PID

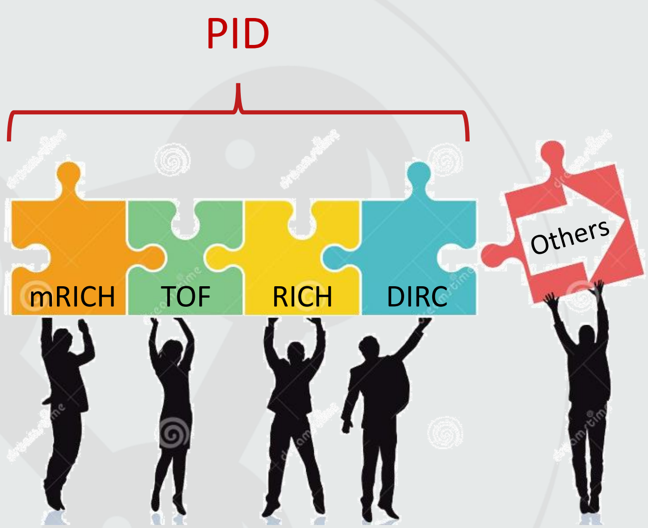
PID Deliverables to Pavia:

- Requirements on “external” systems
- Pro/Con matrix (e-Arm, Barrel, h-Arm)
- Physics requirements.

Physics | Community

Detectors | Machine

:



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JSA

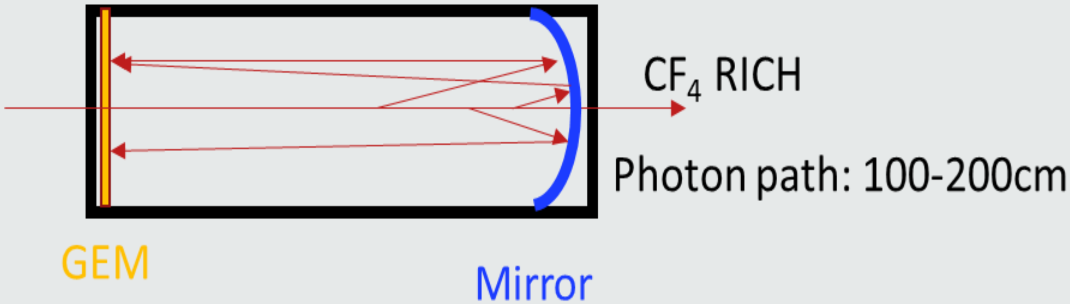
Were we are: Summary Table

	p-Range @ Radiator L	Contr. ϑ_c	Param.	Pro/Con	Ext Const	MONTECARLO Simulatoin
psec TOF LGAD TOF	Up to 10 Depends on σ_T and L	NO	~YES	YES	~ YES	NO
dual RICH (aerogel, gas)	2-60 @ 1.6 m	YES • Chroma • Emission • Pixel • Field • Tracking	YES	YES	YES • Simulated constant w/ momentum	YES • GEMC/Geant4 • AI-driven Optimization
GEM RICH (Gas Electron Multipliers)	20-50 @1m	• Chroma • (Emission) • Pixel • Tracking	YES	YES	YES	YES (Simplified)
modular RICH (mRICH)	2-10 @ 3 cm	YES • Chroma • Emission • Pixel • Tracking	~YES	YES	YES (tracking)	~YES • GEMC/Geant4 work in progress
Detection of Internally Reflected Cherenkov (DIRC)	0.8-6 @ 1.7 cm	YES • Tracking • Mult. Scat • Chroma, Emission, pixel	YES	YES	YES	YES • GEMC/Geant4 without B-field

High Momentum GEM RICH

H. Klest

- 1m of CF_4 radiator at 1.003 bar (slightly overpressure)
- CsI Photocathode on top GEM
- Mirror in deep UV → MgF_2 coating
- Single Photon Capability → quintuple GEM stack with APV25-SRS
- Particles ~perpendicularly incident on spherical mirror, focused onto a GEM stack directly

