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SiPM studies for the ALICE 3 Aerogel RICH detector

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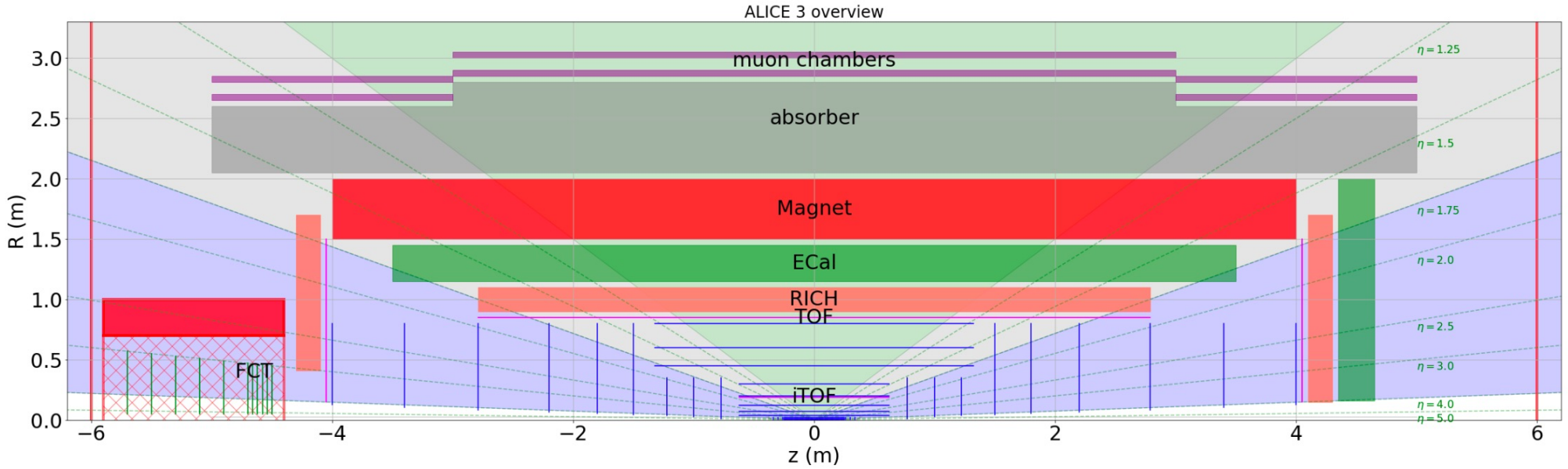
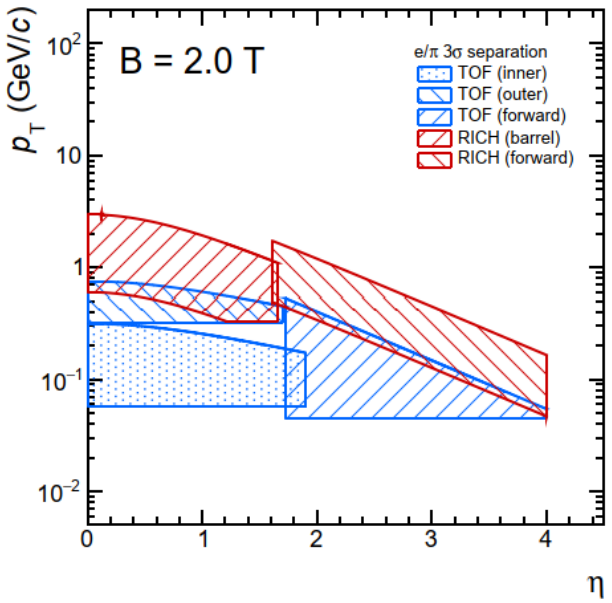
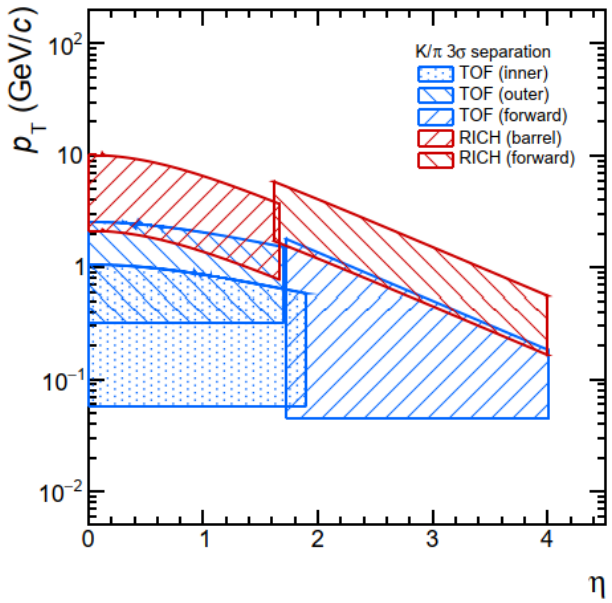
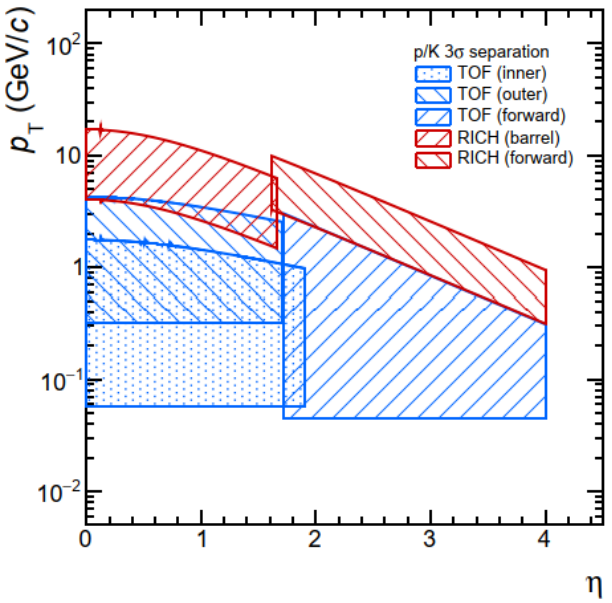
RICH system in the ALICE 3 layout



