A compact dual radiator RICH for the EIC experiments

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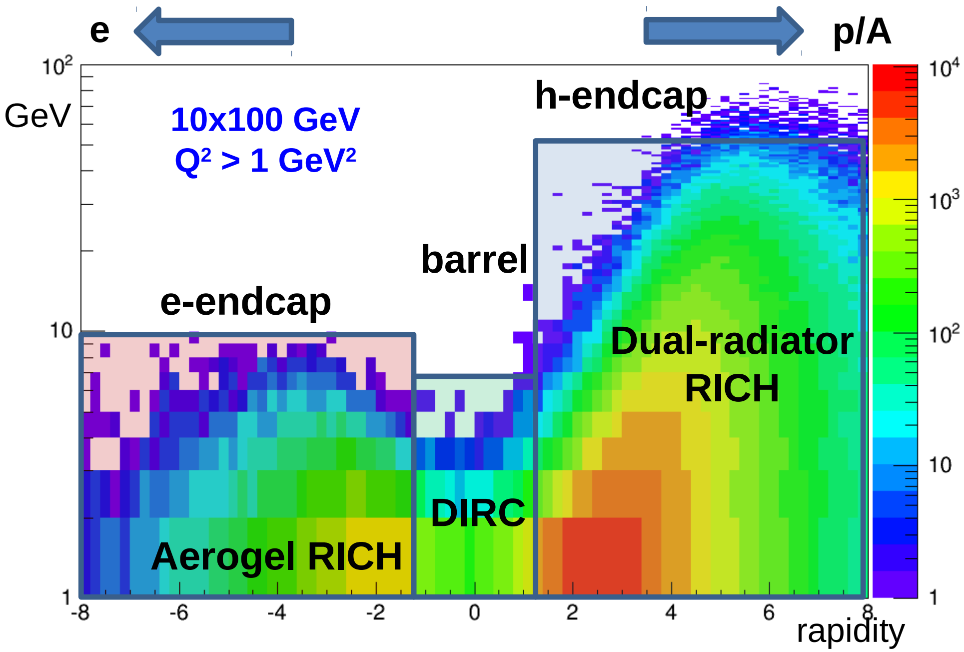
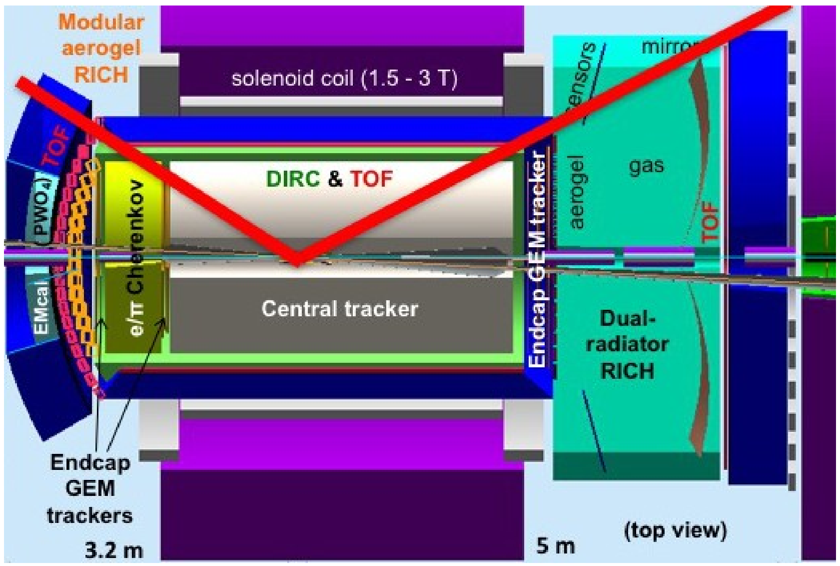
Outline

- Motivations, why a dual radiator RICH (dRICH)
- Simualtion studies
- Ongoing activities and perspectives

A PID solution for EIC (EIC-PID consortium-eRD14)





JLab EIC concept

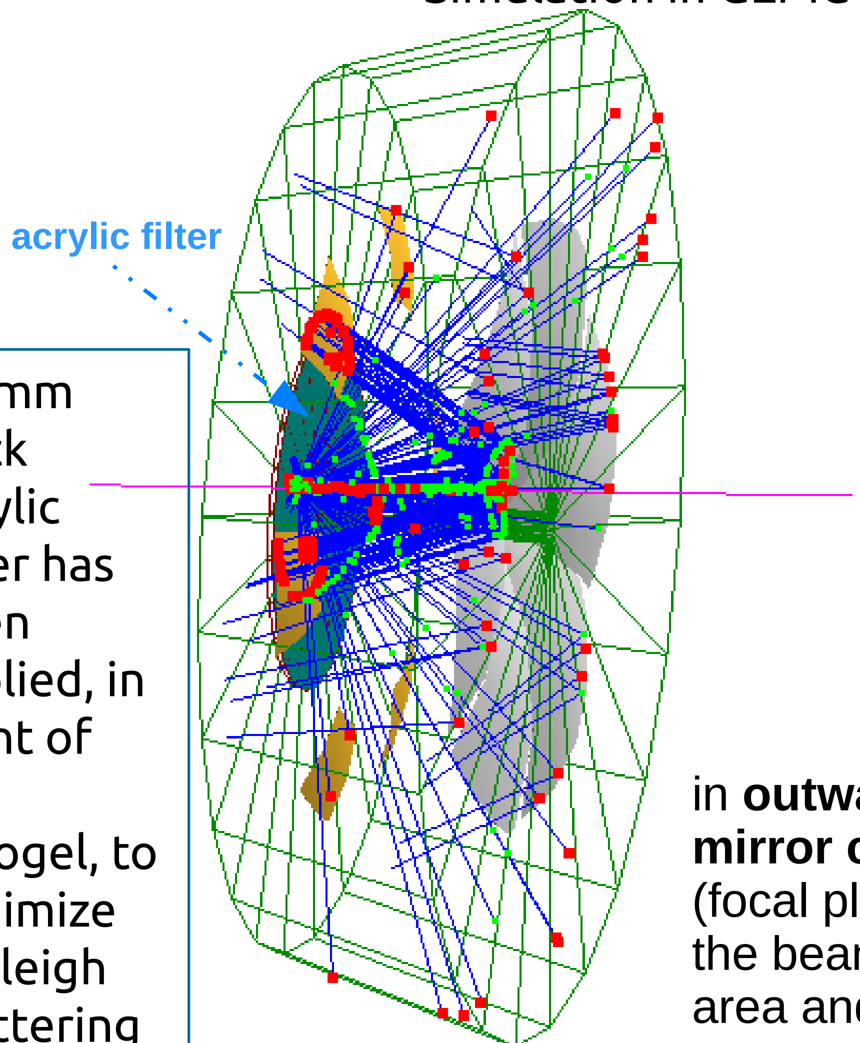
- **h-endcap**: <u>A dual-radiator RICH is needed to cover **continuously** momenta up to 50 GeV/c</u>
- **e-endcap**: A small lens focused aerogel RICH for momenta up to 10 GeV/c
- **Barrel**: A DIRC provide a compact and cost effective way to cover momenta up to 6 GeV/c
- **TOF** (and or dE/dx in the TPC) can cover the low momenta region