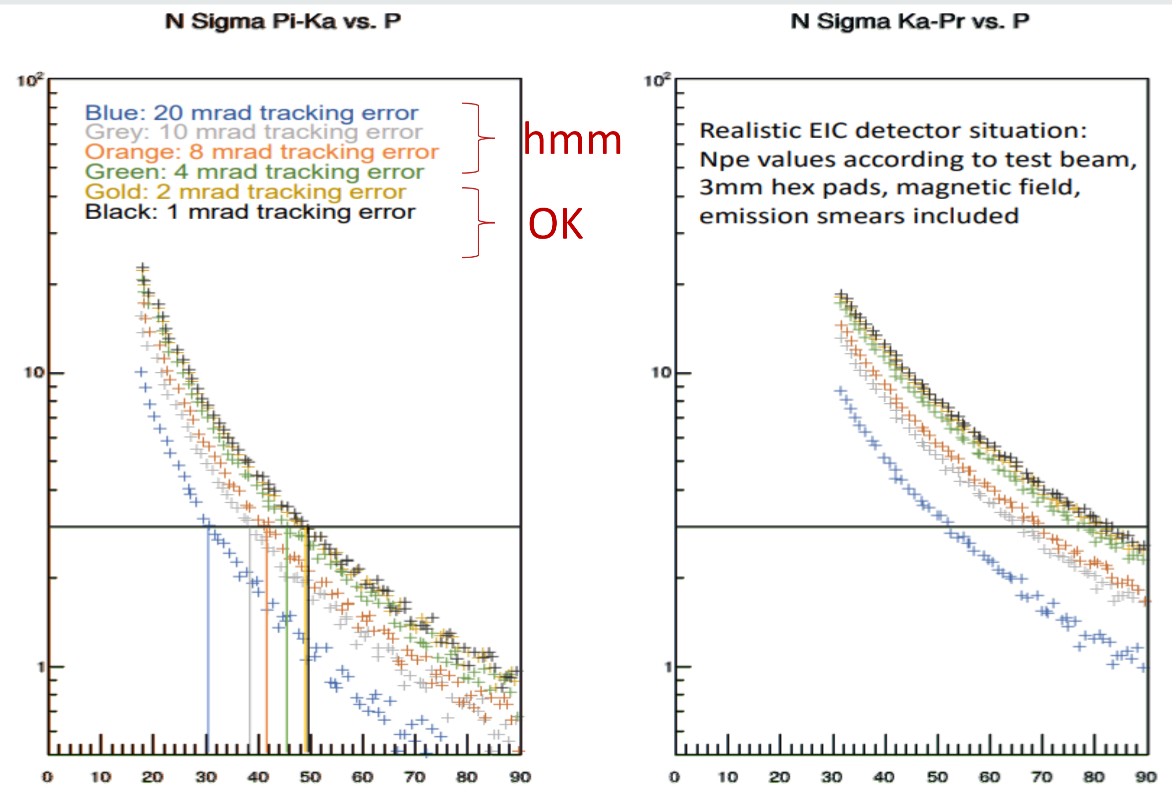


- **Pro**
  - Sensor insensitive to B-field
  - Short (12pe/m windowsless)
  - Thin photo-cathode leads to more ideal optics.

- **Con**
  - Unknown how to bridge the gap in π-K
    - High pressure??
    - Different gas??
  - Loses light with contaminants @ few ppm level (round trip; tougher than PHENIX HBD…)
    - Requires superb gas system (OK)
    - Requires better detector materials
  - Photo-cathode in high radiation zone.

High Momentum GEM RICH

H. Klest



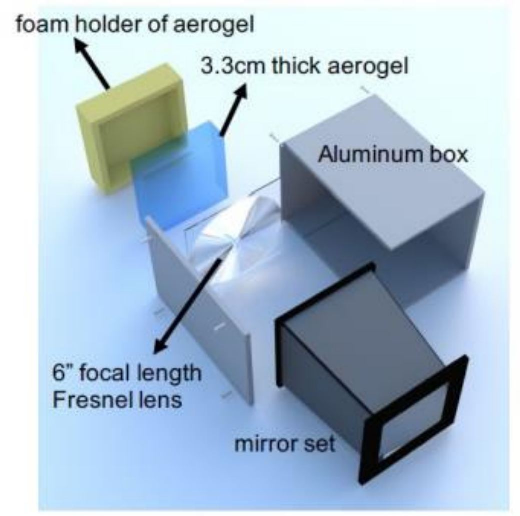
- Tracking is leading error contribution if worse than ~7mrad.
- Negligible resolution factor around 2 mrad.
- Between 2 and 7mrad , more detailed investigation is required.

- Plot shows viscerally the effect.

- More detailed simulation required.

mRICH

X. He
M. Sarsour

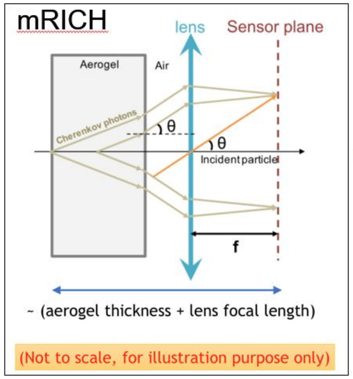


Cherenkov radiator
- Aerogel, n = 1.03
- Radiator length, L = 3cm
- Lens with focal length, f = 6"

Photon Detector
- 3 mm pixel size

Pros	Cons
Sweet momentum coverage for K/pi separation from 3 GeV to close to 10 GeV. It also provides the capability of e/pi separation around 2 GeV.	Photon sensors and readout electronics see direct hits of particles. Radiation hardness concerns.
Modular design for array installation. Each module is independent with other modules and can be calibrated separately. Projective capability.	Acquire aerogel tiles and maintain their long-term stability (optical)
Performed two beam tests. The working principles have been validated in the first beam test in 2016 and the results have been published in NIM A. Further beam tests with tracking capabilities are expected and under planning.	Need high density photon sensors working in magnetic field.
Full GEANT4 simulation has been developed and verified using the beam test data.	Could create extra dead areas between modules. [Could be minimized by projective and creative integration schemes]
An array of mRICH modules have been implemented in the sPHENIX for EIC simulations.	