Extend electron and charged hadron ID at momenta higher than the TOF range



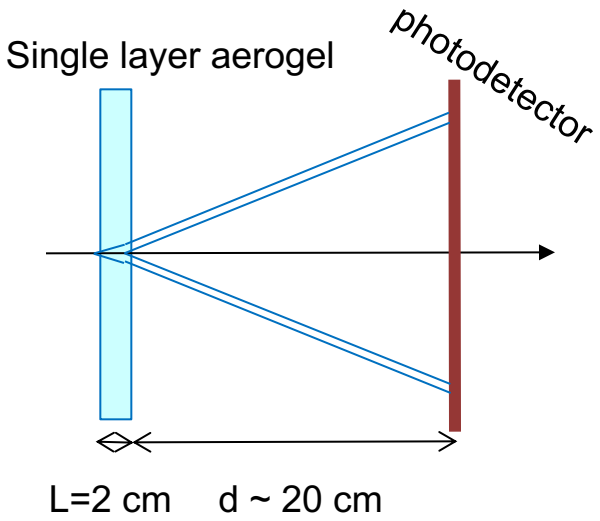




Layout options and photon detector

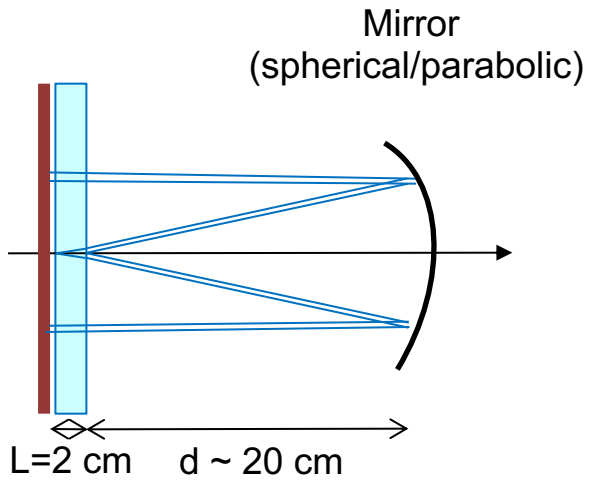
Baseline layout:

- No aerogel focusing
- Aerogel layer @ 0.9 m from IP
- Photodetector @ 1.1 m
- Aerogel ~ 32 m^2, p.d. ~ 39 m^2



Mirror layout:

- With or w/o aerogel focusing
- aerogel layers @ 0.95 m from IP
- photodetector @ 0.9 m
- Aerogel ~ 33 m^2, p.d. ~ 32 m^2



Photon detector main requirements

- Single photon sensitivity in the visible range (Photon Detection Efficiency (PDE) > 40-50%)
- Integration fill factor > 90%
- Pixel ~ 3x3 mm^2
- Time resolution σ < ~ 100 ps
- Magnetic field B ≤ 2 T
- Expected radiation load: NIEL ~ 10^{12} 1-MeV n_{eq} /cm^2

