GD/I's Assessment of the Backward ToF

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- Join next meeting: Oct 31 9AM ET on sim + tracking reco. [https://indico.bnl.gov/event/17568/]
- Sign up email list: [eic-projdet-globalint-l]
- Wiki landing page: [EPIC/DetectorIntegration]

In Response to the Oct-12 SC Charge on Backward TOF

1. In your professional opinion, are the challenges of incorporating an AC-LGAD TOF layer in the backward end cap severe enough to justify replacing it with an alternative solution? Alternatively, should the collaboration invest more resources trying to find a way to make it fit without damaging the performance of other detectors, such as the backward EMCal?

2. Do you see any fundamental issues in using the RICH photo-sensors and interaction vertex measurements for TOF and/or t0 measurements? We realize the complete assessment of these solutions requires a serious study that was not done yet. Therefore, one cannot quantify the degree (e.g. coverage and resolution) to which these solutions can work. Instead we are asking for your technical assessment based on the information available at present to understand if you see anything we might have missed in discussing these solutions so far (and before we charge the relevant working groups with performing a detailed study).

Following your advice the SC will also consult with the project and convey a decision on this matter to the TOF-PID working group and the entire collaboration.

GDI approach

- A series of GDI meetings has been organized around the physics case of TOF and technical implementation to meet these requirement in EPIC. Thanks to all the WG presentations and responses to the GDI calls!
  - June 6: Integrated tracker-TOF core [link]
  - July 7: RICH in threshold modes [link]
  - Aug 29: Tracking (silicon) [link]
  - Aug 22 & Sept 19: physics WG feedback on low pT requirements[link1, link2]
  - Oct 3: backward RICH [link]
  - Oct 20: T0 determination [link]
  - Nov 7: AC-LGAD (scheduled) [link]
  - Oct sim campaign focus discussions:
    - Sept 26: 1st Discussion [link], Oct 13: update [link],
    - Oct 31: sim+tracking (scheduled) [link]
- They form the basis for our opinion in this matter (next slides)
- Besides our opinion, we hope the collaboration could use this opportunity to weigh into this crucial decision and reach a consensus

GDI Assessment

- The physics WGs have identified that the sole purpose of the backward TOF is to provide *t0* tagging that matches the precision needed for the TOF measurement in the barrel and forward directions.
- No compelling physics requirements have been identified that would motivate low-p hadron PID in the backward region.
- Reference to GDI meetings:
  - June 6: Integrated tracker-TOF core [link]
  - Aug 22 & Sept 19: physics WG feedback on low pT requirements[link1, link2]
  - Oct 20: *t0* determination [link]

GDI Assessment (continue)

- In recent meetings, multiple challenges related to AC-LGAD as the backward TOF have been identified:
  - Space available for the MAPS-tracking volume
  - Power dissipation that can compromise the performance of the crystal ECAL
  - The amount of material in front of ECAL.
- Although we encourage design and engineering studies to resolve these concerns, we recommend not to include the backward AC-LGAD TOF as the baseline choice for the backward TOF (but as a risk contingency option detailed next slides).
- Reference to GDI meetings:
  - Sept 26: 1st Discussion [link]
  - Oct 3: backward RICH [link]

GDI Assessment (continue)

- We believe a fast RICH photo-sensor, specifically the LAPPD, provides a better-integrated detector solution for the backward *t0* measurement.
- We have strong indication that this measurement can be realized and augmented using 3D_Vertex-time correlation
  - We do have the concern, if vertex method used alone, may induce TOF PID uncertainties that stem from the non-Gaussian component of the beam bunch and beam conditions
- Reference to GDI meetings:
  - Oct 3: backward RICH [link]
  - Oct 20: T0 determination [link]

GDI Assessment (last page)