Provide a time meas. with proper sensor? Utility of the device is expanded if it provides picosec TOF & Cherenkov



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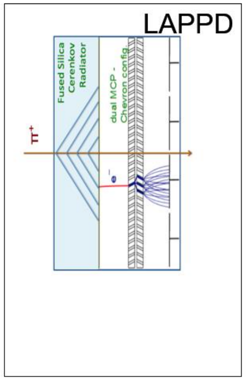
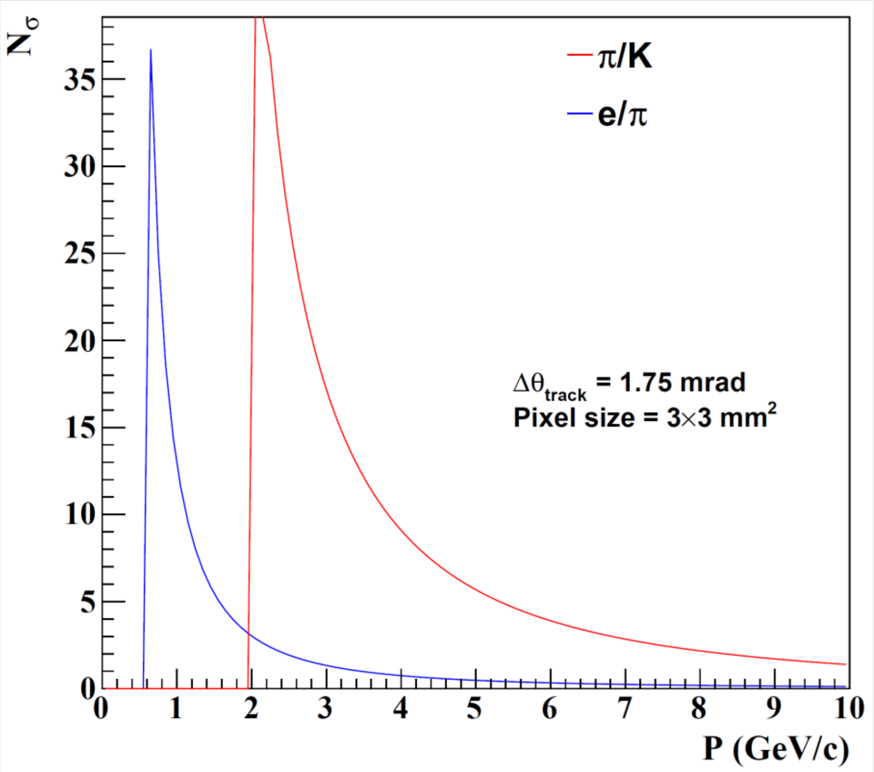


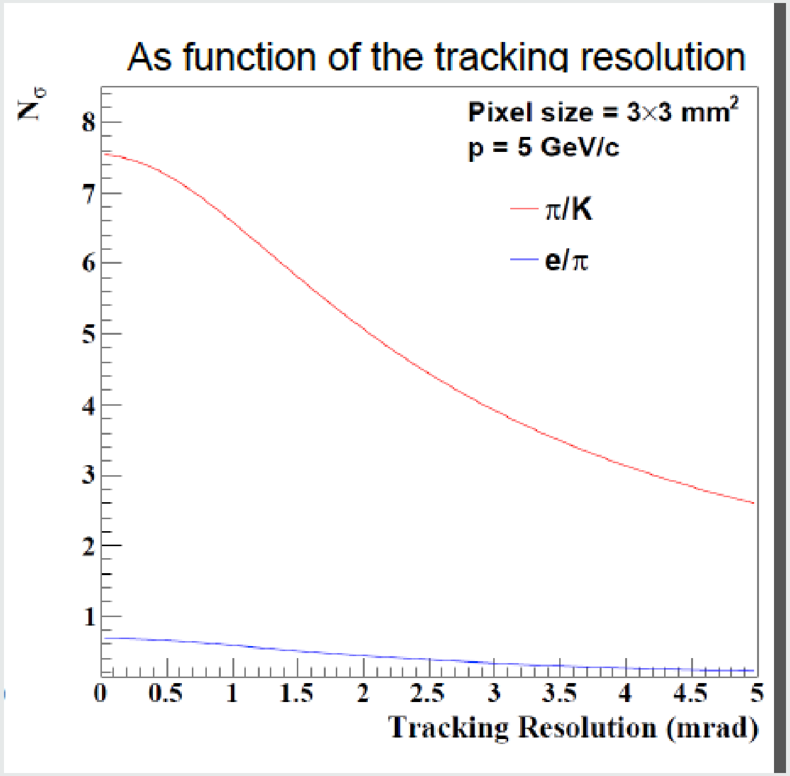
- More quantitative estimate of dead area (foam holder/box/Fresnel corners)
- Sensor issue is general, independent of radiator and optics.