→ **pro's:**

- **Reduce/suppress geometric aberration** depending on mirror:
  - flat: doubling of gap
  - cylindrical: focusing in one direction + doubling of gap
  - parabolic: full focusing
- **reduce p.d. area by 60%**

→ **con's:**

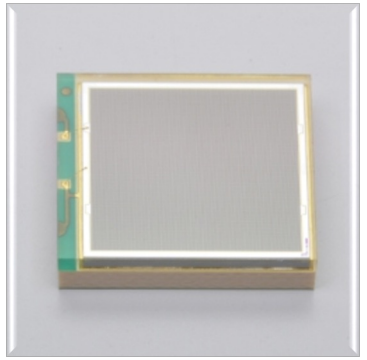
- ~ 20% photon loss due to double crossing of aerogel and mirror reflection
- spherical aberration and mirror alignment to be taken into account

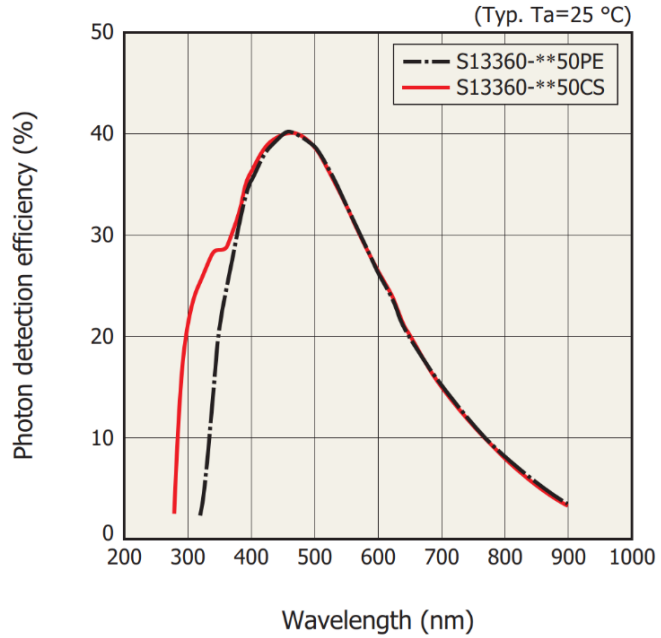
The photon detector

Significant enhancement on the semiconductor process over past decades, excellent improvement of CMOS SPAD performance → renewed interest for the **development of digital-SiPM** for large area coverage in HEP applications (e.g.: development ongoing in Sherbrooke University and FBK)

- **R&D on digital SiPM based on CMOS Imaging technology**
  - Reduce cost
  - Explore solutions for:
    - noise performance improvement (beyond online/offline time gate)
    - radiation hardness improvement (1-2 orders of magnitude, 10^{12} 1-MeV n_{eq} /cm^2 required)
    - TOF applications (MIPs detection with time resolution ~ 20 ps)

- **Backup option: commercial SiPM**
  - Example: SiPM HPK 13360 3050CS
  - 3x3 mm^2 pixel (3600 SPADs with 50 μm pitch)
  - Dark count rate (DCR) ~ 50 kHz/mm^2
  - 50 ps time resolution
  - Above 10^{11} 1-MeV n_{eq} /cm^2 → DCR increasing