As a consortium we are maximizing the interaction in the R&D of the detectors!

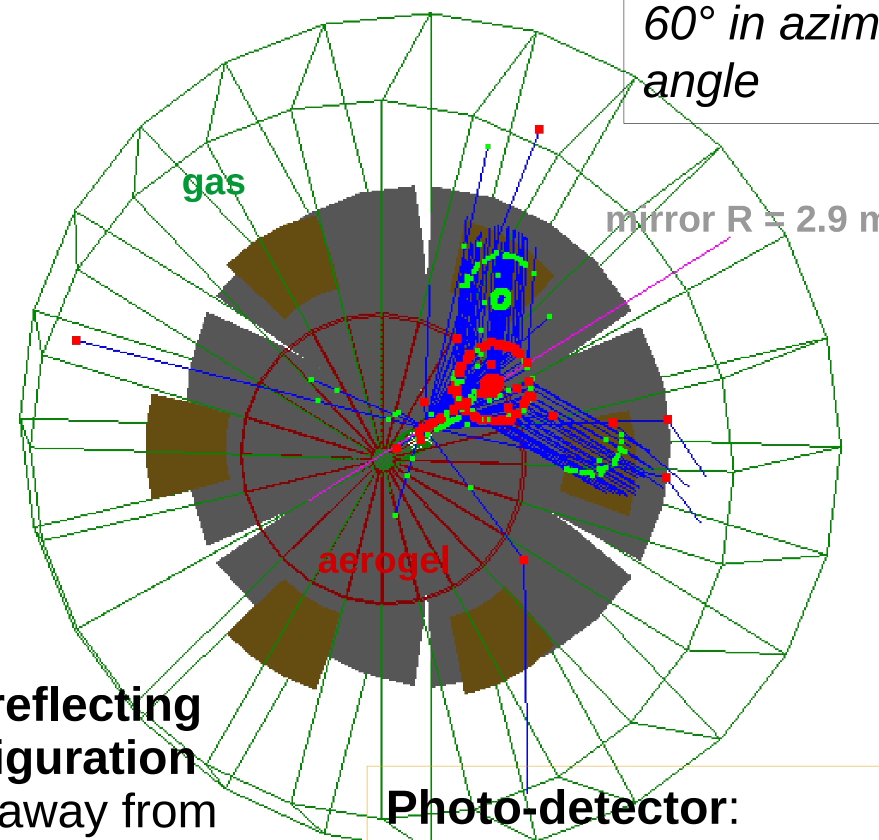
Dual-radiator RICH

Aerogel & C_2F_6 gas (160 cm)

Simulation in GEMC (GEANT based framework)



A 3mm thick acrylic filter has been applied, in front of the aerogel, to minimize Rayleigh scattering effects < 300 nm



Polar coverage
[5°,25°]
6 sectors of 60° in azimuthal angle

in **outward reflecting mirror configuration** (focal plane away from the beam, reduced area and background)

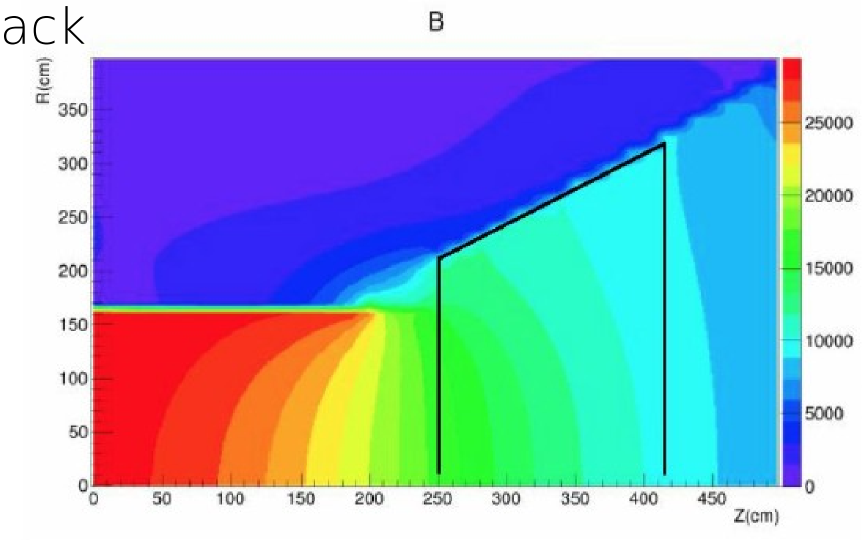
dRICH is in magnetic field (3T central field in the simulation)

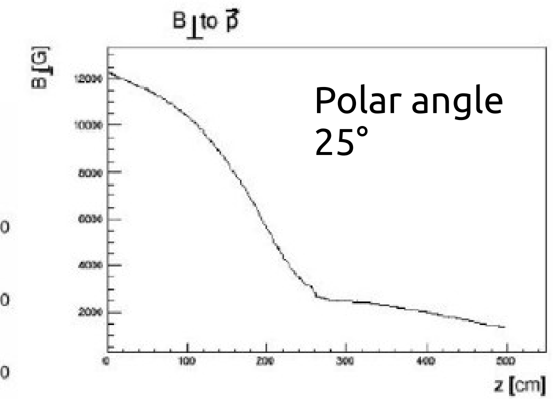
Photo-detector:
spherical shape
8500 cm² (per sector)
pixel size 3 mm,
from UV to visible light