X. He
M. Sarsour

mRICH



e/π excellent at lowest p

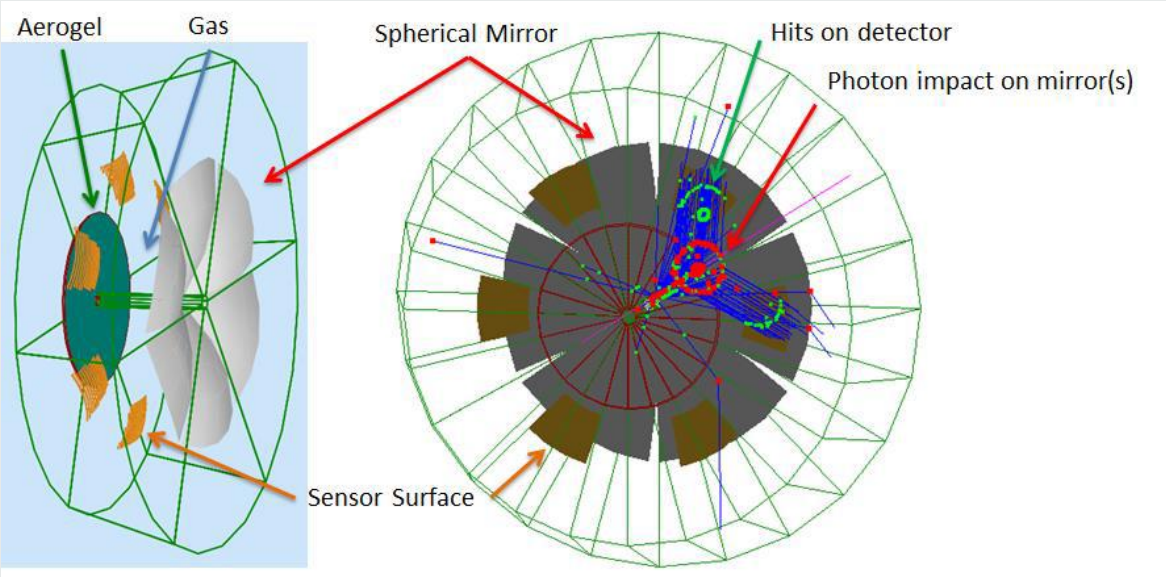


Tracking influence minor

Tracking influence major

dRICH

E. Cisbani
M. Contalbrigo



- Cherenkov radiator
  - Refractive Index
  n = 1.02 (aerogel)   1.0008 (C_2F_6)
  - length of the radiator
  L = 4 cm (aerogel) , 160 cm (C_2F_6)
- Mirrors
- Photon Detector
  3 mm pixel size; 200-500 nm MAPMT
- Particle Generation
  Originate from the vertex

- **Pro**

1. **>3σ π-K separation in 3 – 50 GeV** whole range in RICH mode (Montecarlo simulation) – as well as large coverage for K-p (and electron) PID
2. **Photon detector out of acceptance** and far from the beam pipe in moderate magnetic field (≤ 1/2 of central zone): less constraints on material budget (e.g. mechanical supports, shielding, cooling); neutron flux is also reduced
3. Expected to be **cheaper and more compact** (also in terms of services) than 2 (or more) detectors solution (sparing on photon detector and related electronics)
4. **Material budget** likely smaller than 2 detector solutions: from CLAS12/RICH-LTCC: X_0≈1% vessel (no pressurization) + 1% mirror + aerogel, acrylic filter and gas
5. Two dual radiator RICHes already operated (**lesson learned**)
6. Rather **advanced software available**: detailed Montecarlo, parameterization, full PID reconstruction, automated optimization procedure

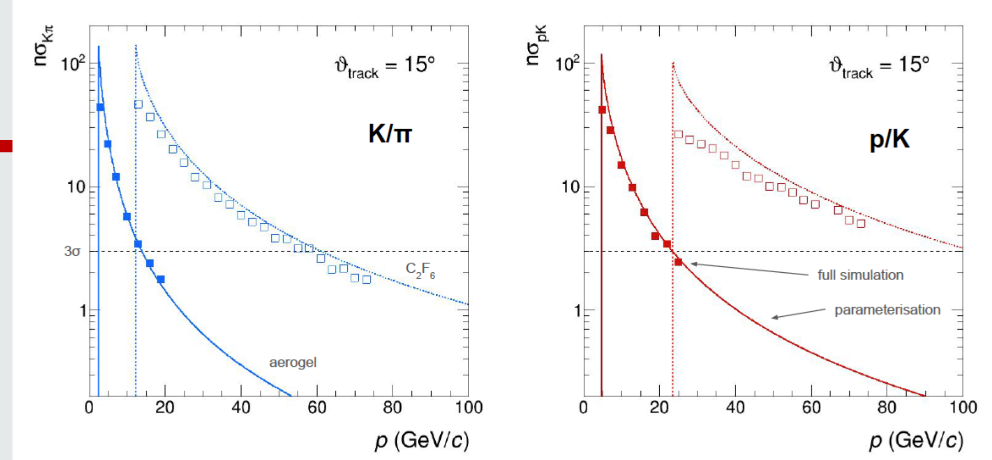
- **Con**

1. **More demanding PID** respect to single radiator RICH
2. **LHCb dual radiator RICH1 issues**: underestimation of aerogel stability in contact with freon gas?
   large multiplicity and relative large background ?
3. **Aerogel chromatic** performances are critical and need to be well investigated in terms of stability and interference with other gases
4. **R&D on photo sensors** needed (common to other detectors)
5. **Gas Procurement** potential issue due to possible ecological restrictions and costs (common to other detectors)

