Update on the PID DIRC for EicC

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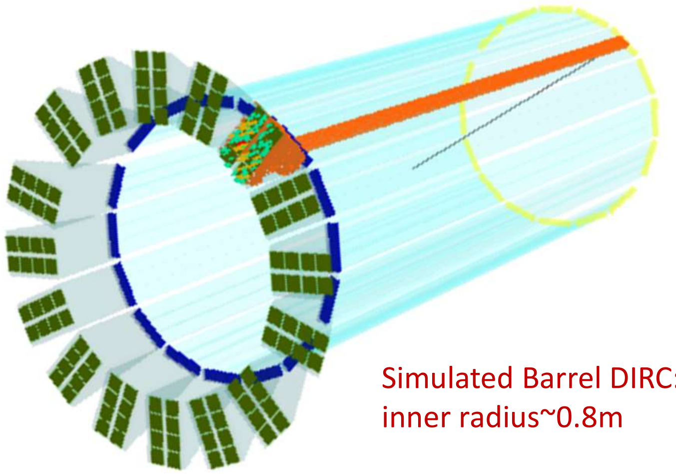
10/19/2022

3rd EicC CDR workshop

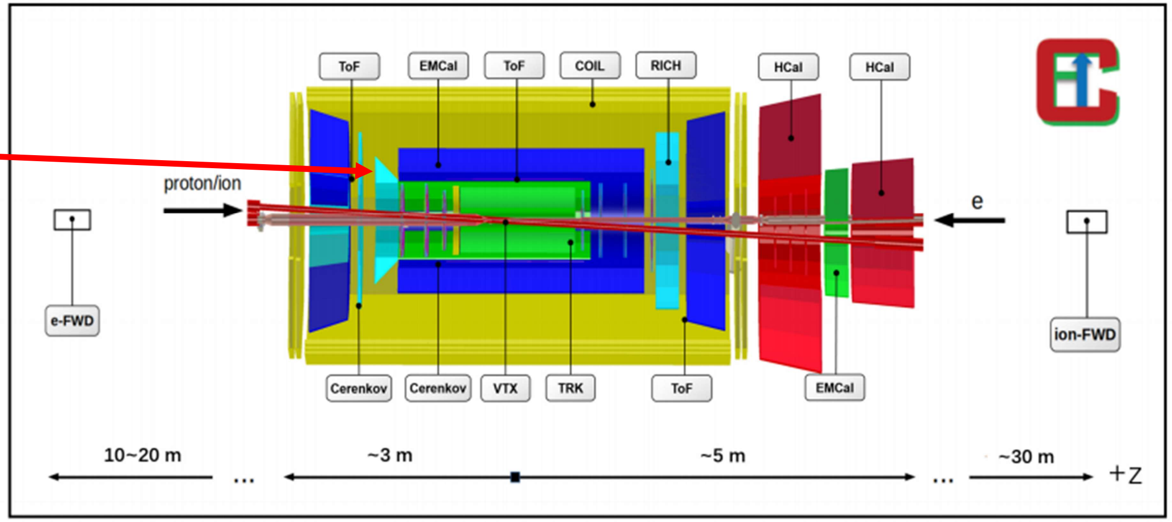
OutLine

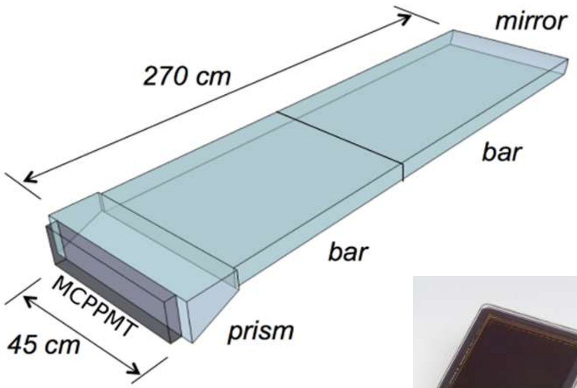
- Barrel DIRC simualtion & readout electronics
- Cosmic ray test platform
- Next Plan

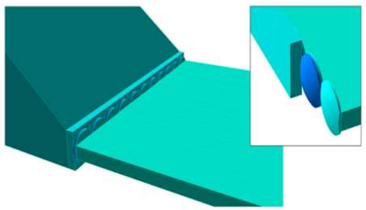
PID Barrel Detectors at EicC

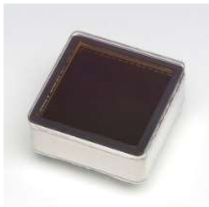


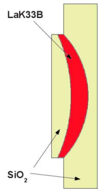
Simulated Barrel DIRC: L~3m, inner radius~0.8m

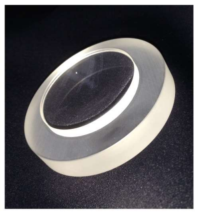












Barrel DIRC for EicC:

- Quartz radiator: 13mm x 36mm x 2400mm
- Expansion volume: 240mm x 360mm x 300mm
- MCP-PMT: Hamamastu R10754 4 x 4 array, pixel size: 5.75mm x 5.75mm
- Focusing: spherical 3-layer lens (Fused silica + LaK33B glass) curvature radius: 30◦, 30/7.5cm, thickness: 1cm

Achieve 3σ π/K separation up to 6 GeV/c with Cherenkov angle resolution ~ 1mrad.

Contributions to DIRC Angular Resolution

The experimentally measured Cherenkov angular resolution is expressed as

$$\sigma_{\Theta_C,\mathrm{Track}} = \sqrt{\sigma^2_{\Theta_C}/N_\gamma + \sigma^2_{\mathrm{Corr}}}.$$

There are various error contributions of the Cherenkov light generation process, which is related to the particle momentum, including track resolution, multiple scattering, system collimation error and other external environment factors.