A step forward: Cherenkov-based TOF system

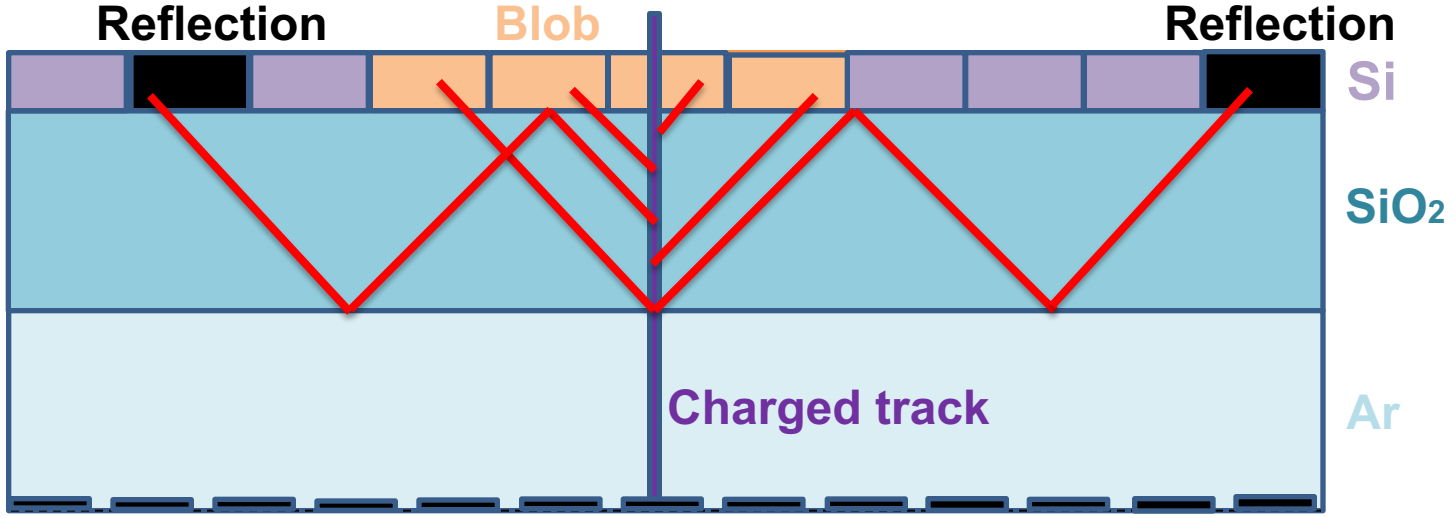
Reflection background

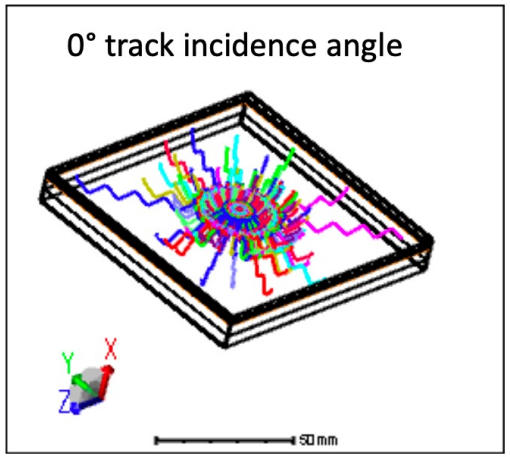
About 30% of photons reflected at SiO_2 - Si
Total reflection at SiO_2 - Ar

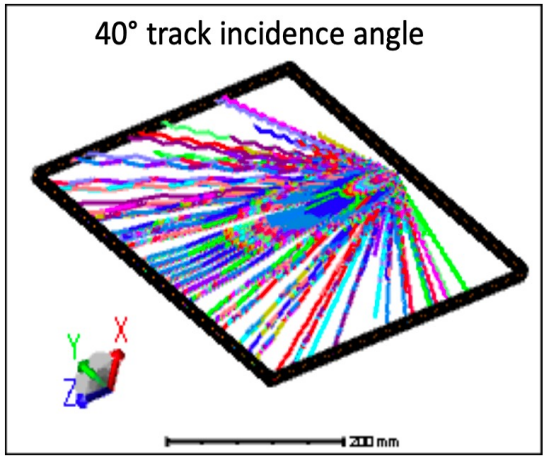
Track time resolution

Determined by single photon resolution and blob size

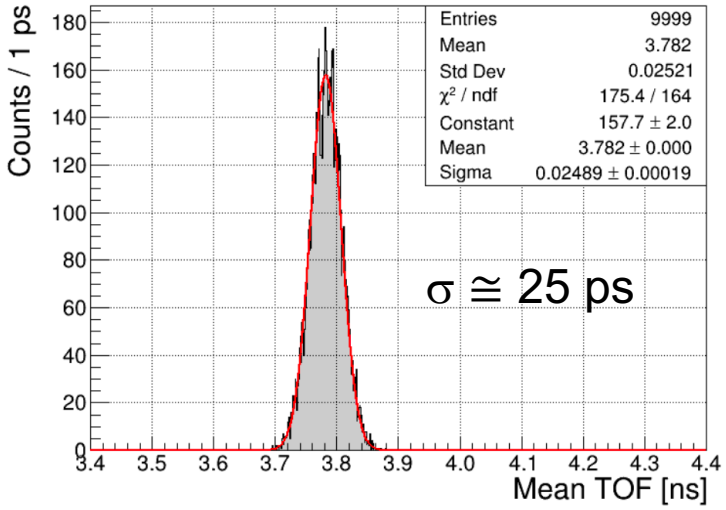
$$\sigma_{\theta_t}^{trk} = \frac{\sigma_t^{\gamma}}{\sqrt{N_{blob}}}$$







1 mm quartz, 3 mm² cells



1 mm high ref. Index glass, 3 mm² cells