dRICH

E. Cisbani
M. Contalbrigo

- Exquisite detail in simulation.
- AI-based optimization.
- Good parametrization
- Uses constant external angular resolution assumption.

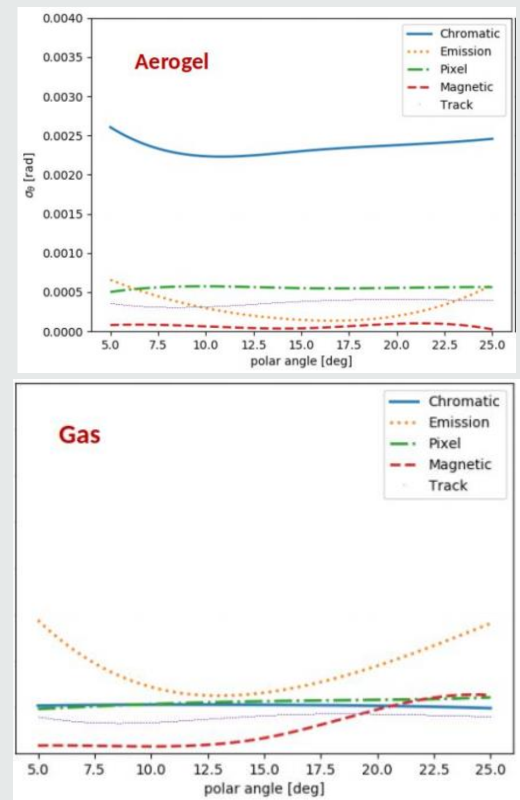


K/π and p/K separation as a function of momentum

External assumption

Tracking	
Angular resolution	σ = 0.5 mrad (1 mm over 2 m) – whole momentum range
Impact point resolution	σ = 0.3 mm
Momentum resolution dP/P	+/- few percent negligible effects in Cherenkov angle reconstruction
Magnetic Field	3 Tesla Central Field in JL-MEIC spectrometer
Space Requirement	(based on original spectrometer constraints)
longitudinal length	JLEIC: ≈1.6 m, ePHENIX: ≈1.0 m
transverse radius	JLEIC: ≈2.5 m, ePHENIX: ≈2 m
beam pipe radius	<10 cm
Background	no direct external background only backrground produced by the simulated charged particle: Delta rays, Rayleigh scattering …

ϑ_c contributions



- Material budget evaluation
- Sensors in the acceptance

Lab

DIRC

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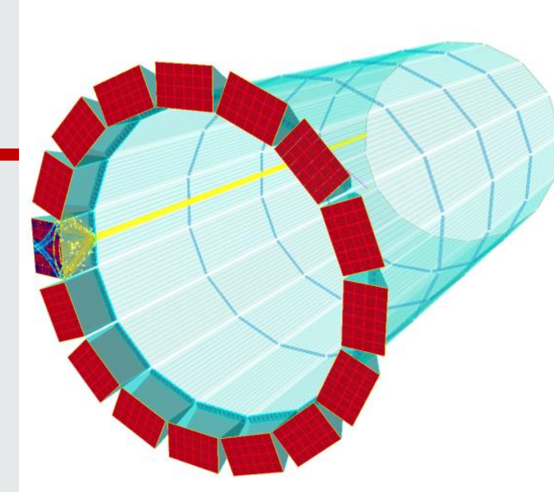
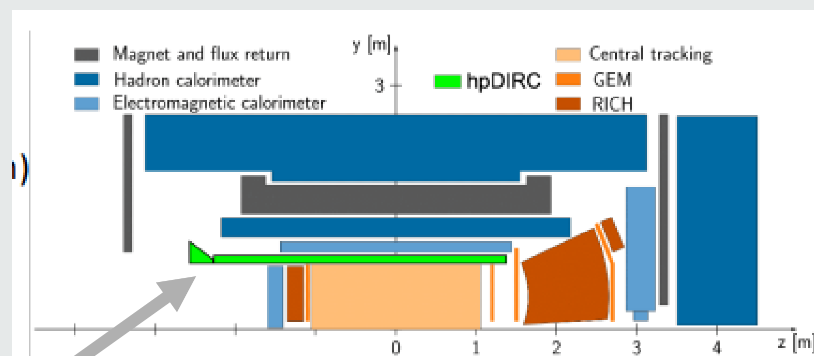
J. Schwiening