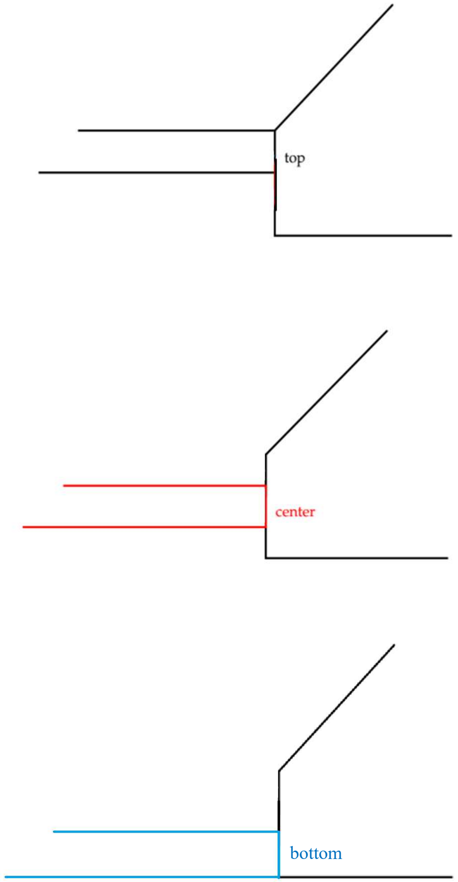
The Cherenkov photon angular resolution for each DIRC module can be refined to

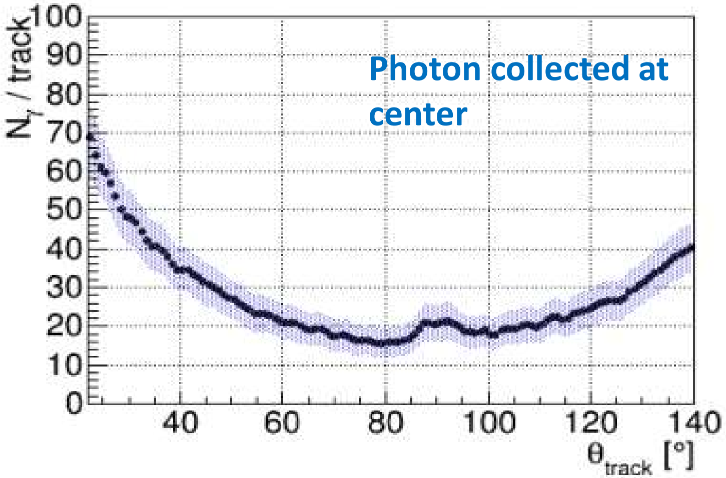
$$\sigma_{\theta_c} = \sqrt{\sigma^2_{chrom} + \sigma^2_{foc} + \sigma^2_{bar} + \sigma^2_{trans} + \sigma^2_{rec}}$$

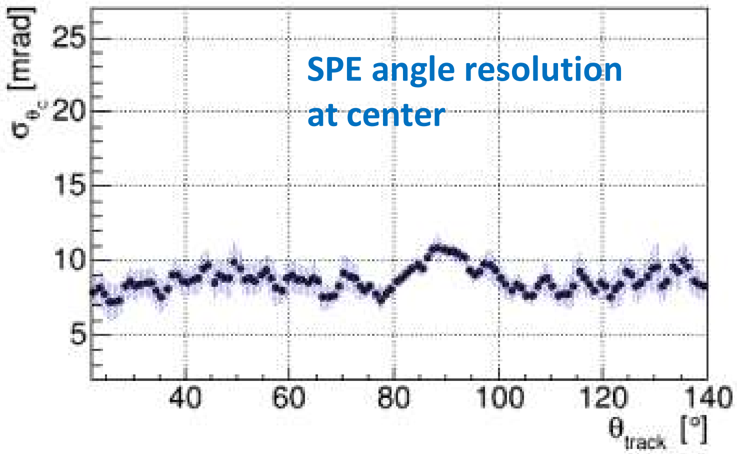
Chromatic dispersion of quartz radiator	Optical focusing lens and MCP-PMT pixel size	Thickness & width of quartz radiator	Surface properties of quartz radiator	Angle of the incident particles and image reconstruction
$\sigma_{chrom} = 5.4mrad$	$\sigma_{foc} < 10mrad$	$\sigma_{bar} \leq 2mrad$	$\sigma_{trans} \leq 3mrad$	$\sigma_{rec} \leq 1mrad$

To improve DIRC's performance, the optical geometry of radiator and focusing lens need to be optimized.