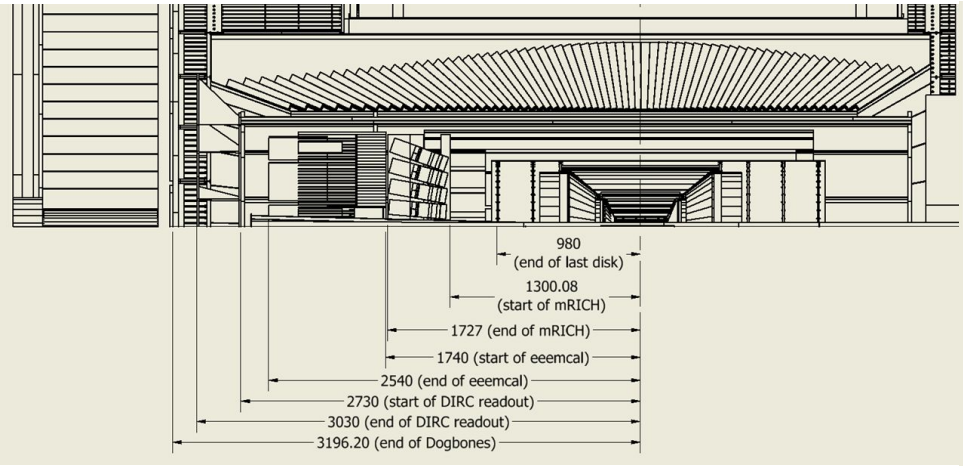
- We recognize that not all information necessary for the backward TOF down selection is available at this time:
  - There are still risks in performance, endurance, B-field resistance, and production schedule for a potential large-scale LAPPD deployment in EPIC;
  - The holistic approach of extracting *t*0 information from vertex reconstruction with RICH+TOF inputs needs to be revisited with EPIC sim + full event *t0* reconstruction.
- Reference to GDI meetings:
  - Oct 3: backward RICH [link]
  - Oct 20: T0 determination [link]

Given the fast approaching CD-2 review and ref design deadline, we recommend the adoption of the fast RICH photo sensors as the reference design configuration, with a risk mitigation option of AC-LGAD TOF layer plus a down selection milestone at a predetermined date after CD-2/3A.

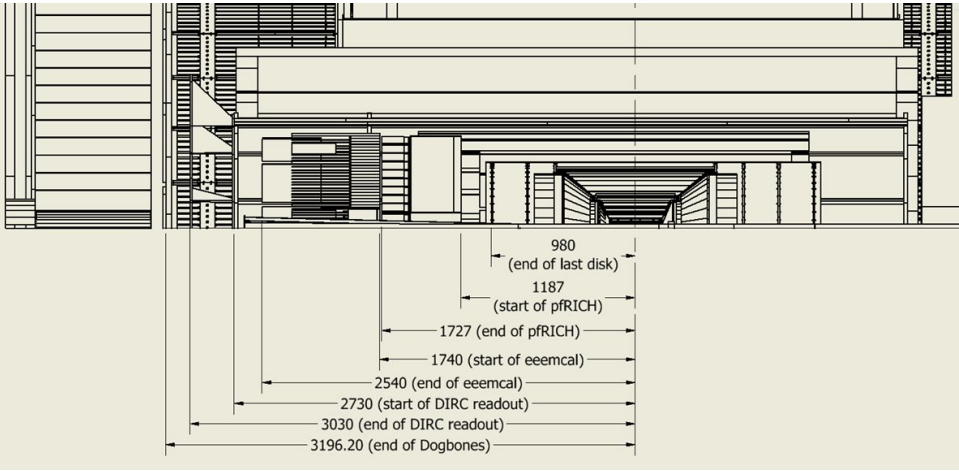
Extra information

Envelope from the project team [link]

Configuration A



Configuration B

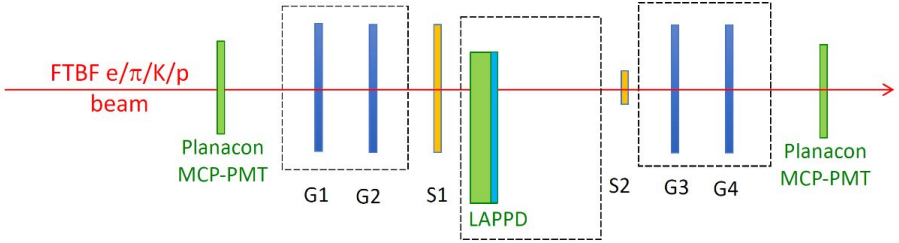


Status of LAPPD technology: Dr Alexander Kiselev (BNL)