Generic reference design: 1m barrel radius, 16 sectors
176 bars: synthetic fused silica,17mm (T) ´ 32mm (W) ´ 4200mm (L)
Photo sensors: MCP-PMTs -3x3mm2 pixels

- Pros:
  - **Radially compact** (impact on cost of post-DIRC systems)
  - **Flexible design** (to deal with sensor in B-field and detector integration)
  - **Low demand on detector infrastructure** (no cryogenic cooling, no flammable gases)
  - **Excellent performance over wide angular range**
    (≥ 3 s.d. π/K up to 6 GeV/c, low momentum e/π (3 s.d. at 1GeV/c)
  - **Supplemental time-of-flight measurement**
  - **R&D at advanced stage** (PID performance estimate based on test beam results, excellent agreement between simulation and prototype data)



- Cons:
  - Potential challenge of integrating expansion volume, in particular for BaBar DIRC design (focusing block and sensors outside flux return?)
  - No currently proven sensor solution for 3 T magnetic field option

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DIRC

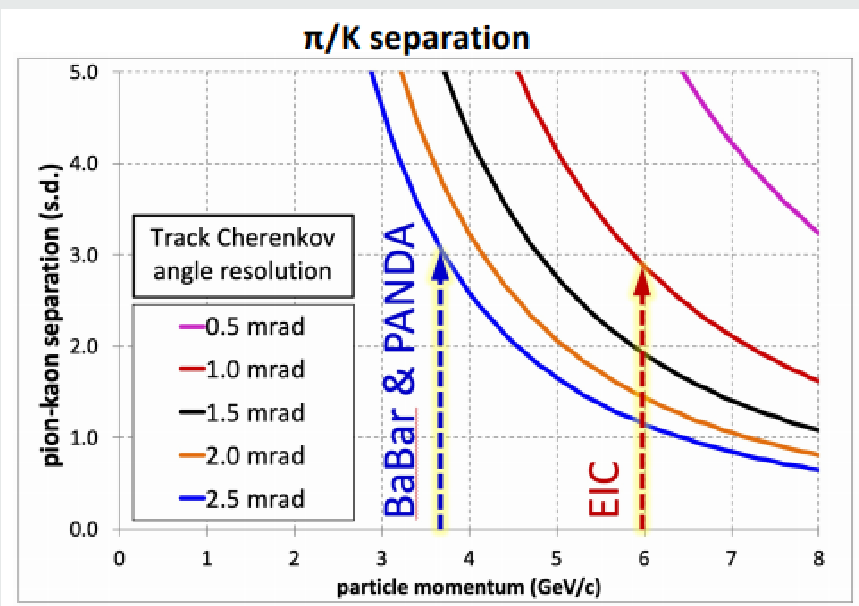
G. Kalicy
J. Schwiening

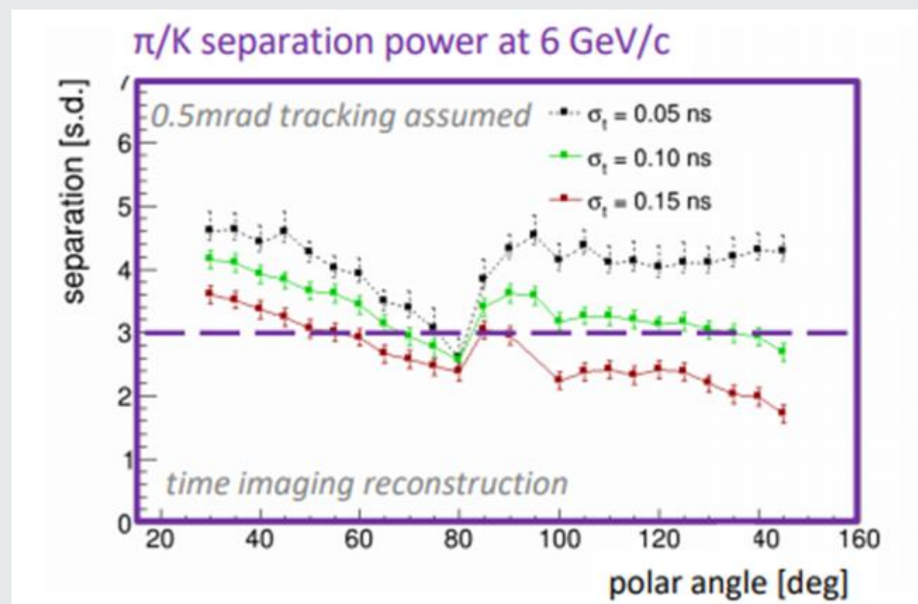
External assumption

NOTE:

- DIRC optics design-level adaptable to magnetic field orientation at the sensors.
- Need ~settled field direction prior to construction.
- Performance ~independent of device radius.