Simulation on different radiator installation positions

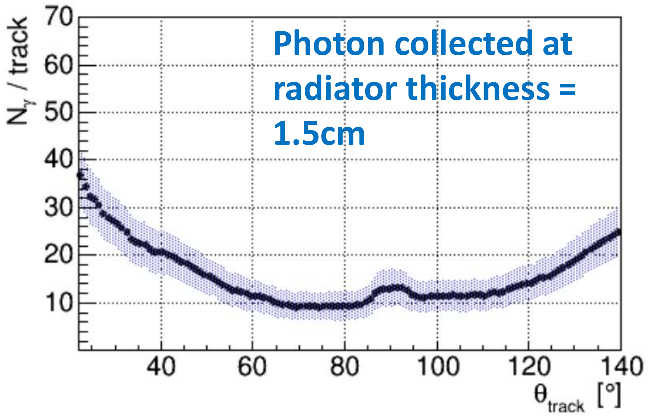


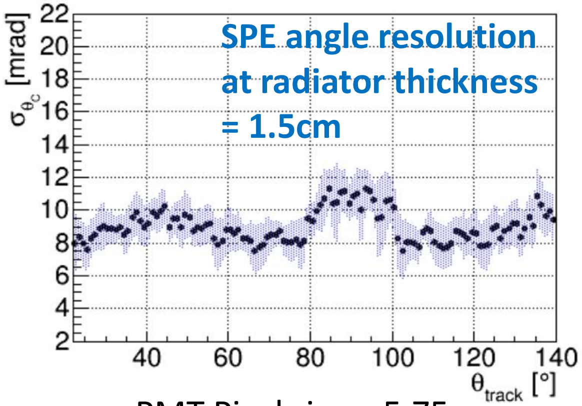




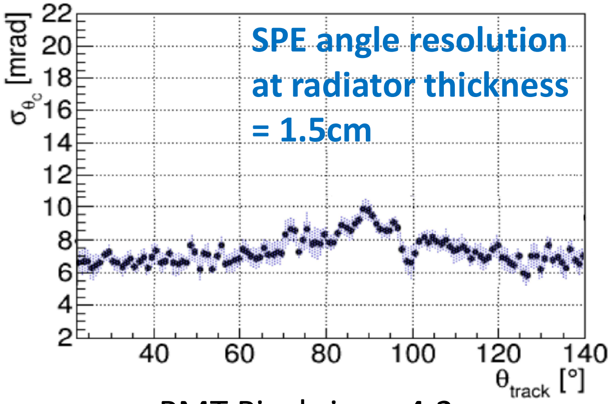
Radiator location	Photon number	SPE Angle resolution (mrad)
top	15 ~ 68	7 ~ 12
center	14 ~ 70	7 ~ 12
bottom	12 ~ 63	9 ~ 13

Simulation on different radiator thickness





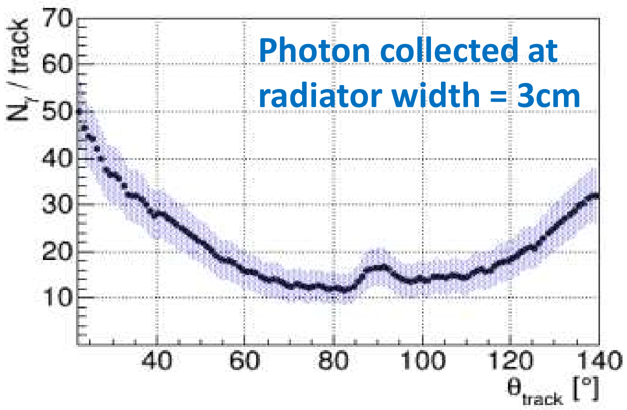
PMT Pixel size = 5.75mm

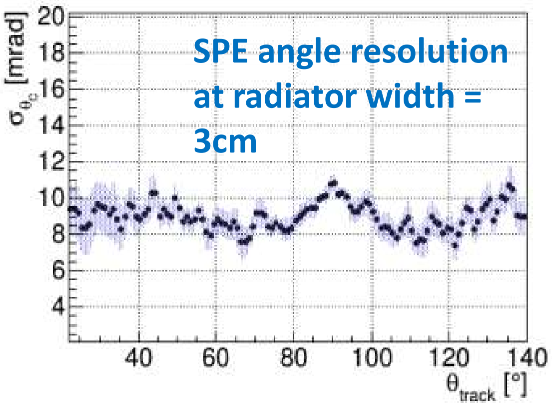


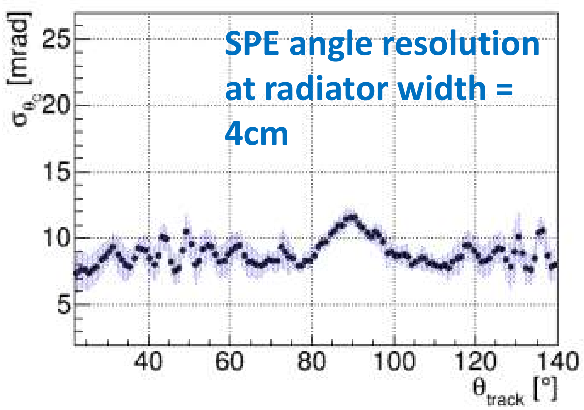
PMT Pixel size = 4.2mm

Radiator thickness	Photon number	SPE Angle resolution (mrad)
1cm	5 ~ 27	7 ~ 10
1.3cm	9 ~ 38	7 ~ 12
1.5cm	12 ~ 48	7 ~ 12
1.7cm	15 ~ 60	8 ~ 15
2cm	17 ~ 74	8 ~ 17

