ePIC dRICH Simulation and reconstruction status update

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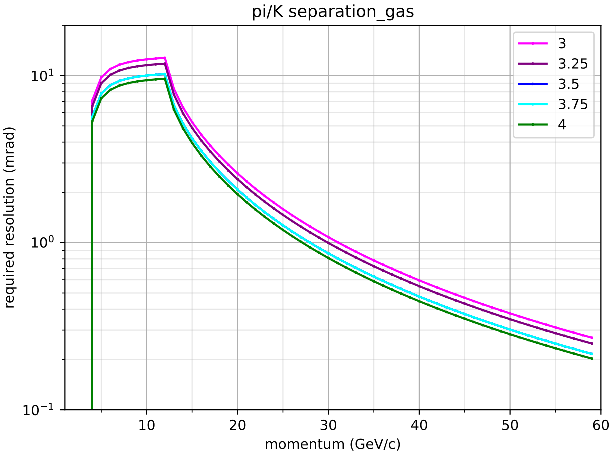
Outline

General Comments

- A dual radiator RICH (dRICH) is designed to perform high momentum particle identification in the forward region of ePIC detector.
- 3-sigma separation for pi/K up to 50GeV in the high pseudo-rapidity and substantial overlap between gas and aerogel radiators.
- Baseline design: total 120 cm of vessel length. A 4 cm thick aerogel of refractive index 1.02 and followed by C_2F_6 gas of nominal (n-1) 800 ppm.
- SiPM based sensors are placed in spherical tiles are placed in six sectors to detect focalized photons from 6 spherical mirrors.
- The dRICH sits 195 cm upstream of the IP and extended up to 315cm.
- Before July review an extensive effort was made to parameterize all optical properties extended up to same wavelength range and tuning of the optics.

Requirements (gas)



- In order to achieve at least a 3σ pion/Kaon separation above 50 GeV/c we need a ring resolution[1] around 0.3 mrad. An optical tuning has been performed for the most demanding pseudo-rapidity region ($2.5 \leq \eta \leq 3.5$).

[1] $\sigma_{PE} / \sqrt{N_{PE}}$ (No noise hits)

Requirements (Aerogel)

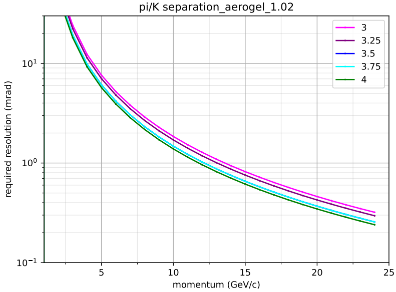


Figure: n=1.02

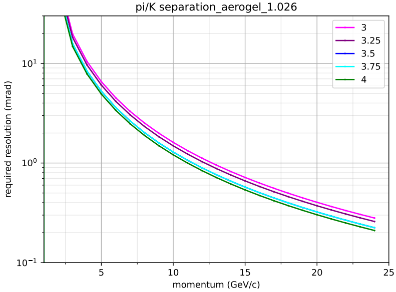


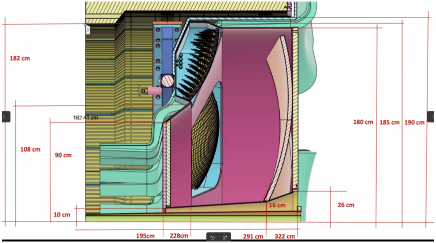
Figure: n=1.026

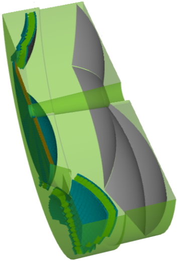
- In order to achieve at least a 3σ pion/Kaon separation up to 15 GeV/c we need a ring resolution better than 0.8 mrad with nominal refractive index.
- If we increase the refractive index to 1.026, slightly we lower down the 3σ. Still it performs positive π-K separation above kaon threshold in Gas with substantial overlap.

Realistic Sensor box (W.I.P)

The dRICH sensor-box shaping has been initiated a first version is merged in the main detector description.

- Vessel radius is reduced to 180 cm.
- The sensor box still extended radially up to 185 cm.
- No quartz window placed so far. The quartz window will play a role in the impinging angle of the photons.