Tracking	
Angular resolution (at DIRC radius)	σ = 0.5 mrad at high momentum (see next slide for momentum-dependence)
Position resolution (at DIRC radius)	Few mm
Momentum resolution (at DIRC radius)	Not very sensitive, post-DIRC track point(s) beneficial (non-Gaussian tails)
Magnetic Field	No specific B-field value assumed in simulation/reconstruction Favor 1.5 T solenoid field to match currently available MCP-PMTs
Space Requirement	*(Note: generic simulation, not matched to any particular detector yet)*
Radius	100 cm (hpDIRC, standalone Geant4 simulation) 83.65 cm (BaBar DIRC bar box reuse)
Radial thickness (in active region)	7-8 cm including mechanical support
Total length (bars plus expansion volume)	330-450 cm (hpDIRC, depending on detector framework) 530 cm (BaBar DIRC bar box reuse)
Material budget (in active region)	~16-18% of a radiation length at normal incidence
Expansion volume size	24 x 36 x 30 cm³ (H x W x L) fused silica prism (hpDIRC) 56 x 42 x 22 cm³ (H x W x L) fused silica block (FDIRC, to be optimized)





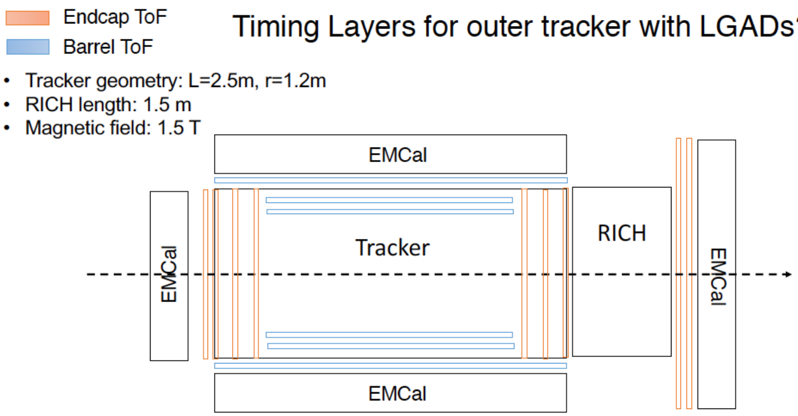
psTOF

M. Chiu
W. Li

- **Multiple technologies (two examples):**
  - **LAPPD:**
    best σ_t B-field ~⊥, moderate pixel size
  - **LGAD:**
    excellent σ_t field tolerant, tiny pixels

Timing Layers for outer tracker with LGADs?

- Tracker geometry: L=2.5m, r=1.2m
- RICH length: 1.5 m
- Magnetic field: 1.5 T



Add timing layers as outer tracker
- at L=+/-1.5, 2.0, 2.5m
- at r=+/-0.8,1.0m

- Pros:
  - Generally Highly compact: 2-10 cm/layer, no expansion volume
  - Generally Rad-Hard: No expected performance loss over EIC lifetime
  - Some technologies are Magnetic Field Tolerant
  - Generally can handle High Hit Rates: >1kHz/cm^2
  - Often cost effective
  - Relatively Simple Calibration: crucial for prompt reconstruction
    - No need for reconstructing rings, just need to get the time right
  - Possibly can be a tracker
  - Might be essential for determining where collding e and ion came from in bunch profile
    - Reduce large(?) systematic due to p_T kick given to bunches in crab cavity
  - In combination with dE/dx (eg from TPC), can contribute to e-ID out to moderate p
  - Leverages Extensive R&D for 20-30 ps TOF @ HL-LHC
    - ASICs are under development and soon (1-3 yrs) to be available
    - Clock propagation and system issues in heavy development

- Cons:
  - System issues (scaling and clock propagation) need a little more R&D
  - Some technologies not Magnetic Field Tolerant enough in certain locations
  - In certain locations, momentum reach may not be quite adequate

