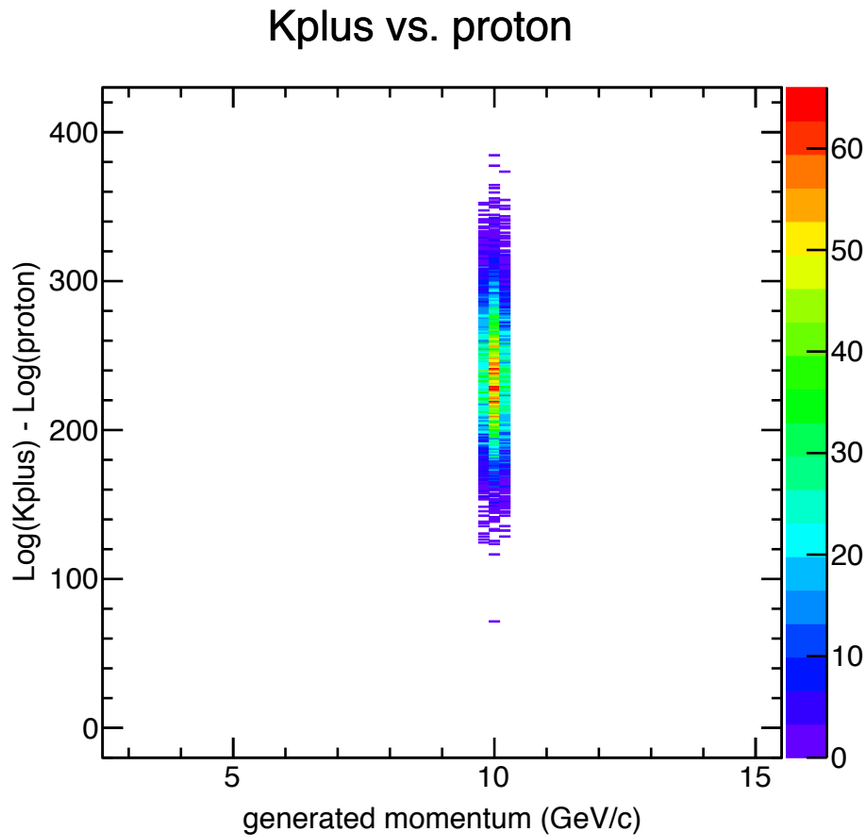
Mass Hypotheses at High Momentum

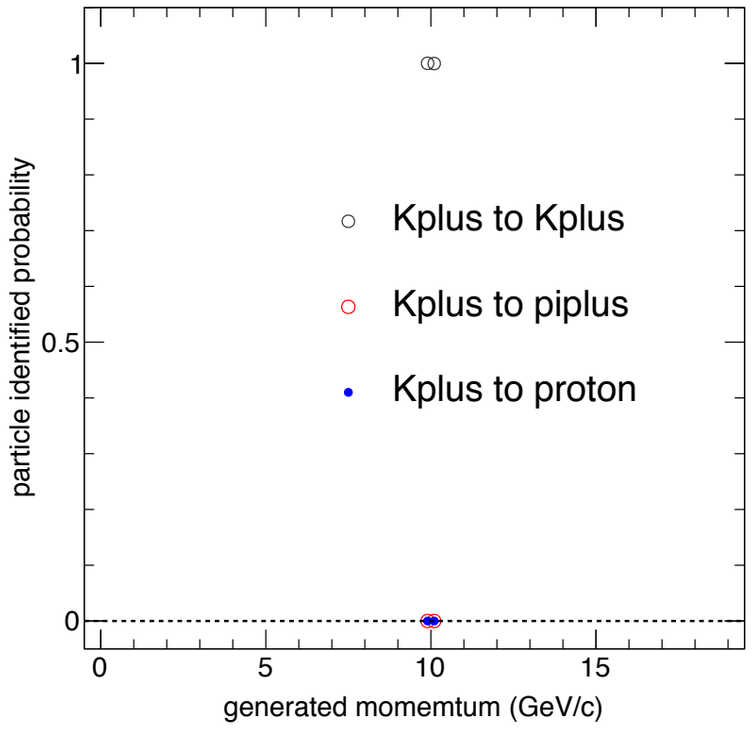


- **vx > -5 && vx < 0mm**
- **vy > 0 && vy < 5mm**
- **p > 10.0 && p < 10.2 GeV/c**
- **theta = 0 deg**
- **phi = 0 deg**
- **pion and Kaon start to merge**

Particle Identification Probability







- **perfect detector**
- **1mm*1mm pixel size**
- **likelihood difference between pion and kaon is much smaller than 4-6 GeV/c**
- **larger pixel size and un-perfect detector will introduce misidentification**

Summary and Outlook

- able to identify particle through maximum likelihood method
- pi/K separation up to 10 GeV/c with perfect detector and 1mm*1mm pixel size
- will simulate mass hypotheses of pi/K/p for full phase space
- will add detector effect
- binning need to be decided (vx, vy, p, theta and phi)

=> 10*10*40*10*36 ~ 1.5M TH2D (100*100) (1mm*1mm)

=> 1.5M*10k*8bytes = 120 GB memory?

- parameterization will be a big lookup table with vx, vy, p, theta and phi as input

Thanks for your attention!