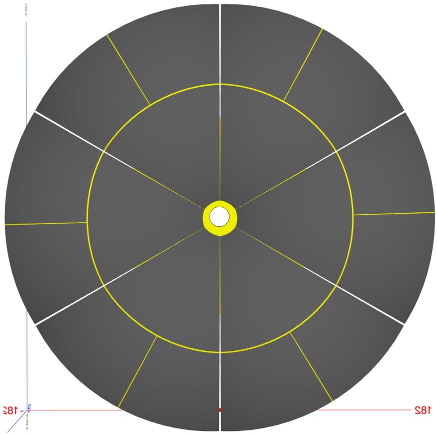




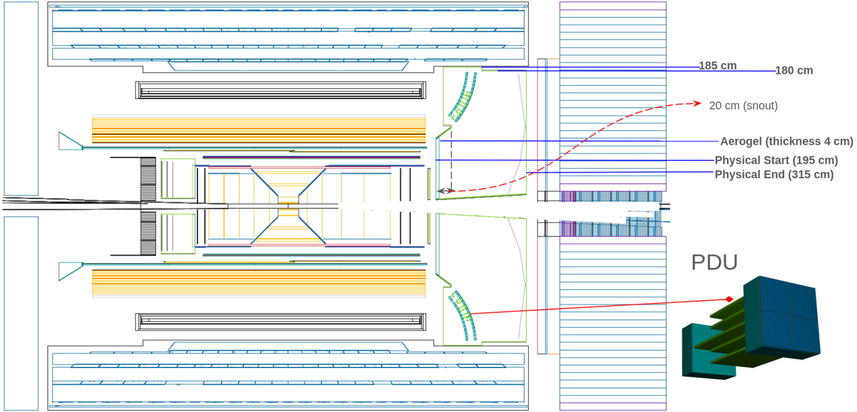
Realistic Mirror and Aerogel tiling (W.I.P)

The Aerogel is currently a unique disk and each petals of our mirror is unique (unrealistic).

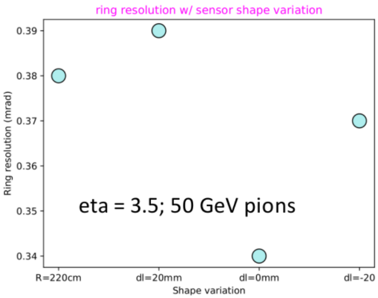
- Titling of the mirror is ongoing (Draft PR).
- Aerogel tiling for the time being can be done like pfRICH (example strategy).
- Estimation of the dead-area will be studied afterwards.

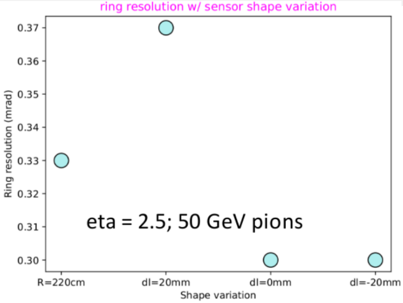


dRICH schematic (current version)

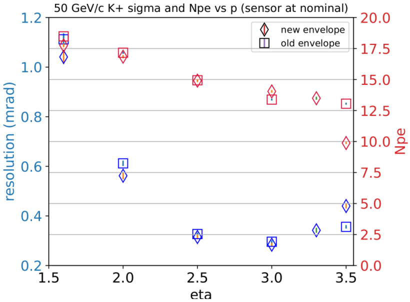


Sensor Shaping and vessel positioning



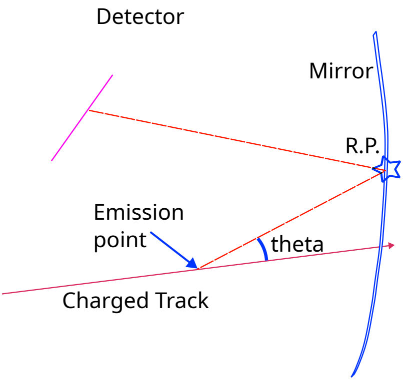


Optimize shape and location has been chosen. It has been demonstrated a global shift[a] of the dRICH by 5 cm has no effect in resolution and number of photons in different pseudo-rapidity.



[a] Old: nominal, New: 5 cm shift; Already reported in June

IRT: Underlying concept



- Used in several RICH detectors; e.g. HERMES, COMPASS.
- Iterative solution to estimate mirror impinging point.
- W.R.T a fixed star (beam direction, mirror centre), given knowledge of detection and emission point, Cherenkov angle can be measured.