Simulation on different radiator widths

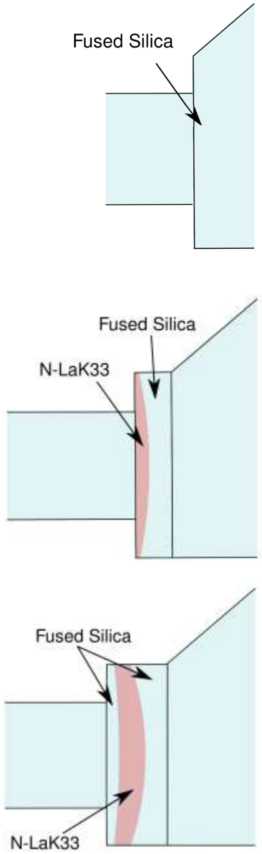


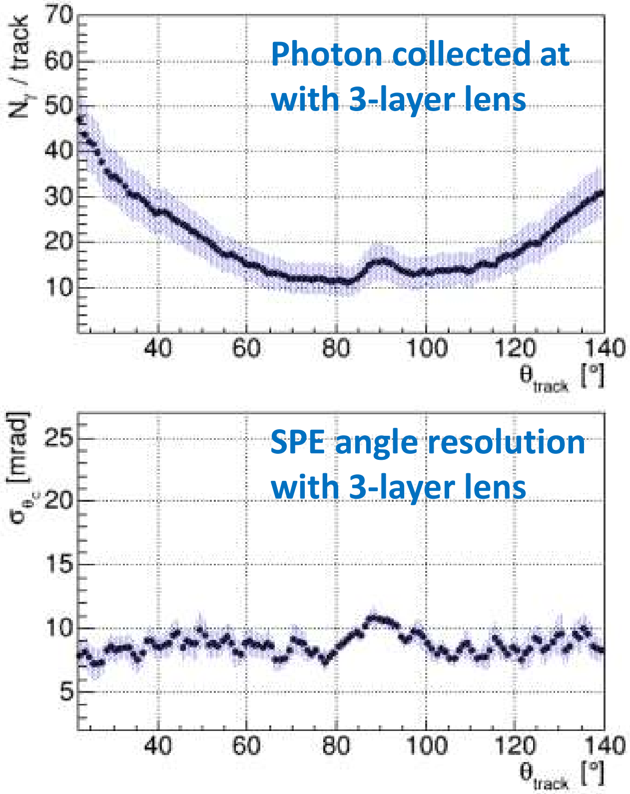




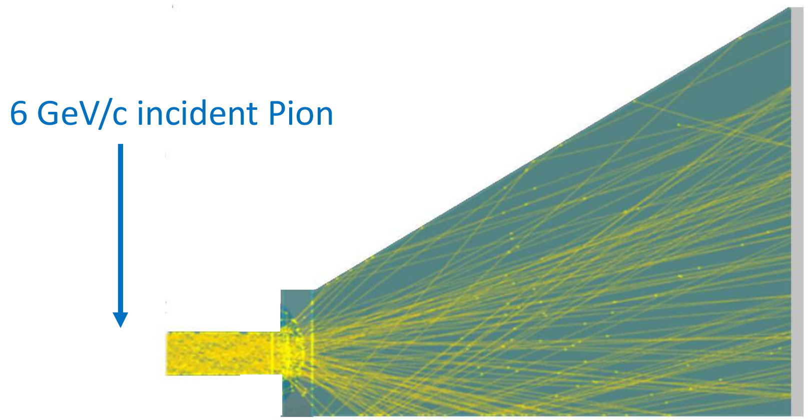
Radiator width	Photon number	SPE Angle resolution (mrad)
2cm	10 ~ 49	7 ~ 11
3cm	12 ~ 50	7 ~ 11
4cm	12 ~ 58	7 ~ 12
5cm	14 ~ 63	8 ~ 12
6cm	17 ~ 70	10 ~ 13

Angle resolution and photon yield with different focus

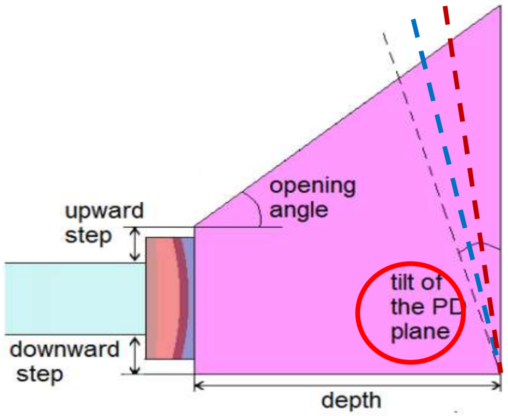


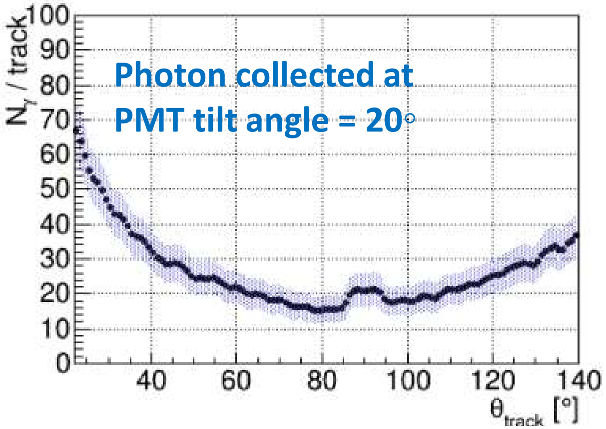


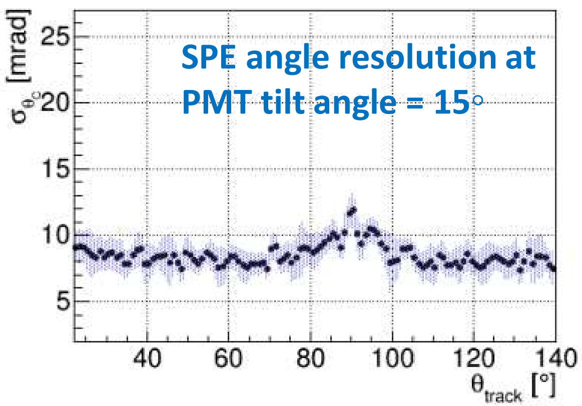
Optical Focus	Size (cm)	Photon number	SPE Angle resolution (mrad)
Without lens		17 ~ 56	11~ 24
2-layer lens	30°, R=7.5	14 ~ 54	8 ~ 18
3-layer lens	30°, 30/7.5	12 ~ 48	7 ~ 12