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psTOF

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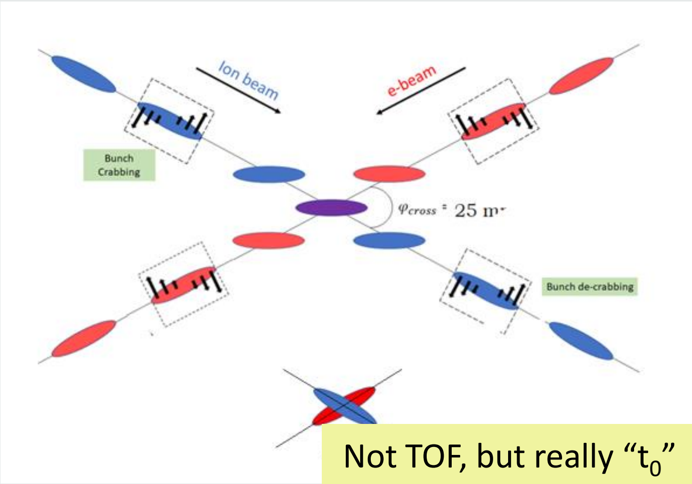
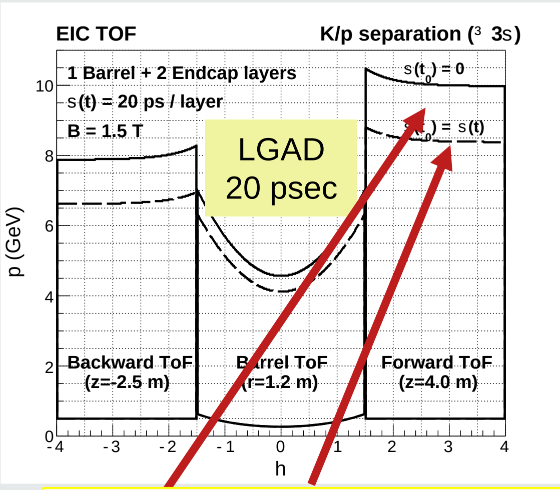
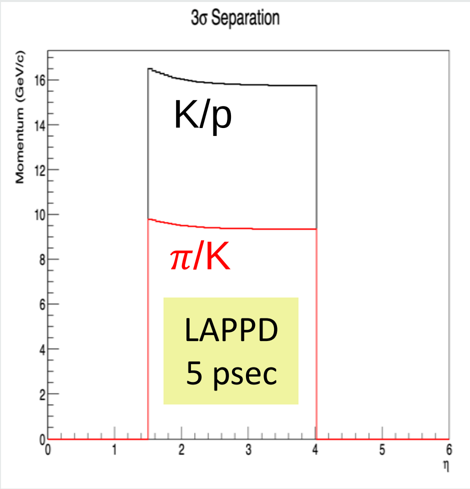


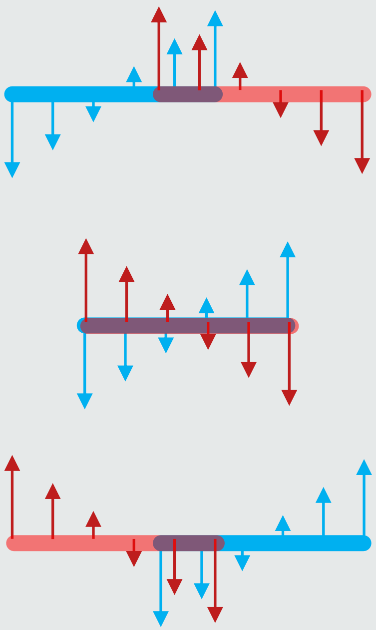
Not TOF, but really "t_0"



LGAD 20 psec



LAPPD 5 psec



$early\ p_T(Z)$

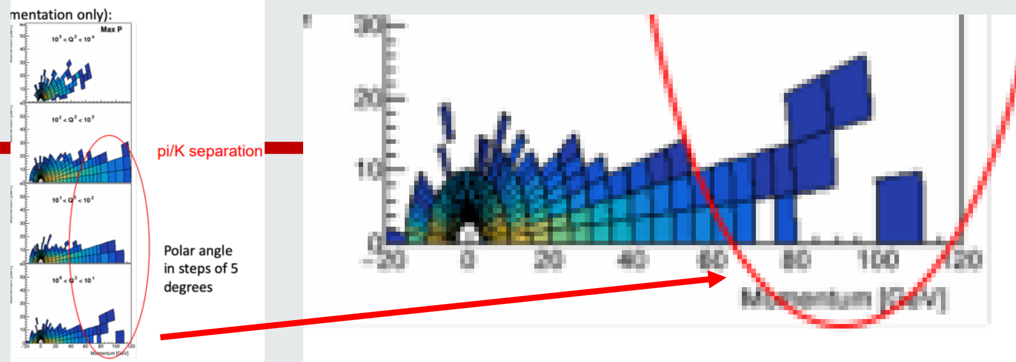
$late\ p_T(Z)$

- Assumes 4m flight path (conflict?)
- Time resolution very challenging
- Multiple scattering may contribute path length uncertainty (coupling to tracking).
- External start time provided by forward detectors could be helpful
- Study of self-timing (Internal) using tracks

Measure (Z,t_0); Learn Collision p_T

- Crab limit vs emittance limit?
- Physics p_T resolution required?
- Polarization variation within bunch?
- Needs additional study

Conclusions



- PID is challenging!

- Tracking requirement for Cherenkov
  - Parameterizations of gas Cherenkov indicate pointing required at 0.5-1.0 mrad level while inside the radiator.
  - Calculations of aerogel devices indicate 0.5 -1.0 mrad level.
  - Calculations of DIRC indicate 0.5 mrad level or better.

- Good progress but still some open questions:
  - Simulations are still preliminary except for a few detectors
  - Sensors and electronics in the detector require an evaluation of radiation hardness.

:

  - R&D on photon sensors is on going (magnetic field tolerance a primary concern: Visible light sensor solution for 3T magnetic field problematic.)
  - No discussion on the material budget
  - Available space is a driving concern for some technologies.
    - Shifting vertex is expensive, but helps most technologies in hadron arm.
    - Need quantitative optimization of cost/benefit
  - Resolution for TOF includes multiple terms in addition to superb σ_t
    - Clock reference/distribution
    - Path length.