IRT: Underlying concept and our features

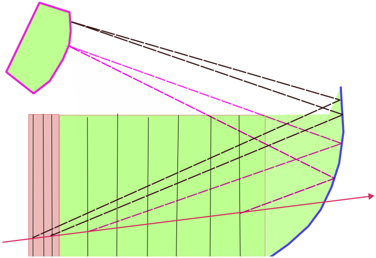
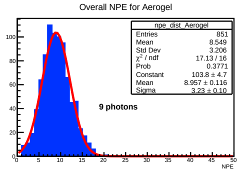
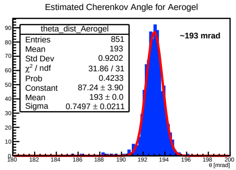


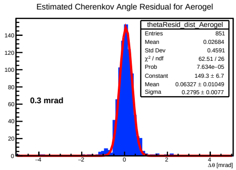
Figure: IRT working principle

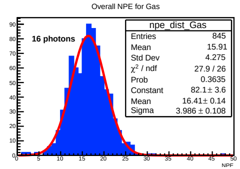
- Currently we are using the IRT v1.0. So called ATHENA IRT or dRICH IRT.
- Surfaces are parametric: e.g. Flat surface, spherical surface.
- Optical boundaries have specific surface and refraction/reflection are taken accordingly.
- Given the detection point, the reflection point around the mirror can be guessed.
- Average of the converged solution for a set of assumed emission points are passed as the Cherenkov polar and azimuthal angle.
- Currently we are using 5 points for aerogel and 10 points for gas tracks.
- Based on each photon's angle an weight is assigned with 3σ window for different hypotheses. Brute PID performance.

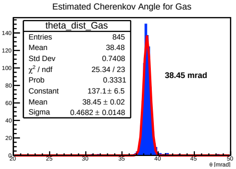
IRT performance: single particles

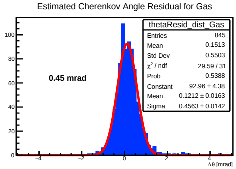












- Reconstruction provides reliable values for angular resolutions[2].
- Sufficient to perform detector characterization without noise.

[2] slight tension with test-beam data for Aerogel (recently understood and fixed)

Performance of dRICH: updated PDU description I

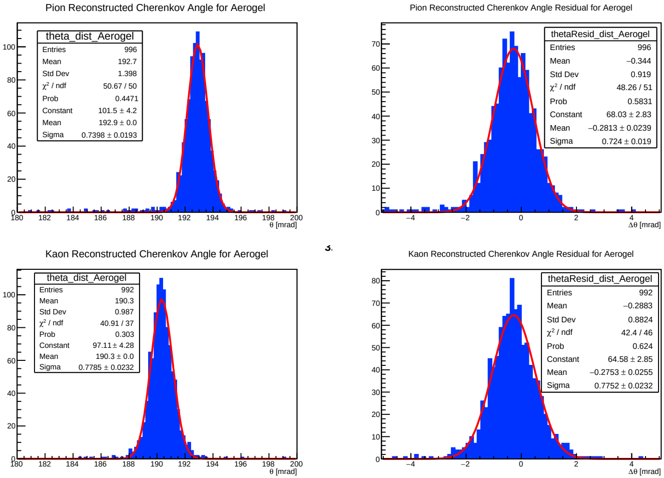


Figure: 15 GeV pion/Kaon ring angle distribution and residual plot for Aerogel. 3.5σ separation can be achieved

Performance of dRICH: updated PDU description II

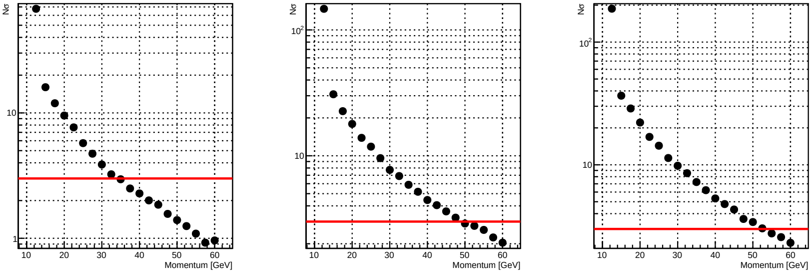
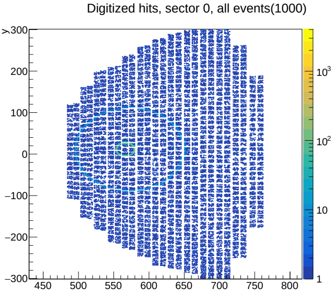
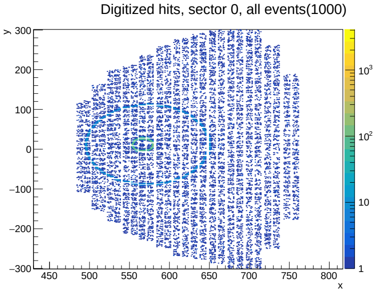