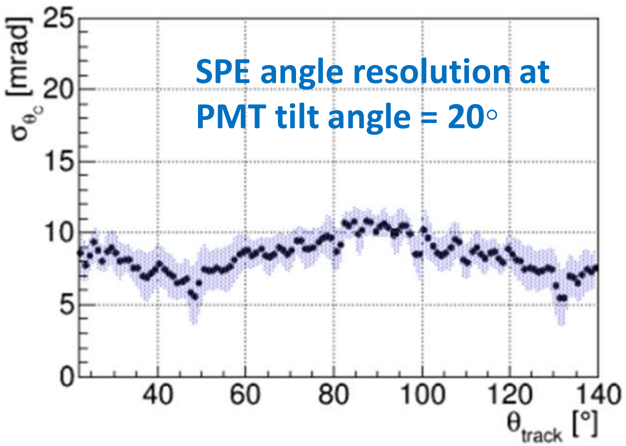


Simulation on different PMT tilt Angle



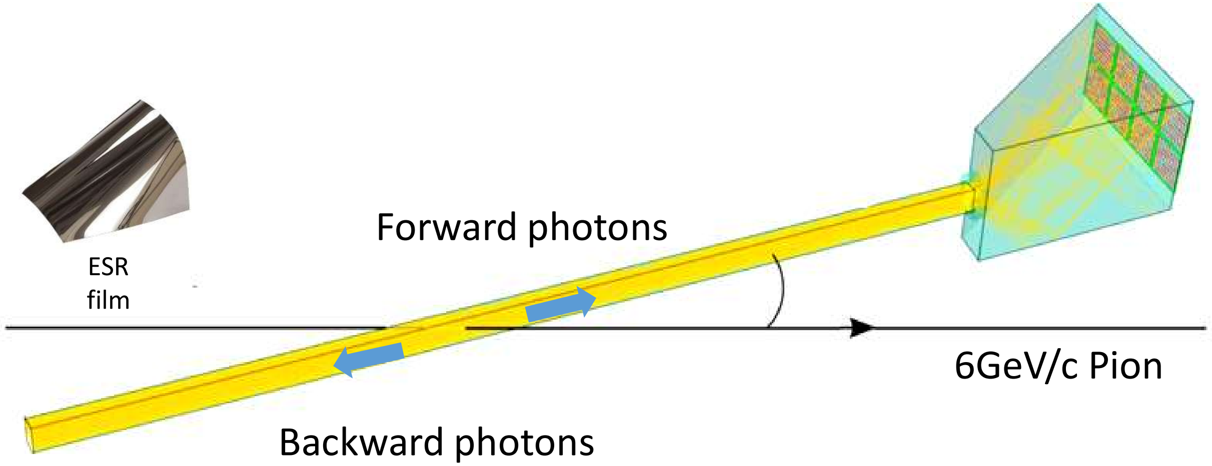


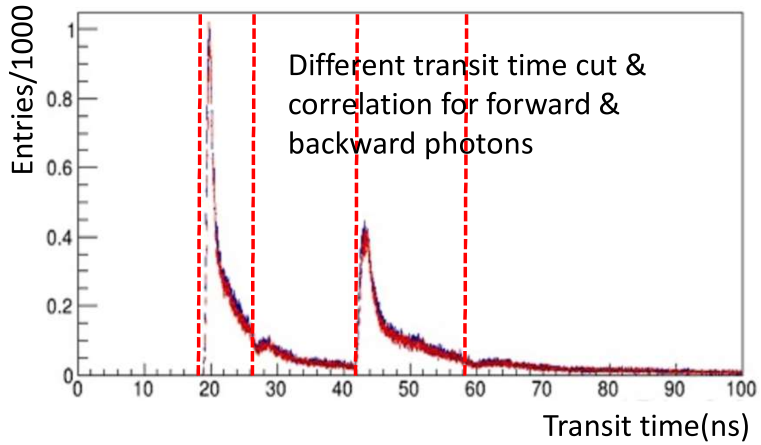


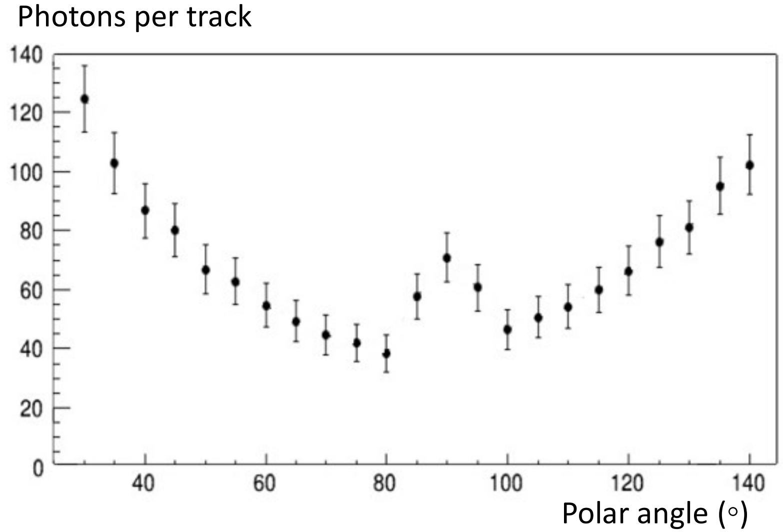


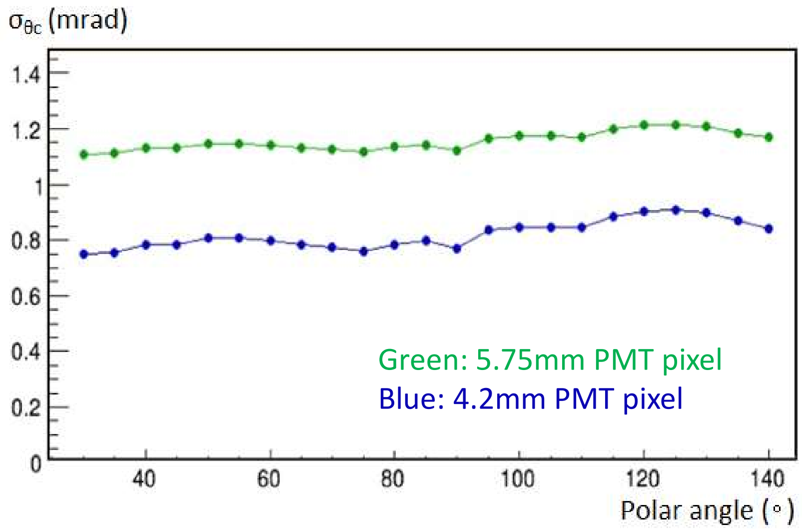
PMT plane Tile angle	Photon number	SPE Angle resolution (mrad)
10°	16 ~ 71	8 ~ 12
15°	16 ~ 69	7 ~ 12
20°	15 ~ 68	7 ~ 11
25°	13 ~ 67	7 ~ 13

Simulated performance for a single module



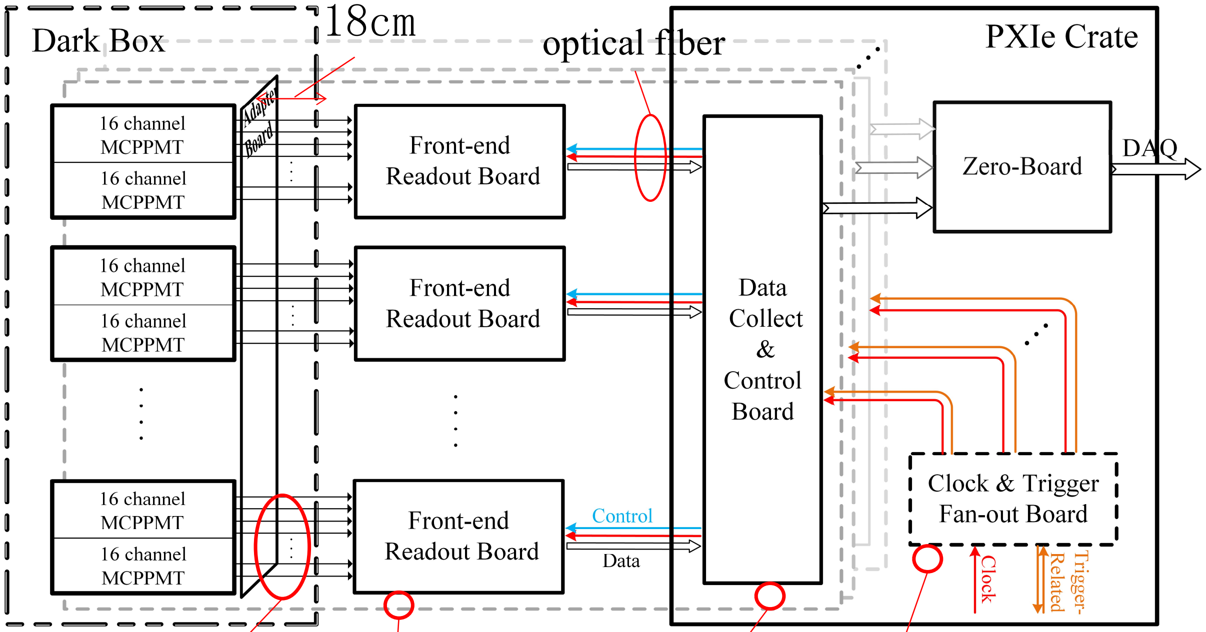




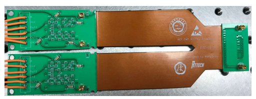


Readout Electronics

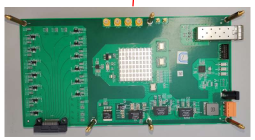
*The preliminary design from EicC USTC group



- 672 channels, 21 front-end boards and flexible boards, 1 T0 timing board, 2 data control boards, 1 clock fanout board, and 1 slot controller are finished
- 1 data control board coupled with 12 front-end readout, the bandwidth of the front-end readout is 320mb/s
- 1 slot controller can have up to 17 data control boards, and supports up to 17 × 12 × 32 = 6528 channels