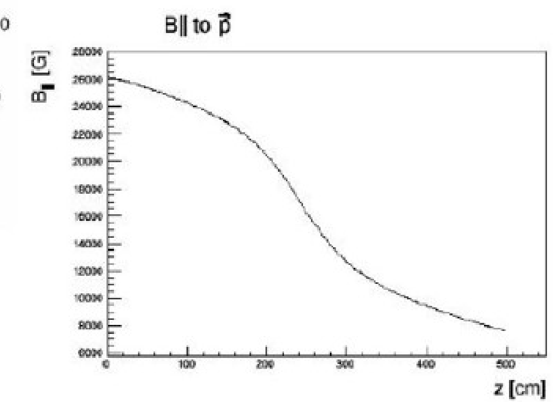
Field effects

Smearing from field perpendicular to the track affects the Cherenkov angle (Ring) resolution

- **Can be suppressed by active shaping of the field**







Related issues:

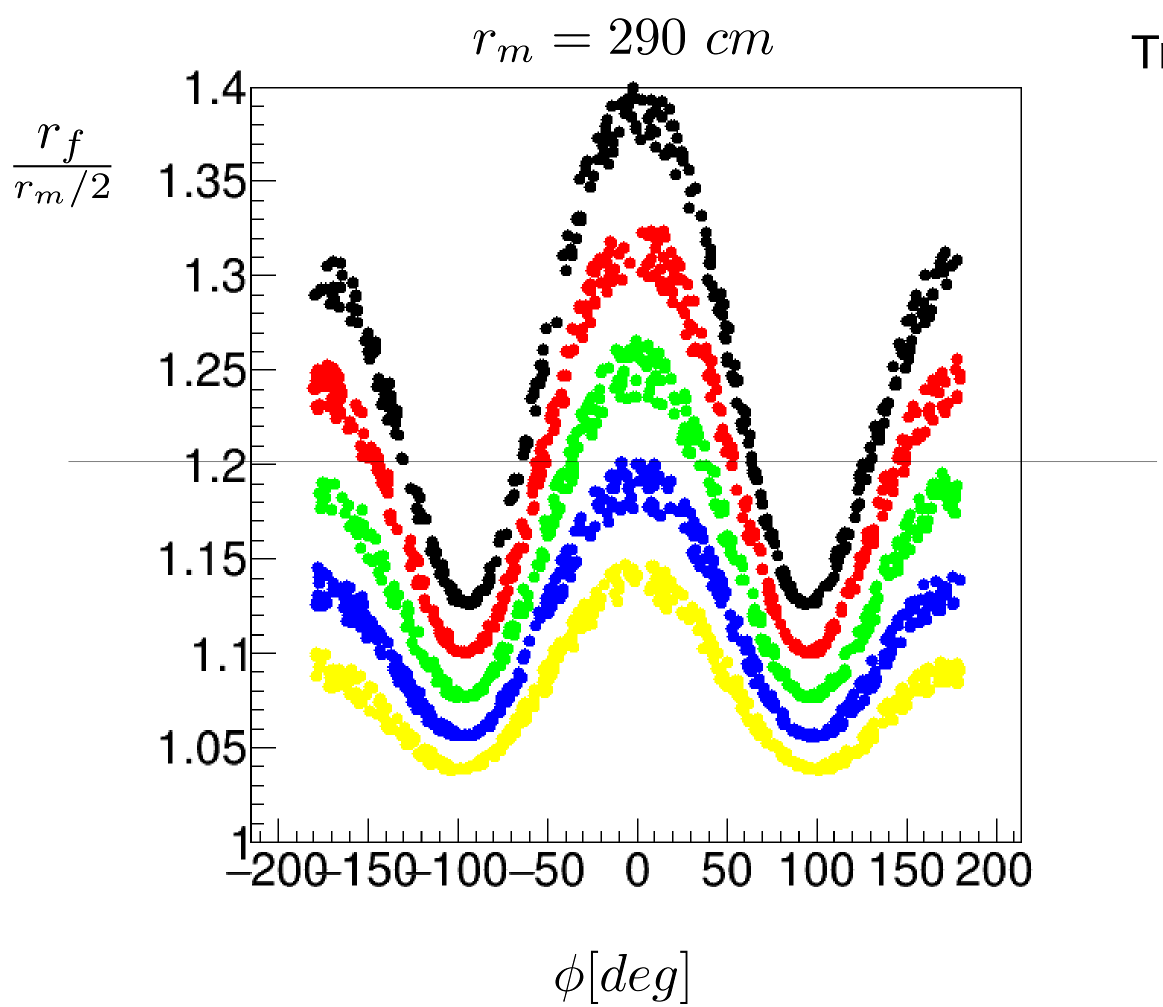
- Cost and space for adapting the magnet
- Effect of the field on the photo-detector

Indeed the choice of the photo-sensors will be driven by magnetic field and cost effectiveness!

Focal surface – C_2F_6 gas

Spherical aberrations of the mirror grows up with the tilt angle; they are sizable in a small space outward-reflecting configuration!

Position of the focal r_f with respect to the "naive" sphere $r_m/2$



Track polar angle

θ = 5°
θ = 10°
θ = 15°
θ = 20°
θ = 25°

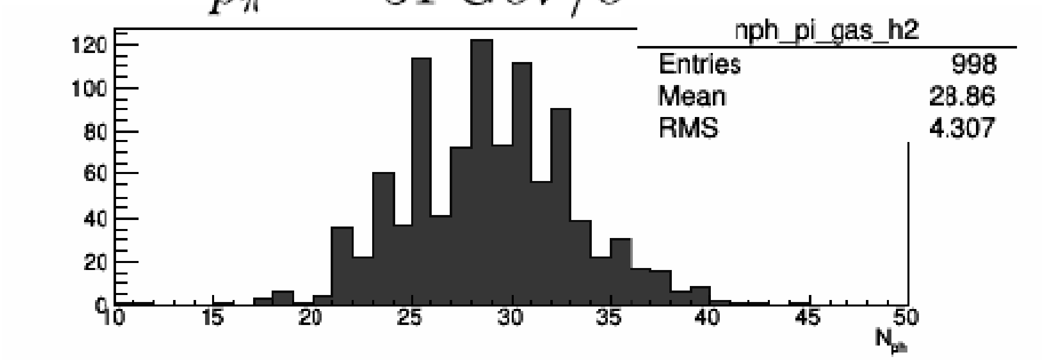
Detector position (spherical - like)