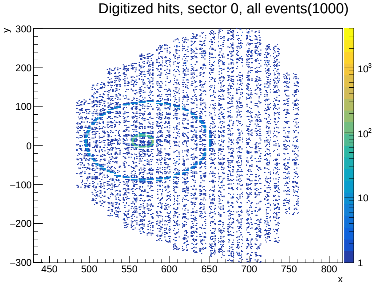
Figure: Seperation power(Aerogel to be redone); eta (1.3-2.0); (2.0-2.5);(2.5-3.5)

- Pions kaons can be separated upto 50GeV for a large range of pseudorapidity.
- Blow eta = 2.0 the the focalization is not optimal; this enhances the error due to emision point uncertainty. The separation is limited up to 35 GeV/c.

Injection of Noise (Hit map)

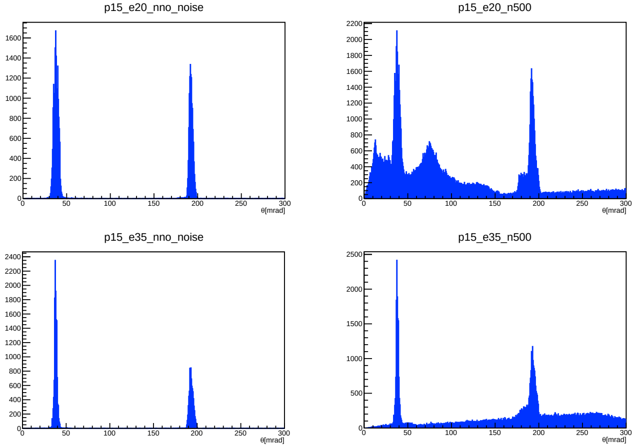






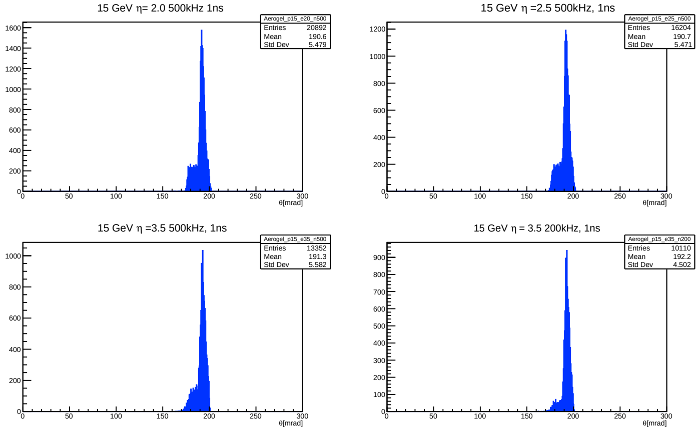
- The noise has been implemented at the reconstruction level. It takes into account Poisson distribution. Randomly a cell ID is assigned for each expected noise hit. Images are accumulated over 1000 events (TL: 500kHz, TR: 200 kHz, BL: 100 kHz)
- The rates and time window are configurable in a '.yml' file.

Injection of Noise: Performance of IRT



- SPE distribution changes with pseudorapidity. Roleplay of emission point uncertainty.
- Current IRT is pushing solutions towards convergence.
- Distribution shape has no dependence on noise rate.

Injection of Noise (Aerogel): IRT Noise anomaly



- No side bands for aerogel.
- Possible effect of emission point uncertainty.