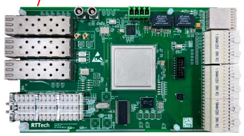


Flexible readout backpanel



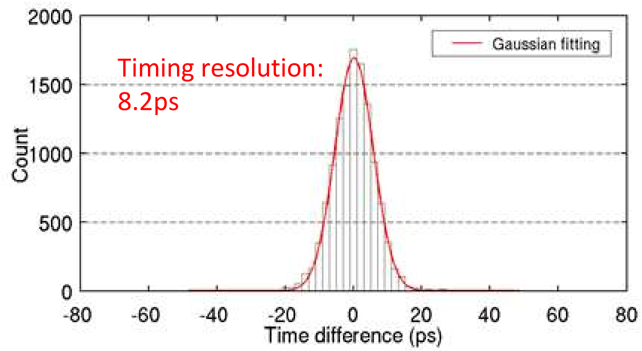
Front end readout board

Data control board



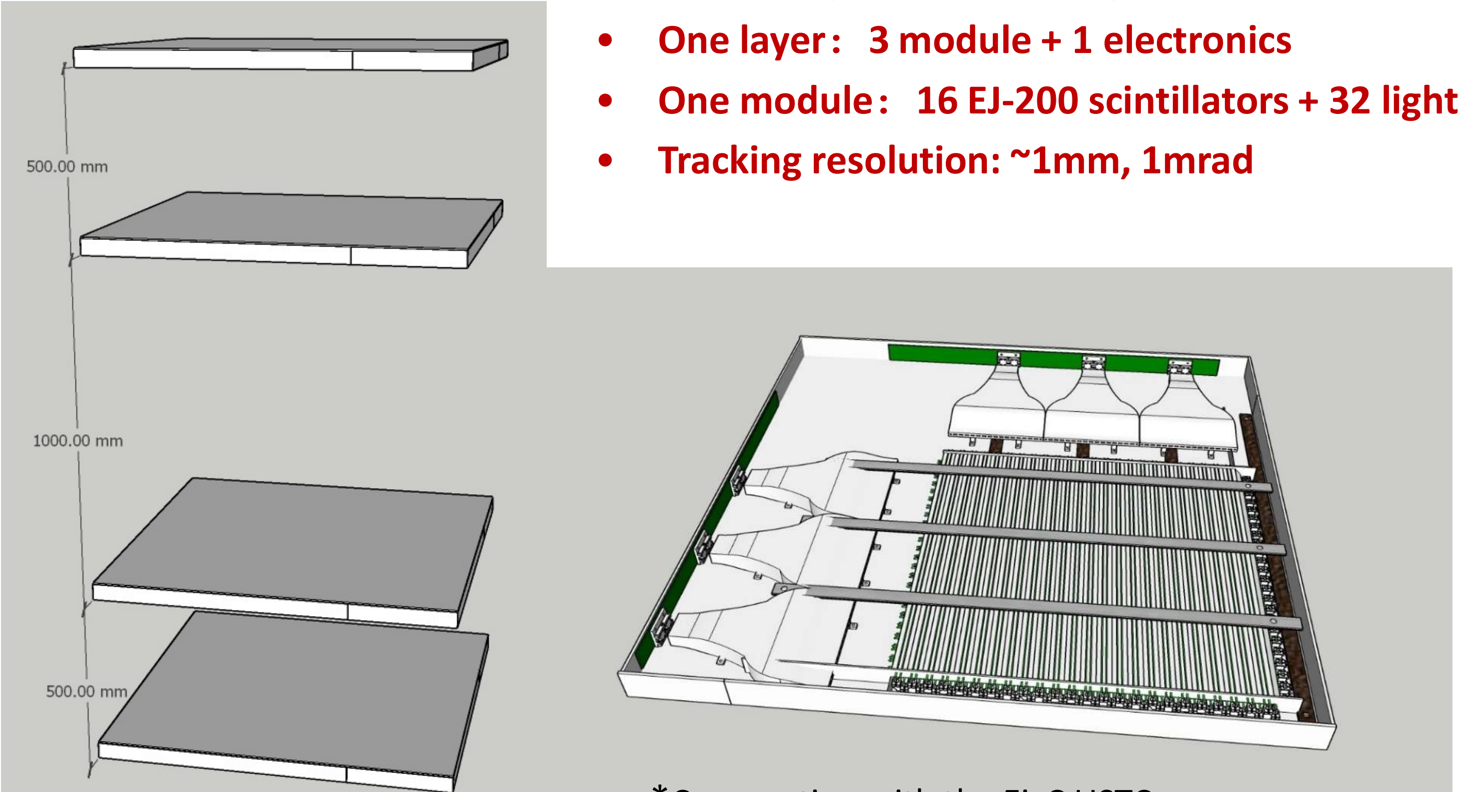
Clock fan-out board

slot controller



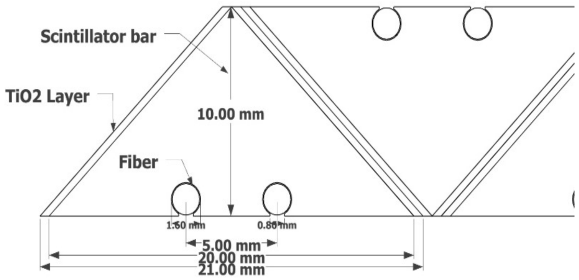
Cosmic Ray Test Platform

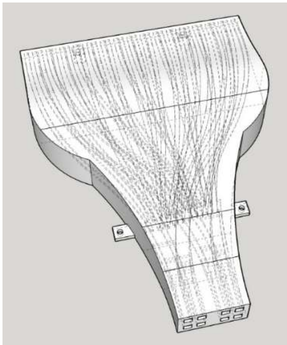
- **Cosmic ray detector： 8 layer 50cm x 50cm tracker (4 layer for x, y each)**
- **One layer： 3 module + 1 electronics**
- **One module： 16 EJ-200 scintillators + 32 light fiber + 8 SiPM**
- **Tracking resolution: ~1mm, 1mrad**