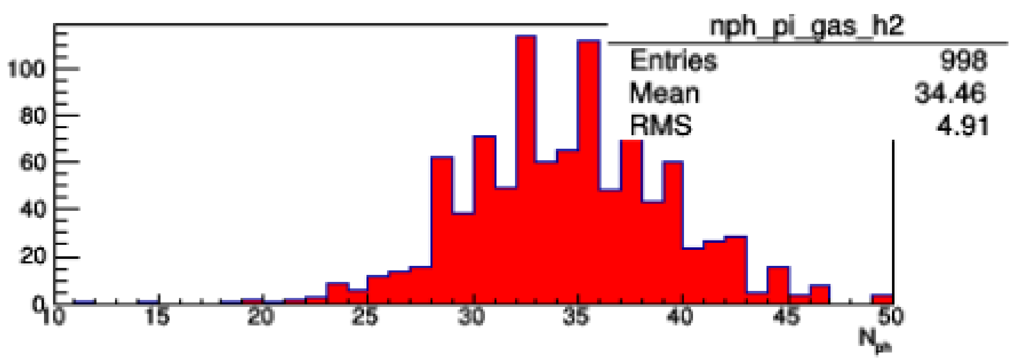
Mirror tilt angle: 28°

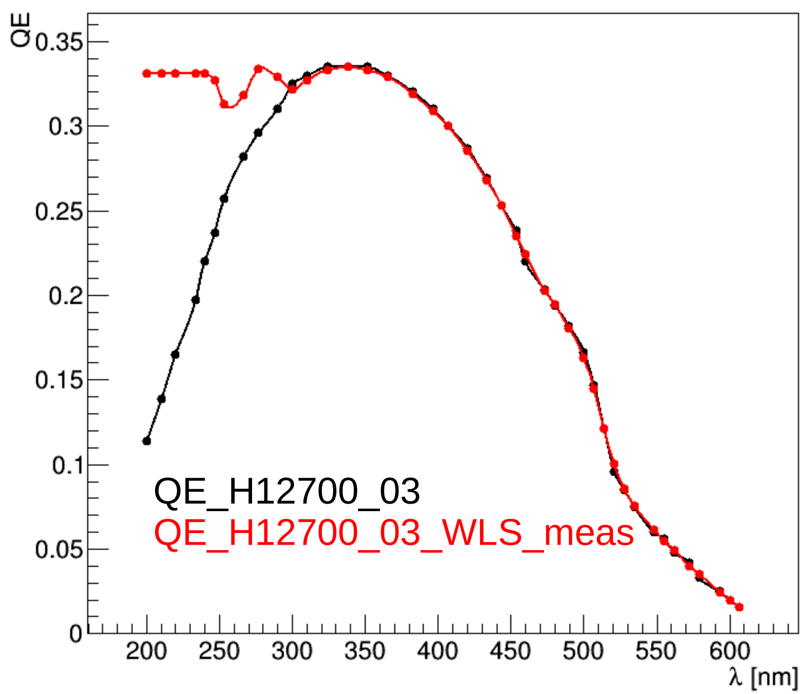
Azimuthal angle of the photons with respect to the track direction

Number of p.e. for the gas – C_2F_6 (n = 1.00086)

$p_\pi = 31\ GeV/c$



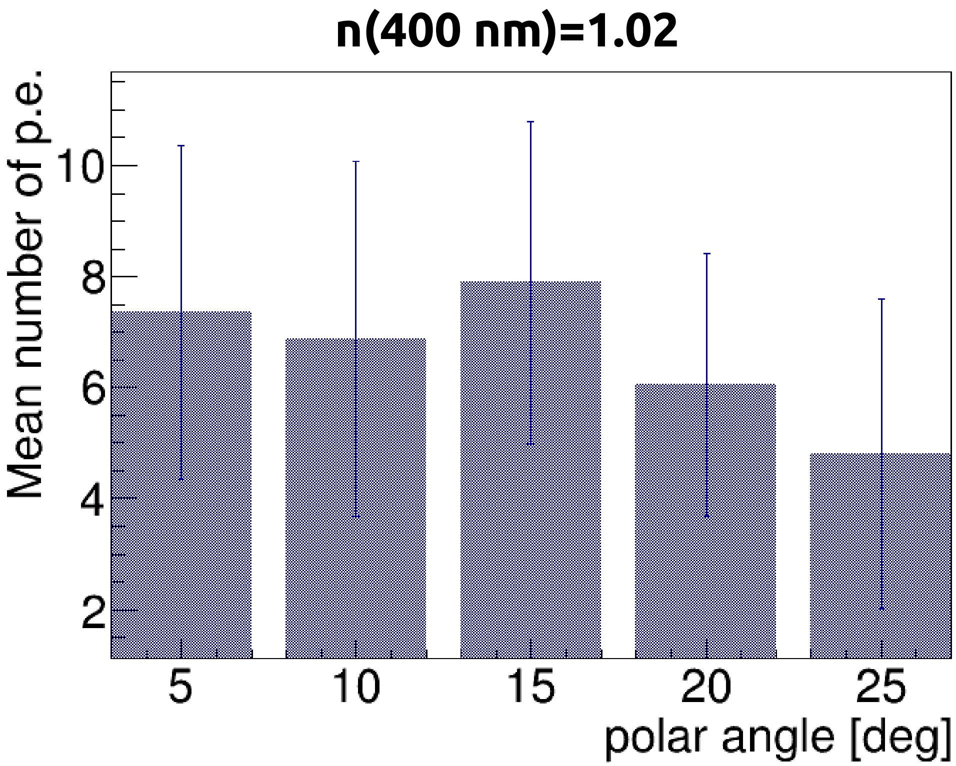




$$\lim_{\beta \to 1} N_{ph} = C \cdot L \cdot \epsilon(\lambda) \cdot \frac{n^2 - 1}{n^2} \propto \frac{n^2 - 1}{n^2}$$

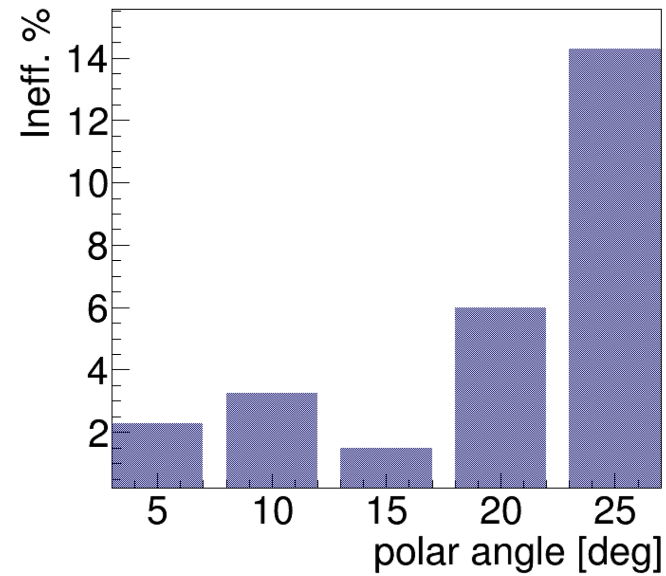
- The above distributions are resized by 0.7*Npe, assuming the same normalization of CF_4. To be validated with a prototype.