Effect of Emission point Uncertainty on IRT

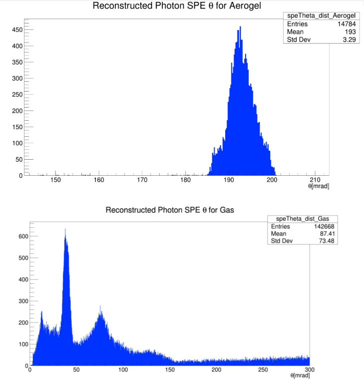


Figure: aerogel 2; gas 10 bins; η 2.0

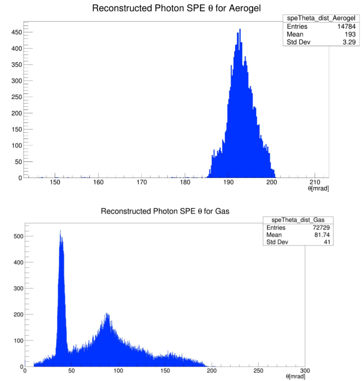


Figure: aerogel 2; gas 2 bins; η 2.0

- Still No side bands for aerogel photons.
- With fewer track projections (gas) angle distribution for noise hits becomes more intuitive.
- No visible changes for aerogel (extremely short emission point uncertainty).
- Still preferential pick-ups present in gas photons (around 70 mrad, 150 mrad).
- Effect of sensor acceptance?
- pfRICH IRT does not consider these track projections. First thing to try with dRICH.

Azimuthal and polar angle dependency

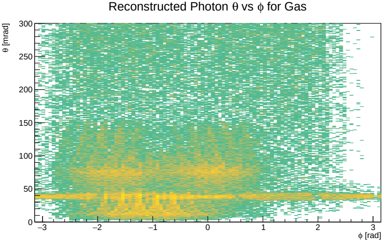


Figure: 10 track projections

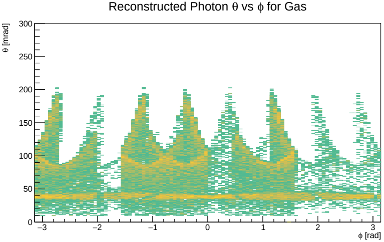
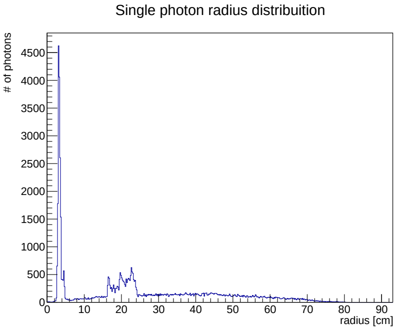


Figure: 2 track projections

- The polar angle (in the nonphysical zone) prefers particular azimuthal angles.
- Reduction of track point projections reduces them but does not totally removes them.

Injection of Noise: Radius distribution



- Ring radius can be computed from the hit-map distribution for digitzed photon hits.
- We haven't seen any peak around 6.5-7 cm (corresponding to 75 mrad) in the radius distribution [a].
- SPE theta distribution and radius distributions seems incompatible for large angle tracks.

[a] $\tan(\theta_C) \sim r/f$

Role-play of EICRecon I

- Selection of photons based on at least one hypothesis assignment.
- Storage of all selected photons in 2D vector (theta, phi).
- If no photon selection is made aerogel side band appears (kaon under-threshold in gas).

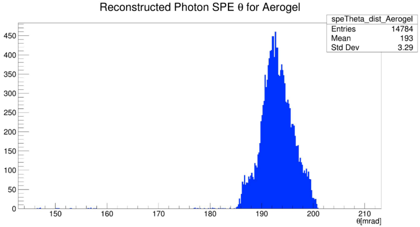


Figure: Selected photons

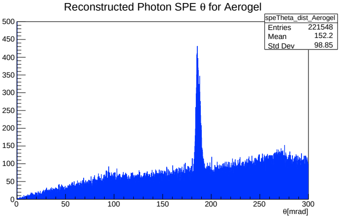


Figure: No photon selection

Role-play of EICRecon II

- The noise under the peak picks up relevant photons from other sectors.
- We switched off all five other sectors.
- The noise under the peak changes substantially.