Timing resolution for Time-of-Flight purposes

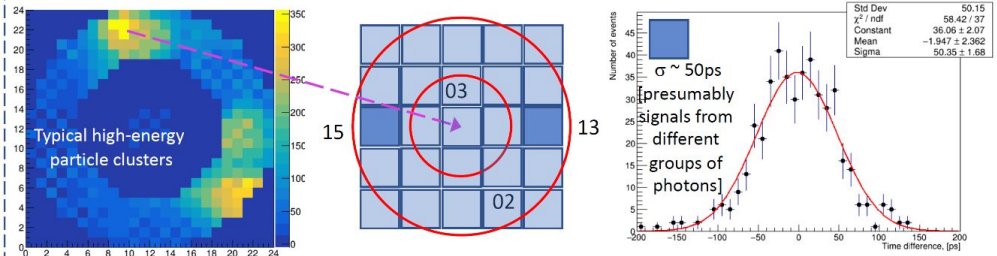
- G1 .. G4 – COMPASS GEM reference tracker
- S1 .. S2 – trigger scintillator counters

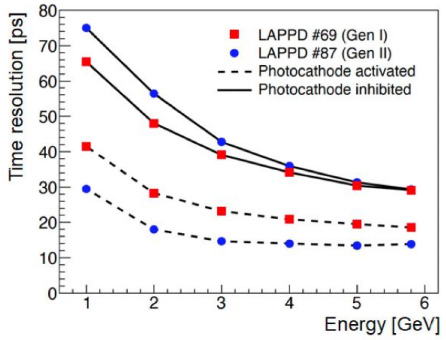
Our June 2022 FTBF data

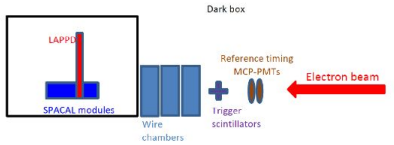


LAPPD quartz window as a Cherenkov radiator

- *Single* photon TTS ~50 ps
- UV grade quartz window: a 120 GeV proton produces a **blob of ~100 p.e.'s**





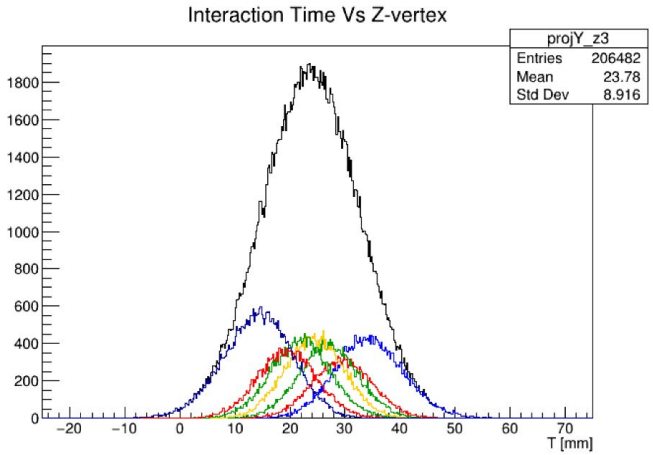


LHCb spacal tests at DESY

- Expect resolution σ < 15-20 ps in the mRICH / pfRICH configuration

t_0 determination: Brian Page

Adding X-Vertex Information: 18x275

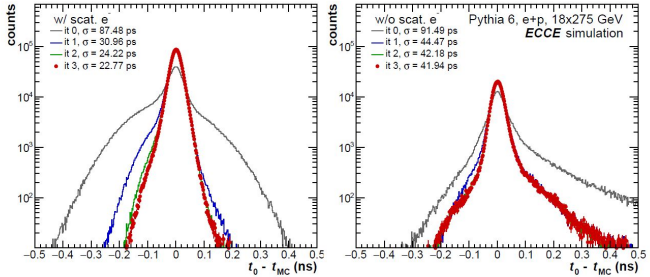


X Bin	Mean [mm]	Sigma [mm]
0	34.6	6.14
1	29.5	5.4
2	27.0	5.36
3	24.5	5.39
4	22.0	5.44
5	19.5	5.38
6	14.1	6.24