Aerogel (4 cm) N_{pe} vs polar angle

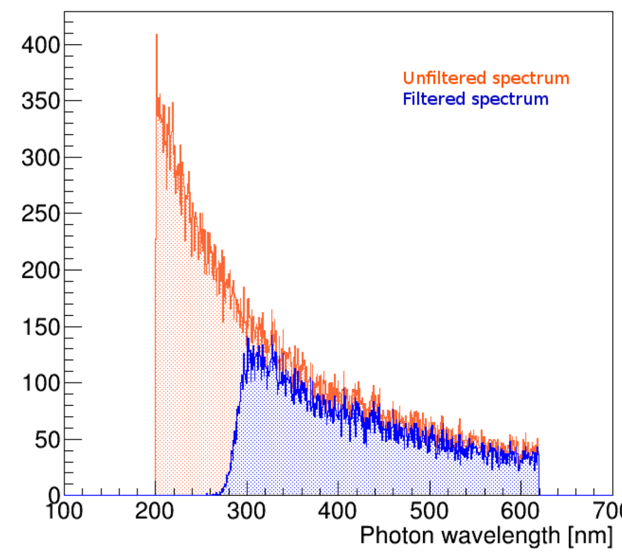


- The QE_H12700_03 quantum efficiency curve applied
- Events with $N_{ph} > 3$ are considered good events
- On the rigth, the effect of the actylic filter

$$P(N_{ph} < 3) = \exp(-\langle N_{ph}\rangle)(1 + \langle N_{ph}\rangle + \langle N_{ph}\rangle^2/2)$$