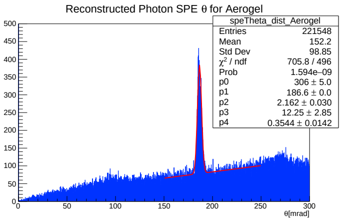


Figure: Noise within $2\sigma \sim 30\%$

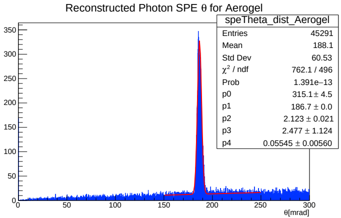


Figure: Noise under peak(Just 1 sector): 1%; 6% within $\pm 2\sigma$

Photons from different sectors are falling under the peak (uniformly)

New Aerogel parameters

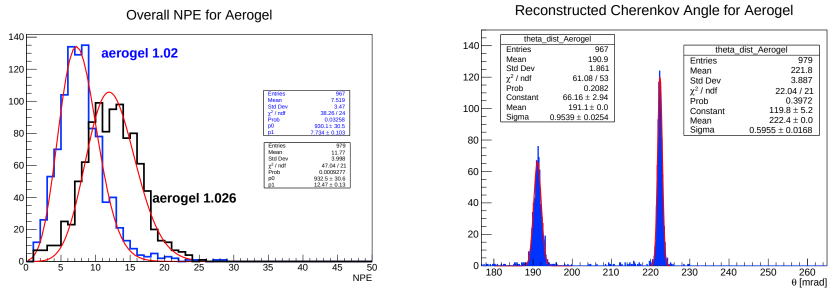
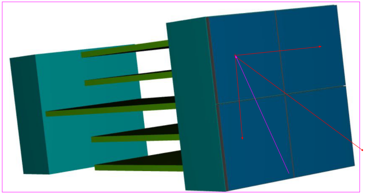


Figure: Comparison of Npe and theta distribution of different aerogel types

- New Aerogel properties (all properties will be extrapolated up to 1000 nm) has been implemented.
- Preliminary studies performed. Npe (7→12 (eta 2.5)); improvement in SPE sigma (thanks to the fact SPE resolution remains similar).

Photon impinging angle

Definition of the sensor surface normal



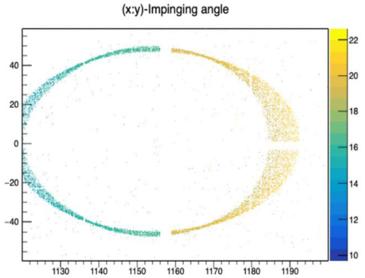


Figure: Gas ring $\eta = 3.5$

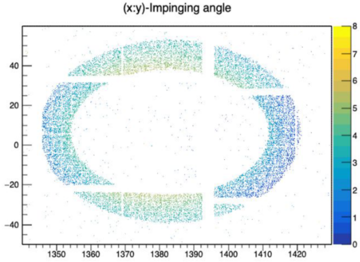


Figure: Gas ring $\eta = 1.8$

- It is demonstrated: interplay between focalization and impinging angles.The impinging angle also depends on azimuthal angle of Cherenkov photons.
- The feature is independent of Cherenkov angles. At higher rapidity Aerogel photons reflected from split mirrors make large angles (close to

Conclusions I

- Several updates have been made after July review; preserving dRICH performance.
  1. dRICH is capable of 3σ pi/K separation slightly above than 50 GeV/c in the forward region.
  2. Emission point uncertainty enhances due to spherical aberration in the lower rapidity, PID limited to 35 GeV/c.
  3. electron/pion separation can be achieved up to 4 GeV/c. The lower limit will be studied with new aerogel parameters and modified ring resolution estimation.
  4. Substantial overlap between aerogel and gas PID in all pseudo-rapidities.
- The current reconstruction is capable of doing its job for single particles without noise and maybe to some extent with noise but we have to careful with the rate and region of the optics. Can only be used for detector characterizations.

Conclusions II

- The current reconstruction(IRT v1.0) is extremely useful to validate proof of principles and quantitative estimation of intuitive figures, e.g. Npe, N-sigma separation etc.
- IRT v1.0 incapable to perform complicated noise handling, thus we can ignore its contribution to physics performance studies.
- Priorities: Improve and fix the reconstruction limitations, and start looking into more complicated scenarios than just detector characterization. Start ASAP to validate (first) IRT v2.0 and use it.
- Workforce (Technical): Tiziano, Luisa, myself. Also time to time help from Chris Dilks. In future possible overlap with Alexander and Kolja for pfRICH IRT implementation and validation.
- Marco and Silvia for suggestions and comments.


2024
HAPPY NEW YEAR