- Choose the Z-vertex bin at -25 mm and look at T0 distributions for various X-vertex bins
- X and Z binned T0 distributions have much better resolution than Z binned alone (~18 vs ~30 ps)
- Basically, X-Vertex position is telling where within the electron bunch the colliding particle comes

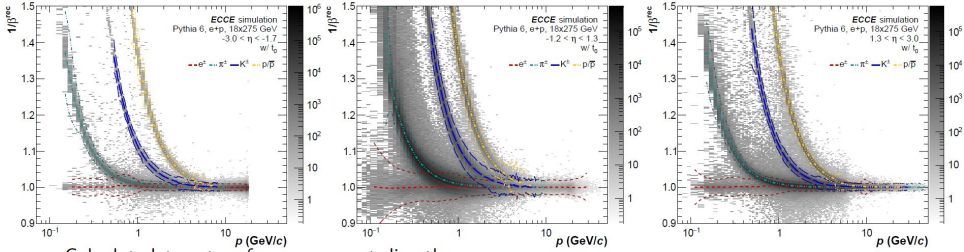
t_0 determination: Friederike Bock (ORNL)

Iterative Improvements to t_0



- Common procedure after intial t_0 determination
- For all particles the velocity estimate is based on $t_{part,rec} - t_{0,it-1}$
- In iterations $1/\beta$ is calculated and compared to expectation value for π,K,p and e
  → assumed to be corresponding particle if within 1% of expectation value & $p < 6$ GeV/c
  → $p > 15$ GeV/c pion mass assumed, except for scattered electron candidates
- Latest after 4 iterations no significant change observed any more

PID performance of TTL



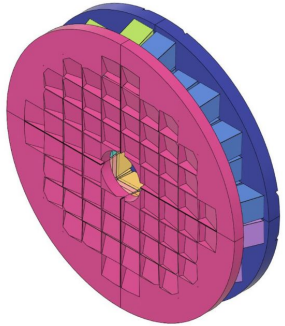
- Calculated t_0 enters for every event directly
- Optimized η coverage in particular towards electron end cap would improve scattered electron finding
  → PID discrimination in barrel & forward direction

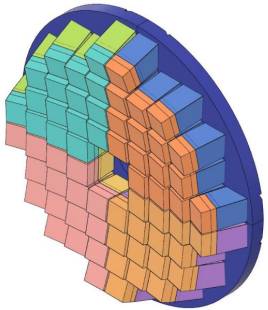
mRICH : Murad Sarsour (Georgia State University)

mRICH Support Frame & New Prototype Design

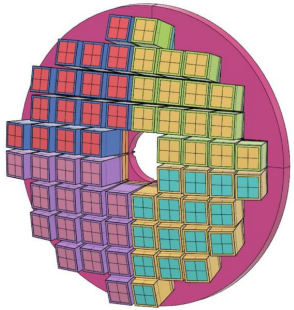
JLab engineer:
Alex Eslinger

- mRICH Support Structure





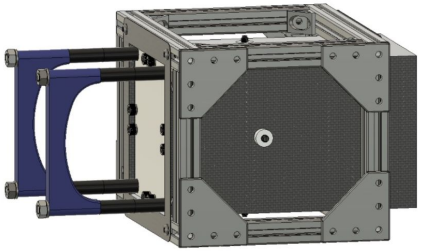
Front



Back

- New mRICH Prototype Design

  Optimizing the sensor location and Aerogel thickness



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low pT impact on HF reconstruction : Wenqing Fan