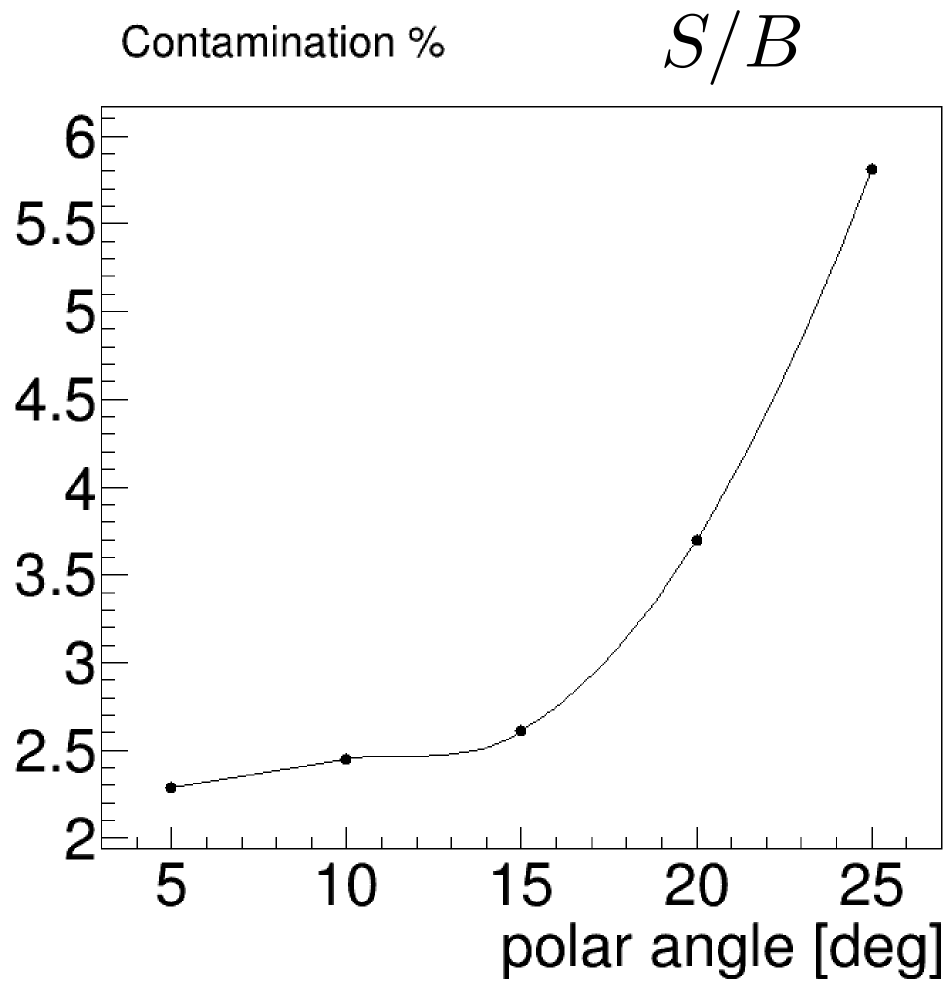


Aerogel transmitted spectrum



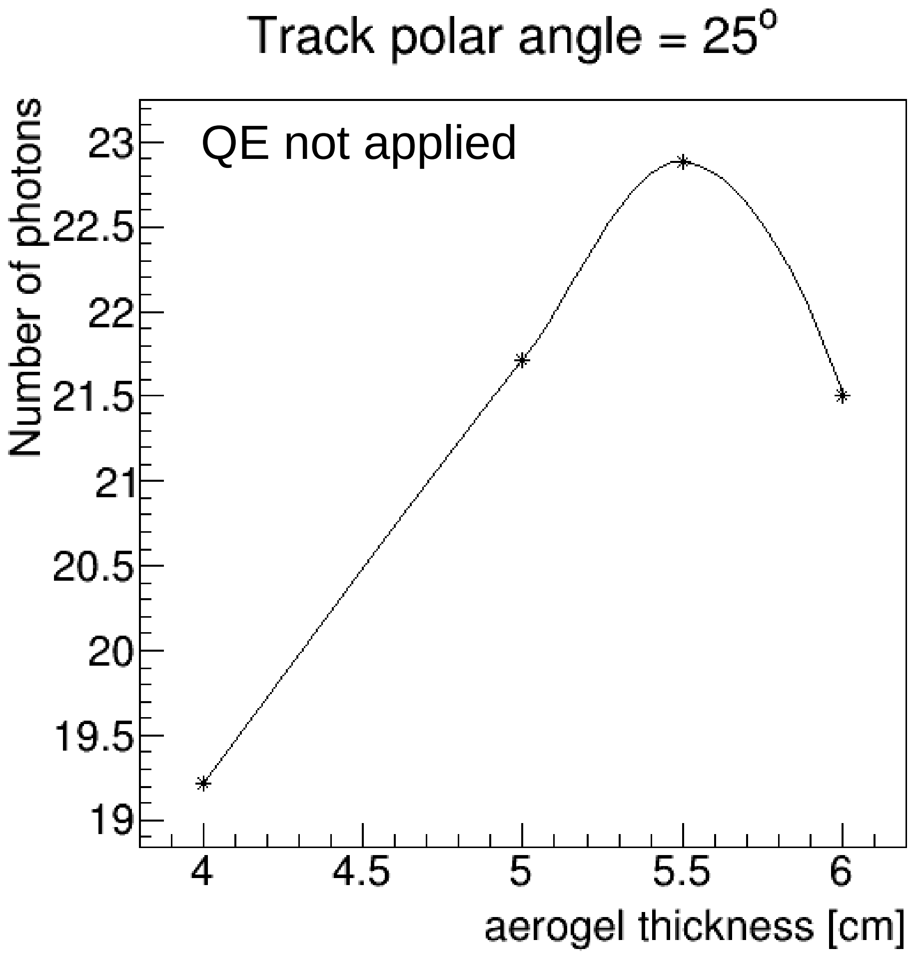
On the background, with the shield

- Contamination always below 10%, assuming a track multiplicity of one
- The EIC multiplicity is expected to be a little higher, but not extremely high



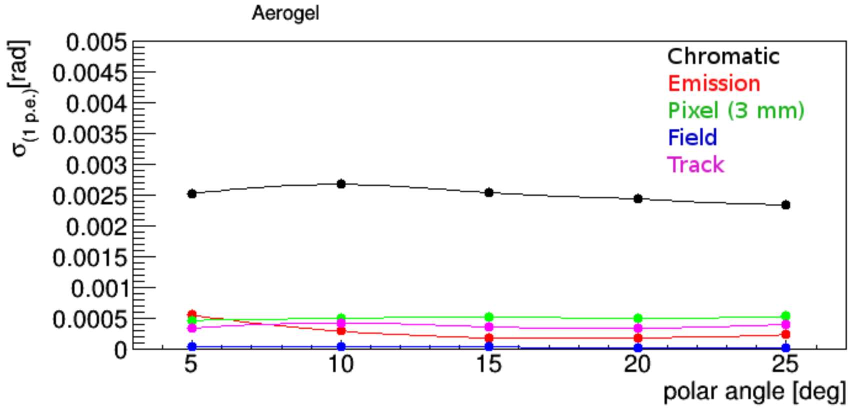
Aerogel – thickness vs number of photons

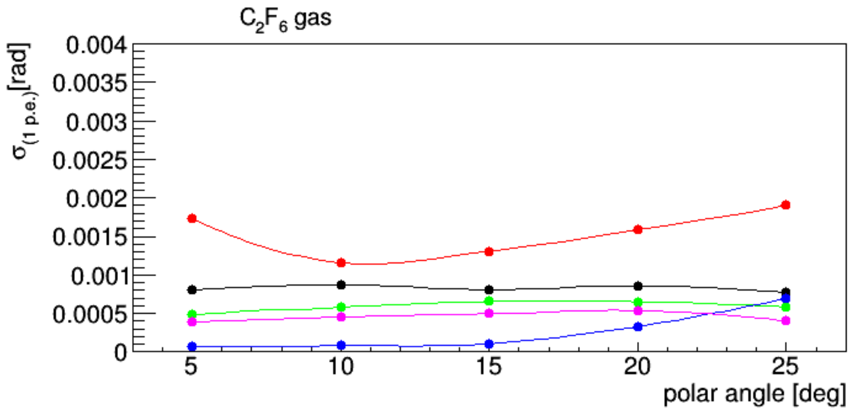
- Aerogel can be extended to 5 cm thickness to gain some photon at high angles

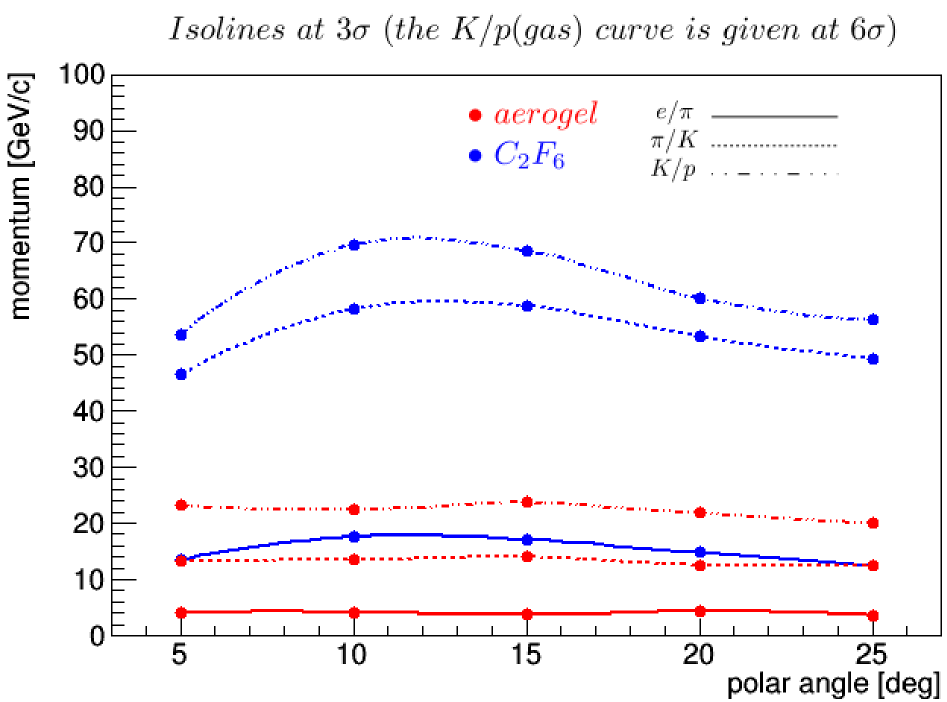


dRICH characterization

- **Detailed optical properties of the aerogel (inferred from the detailed prototyping study of the CLAS RICH collaboration) included in the simulation (i.e. Rayleigh scattering, n(λ), absorption length, ...)**
- **All the main contribution to the Cherenkov angle resolution have been evaluated**
- **The emission error deal with the position of the detector with respect to the focal surface (spherical aberrations → not a naive sphere)**