Physics impact

- Negligible impact on D^0 meson
  - Charm F_2, gluon helicity, gluon TMD measurements via D^0 will not be affected
- Larger impact on Λ_c baryon
  - Charm hadron double ratio R_{eA}: negligible impact on D^0 meson, about a factor of 2 stat. err. increase for Λ_c
  - Λ_c/D^0 ratio to study hadron chemistry: increasing impact at low p_T range and forward rapidity

Figure from ATHENA proposal (credit: Yuanjing Ji)

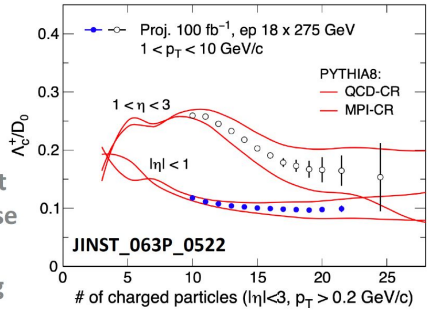
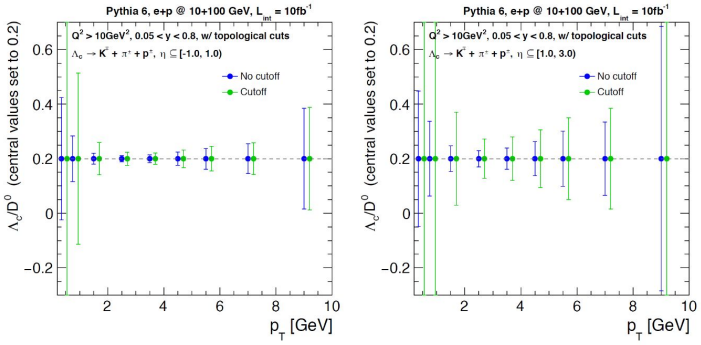
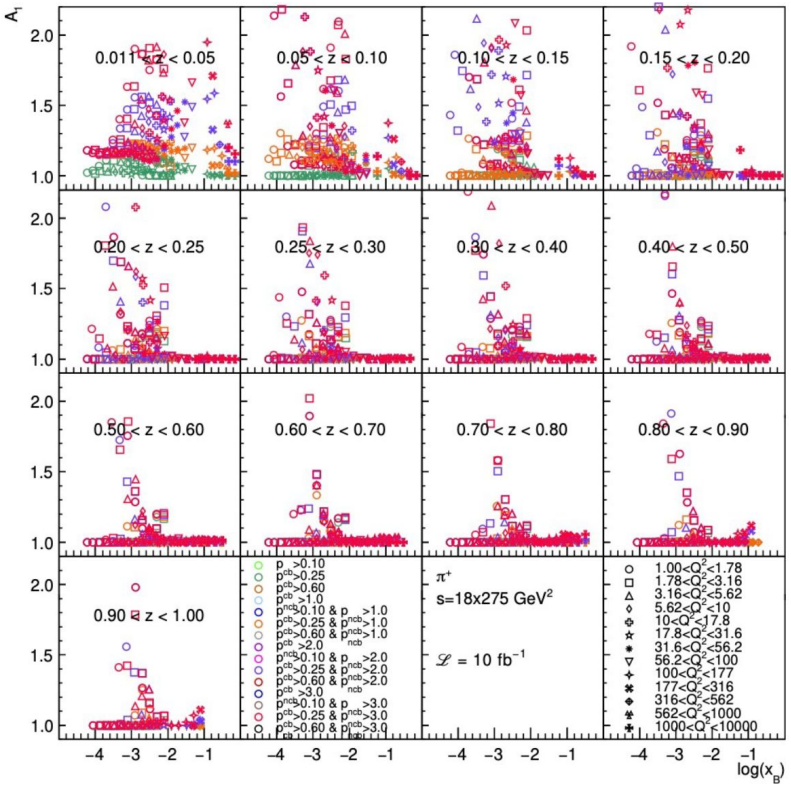


Figure 3.28: Projections for ATHENA measurements of the heavy-quark Λ_c^+ to D^0 baryon-to-meson ratio as a function of the charged track multiplicity (FastSim).