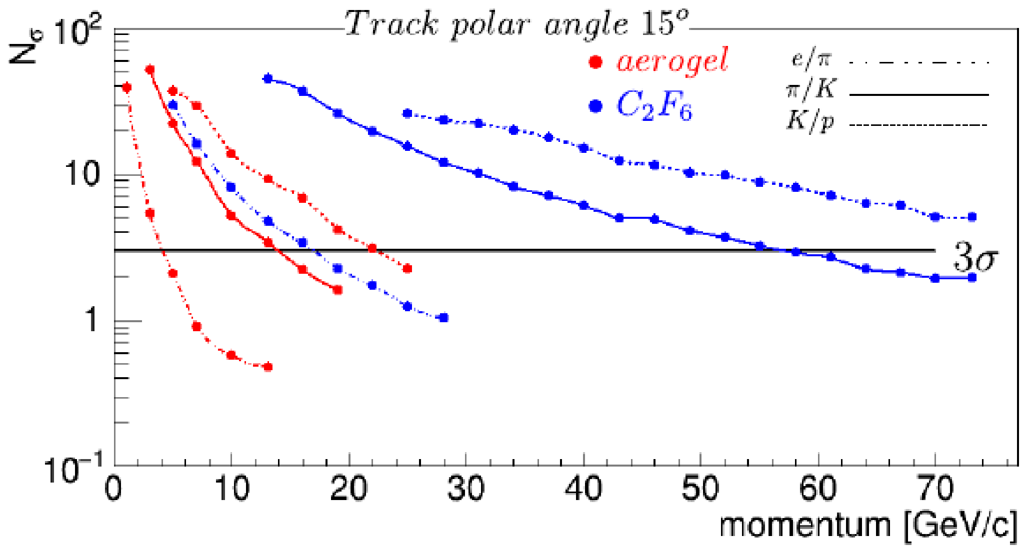




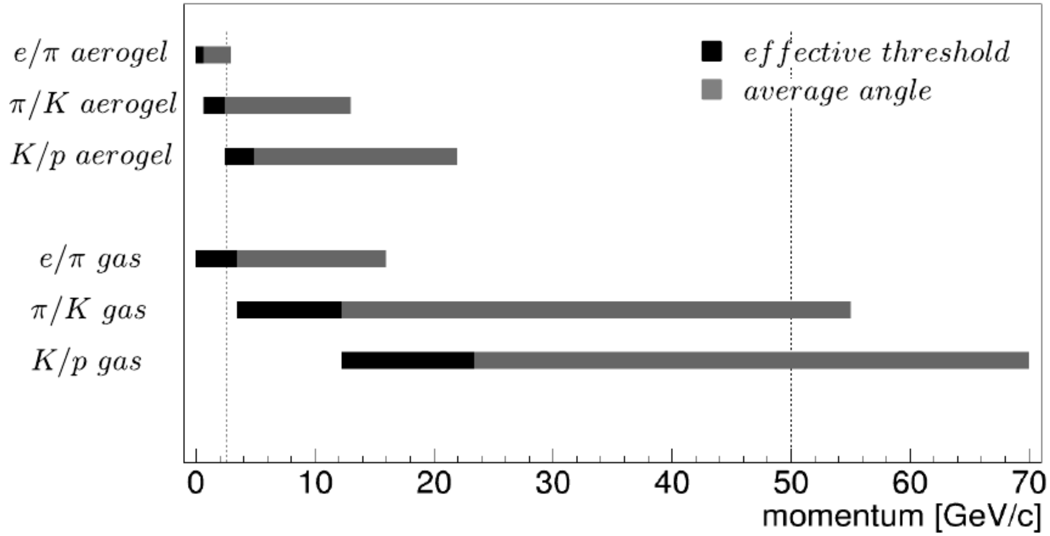


Particle identification power

“Design and R&D of RICH detectors for EIC experiments” A. DD, C-P Wong et al. published in NIM A



The indirect ray tracing algorithm developed and used for the dual RICH of the HERMES experiment have been implemented



Aerogel n=1.02 allow pi/K separation beyond 10 GeV/c at 3 sigma

Ongoing activity

- Tesselation of the photo-detector planes:

  tiles 5 x 5 cm^2

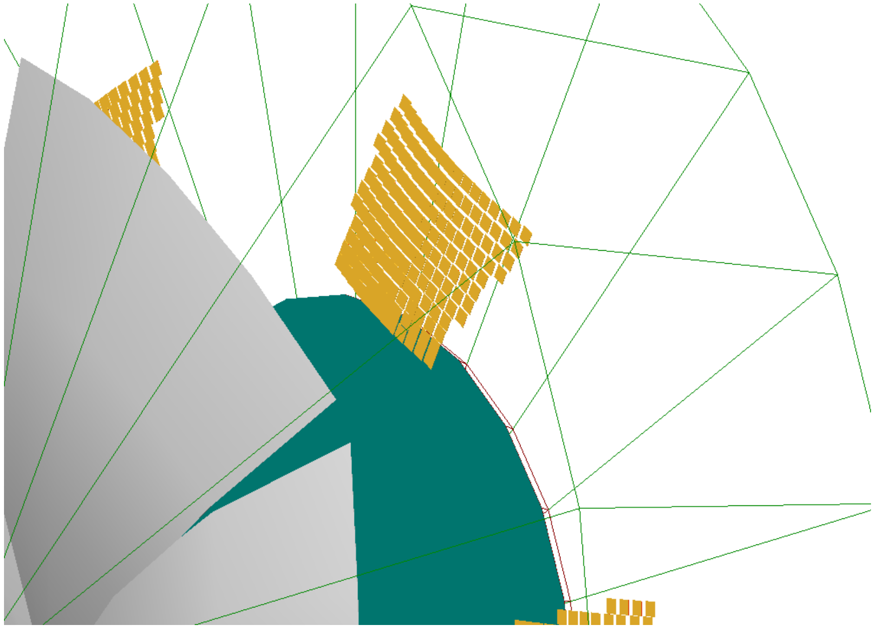
- Adaptive surface:

  for optimizing emission error for the gas

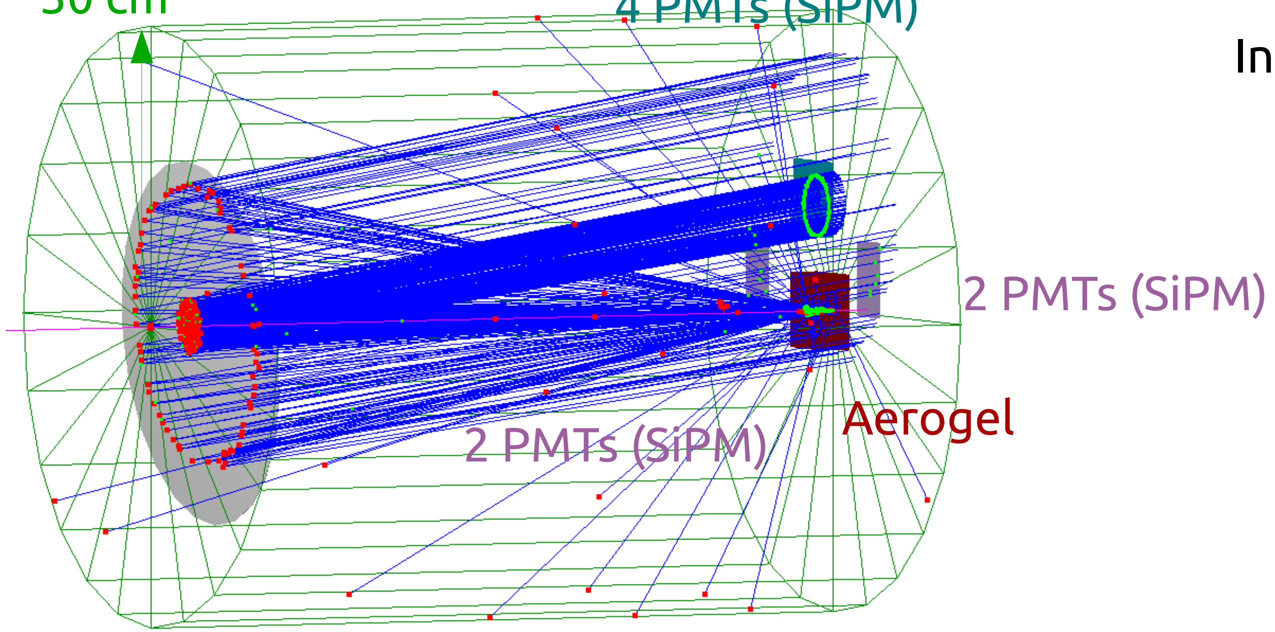
  reduce the emission error for the gas

  potential improvement of quantum efficiency by tilting each tile by the proper angle

- A synergy to test the dRICH principle in the ePHENIX and BeAST EIC configurations has started and will continue to be pursued in FY18



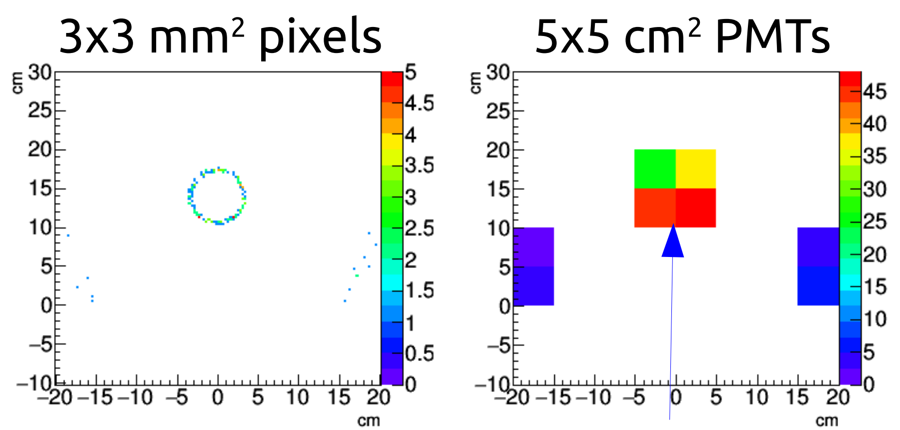
A simulated prototype (minimal version)



The same 4 PMTs
used for gas and aerogel
In two different configurations

Synergy with
mRICH will give
important hints
on the possible
choiche for the
photon-detector

<u>SiPMs?</u>



4 PMTs cover the gas
and 4 for the aerogel

1 p.e. error (mrad)	Aerogel	gas C_2F_6
Chromatic	3.7	0.85
Emission	0.2	0.85
Pixel (3 mm)	0.9	1

Conclusions and perspectives

- A baseline configuration for the dRICH has been almost completed and implemented in GEMC
- A preliminary minimal version of a dRICH prototype has been implemented in GEMC
- A synergy to test the dRICH principle in the ePHENIX and BeAST EIC configurations has started and will continue to be pursued in FY18
- First publication on NIMA

Main next steps:

1) Study of a physics channel of interest to the EIC in the presence of physics backgrounds
2) Adapt the dRICH for the geometry currently used in the BNL concept detectors (as well their magnetic field maps) to allow a direct comparison with the eRD6 gas RICH

Backup slides

Table of comparison

* combined with a good electronics

Parameters	PMT	MCP-PMT	SiPM	LAPPD
Gain	10^6	10^6	10^6	10^6
Timing Resolution*	Ok TTS ~ 300 ps	Fast TTS < 50 ps	Ok* < 200 ps	Fast
Dark noise	(KHz)	(KHz)	(MHz)	(KHz)
Radiation Hardness	ok	ok	Rate and temperature dependent	ok
Single photon	ok	ok	ok	ok
Magetic field tolerance	Less tolerant	ok ~1T	Insensitive	ok
Detection efficiency	>20%	>20%	>20%	>20%
Cost	2K USD	10K USD	2K USD	?