SIDIS WG studies : Anselm Vossen

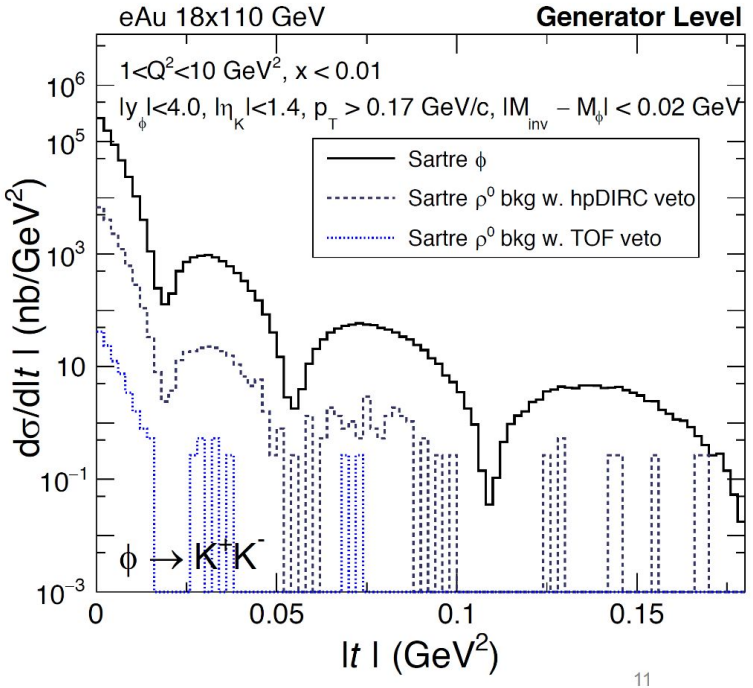
- Impact of forward PID



Low-pt PID for the VM program in eA : Zhoudunming Tu

What's the impact on -*t*

- PID detectors have significant improvement on suppressing background from ρ^0
- hpDIRC seems to be sufficient, because incoherent ϕ background will dominate, except for –t < 0.02. (Go to backup to see why)
- Of course, TOF will kill this problem entirely; bottle neck then will be the first 2 challenges on page 2.



Detector configuration / subsys level overview

detector region	option A	option B	notes
all	"standard" Si tracker system (layers: 5 in barrel; 5 disks in FW; 5 disks in BW)		if possible, converge towards 1 single configuration with 1 single envelop
barrel	2 MPGD layers (1 behind DIRC; First layer at 55 cm)	1 MPGD layer (in front of the DIRC)	option B more consistent with imaging Ecal
barrel	ToF layer (1 % X0; strips)		X0 correlated to resolution
barrel	"standard" DIRC		
barrel	**SciGlass Ecal**	**imaging Ecal (same inner radius, 21 X0)**	thicker imaging Ecal if supported by preliminary studies
barrel	(Reused sPHENIX) HCAL outside		implementation in progress

Detector configuration / subsys level overview

detector region	option A	option B	notes
FW	no MPGD behind the RICH		
FW	"standard" dRICH		not realistic to elaborate two different optics by mid October
BW	**mRICH**	**pfRICH**	pfRICH shorter than in ATHENA: 45-55 cm in total
FW/BW	standard Ecal and Hcal	standard & insert in the FW Ecal/HCal	status of implementation in global simulation: advanced; about insert, to be used in October simulation if a preliminary mechanical support will be designed
BW	Tof Not installed		BW ToF layer simulated if integration in the the detector layout possible (second priority). Expect standalone sim.
FW	ToF layer (15 cm; 8% X0; pixelated 0.5*0.5 mm^2)		X0 correlated to resolution
FFW/FBW	"standard"		implementation advanced; some open points in B0; ZDC is the "Simplified" version currently in DD4HEP;