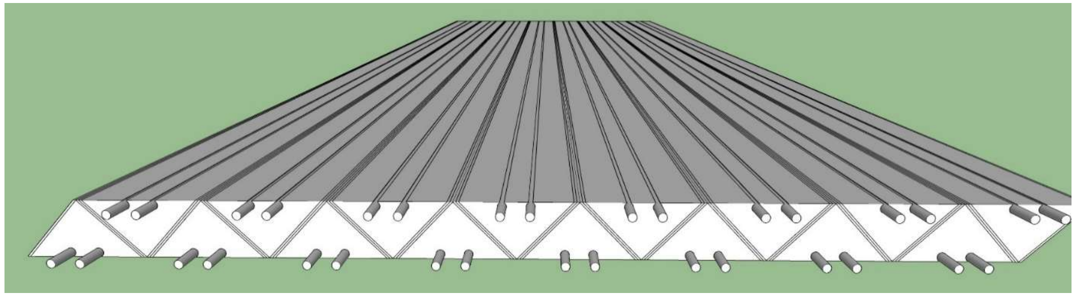


*Cooperation with the EicC USTC group

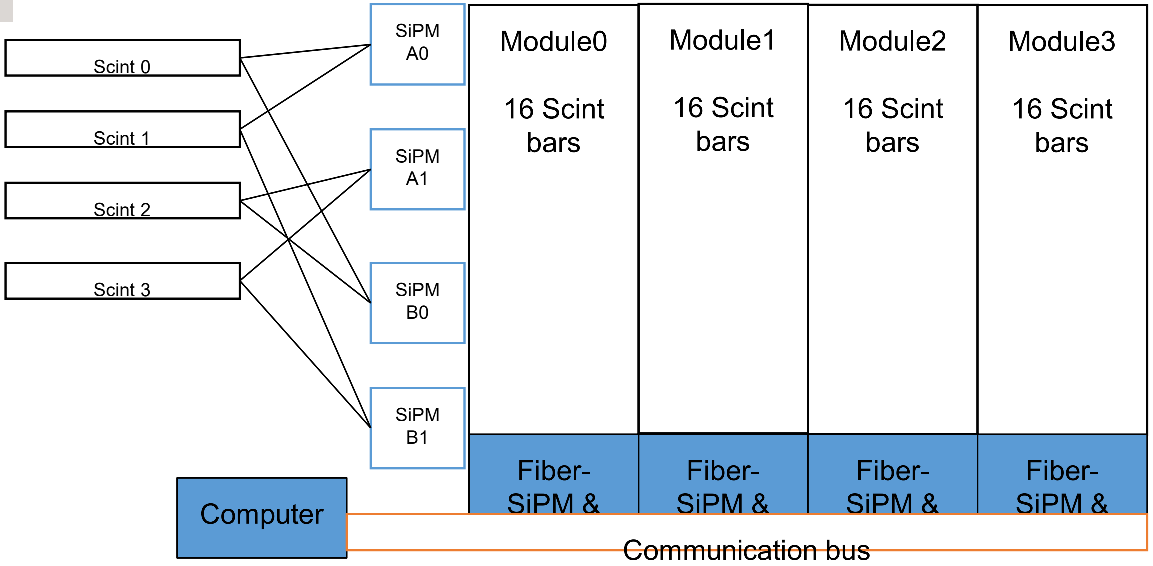
Cosmic Ray Module Design





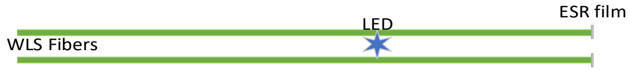


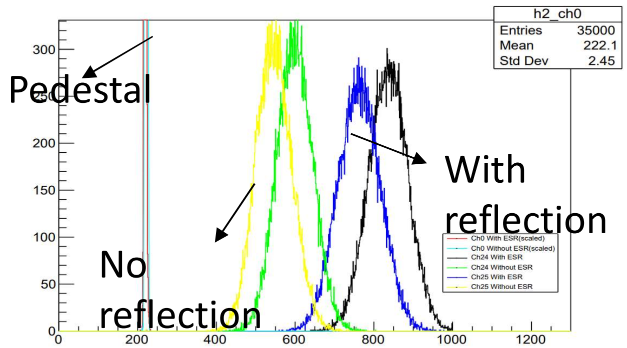
- **Detector module:**
  - **Larger detection area (50cm * 50cm)**
  - **Encoding readout**
  - **Tyvek wrapping**
  - **Double fiber design:**
    - **SiPM put in one side**
- **Light fiber:**
  - **Wider fiber**
  - **4 fibers correlated to 1 SiPM, a module consists of 8 SiPMs and 16 strips**
  - **Reflective end (ESR film)**



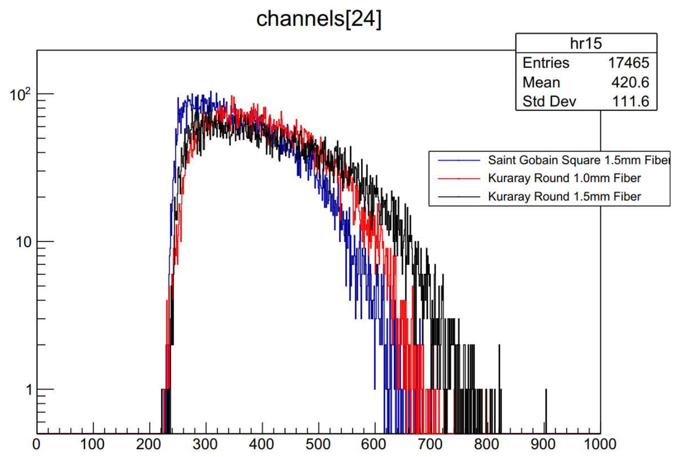
Performance Test of Single Strip

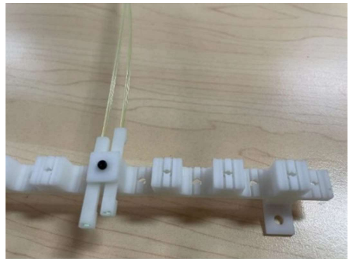
- ESR film reflection factor:
  - LED light source
  - 2 SiPMs coincidence
  - Yellow, green: ch24, ch25 without reflection
  - Blue, black: ch24, ch25 with reflection
  - Light collection: 50%-70% improvement





ESR film measurement

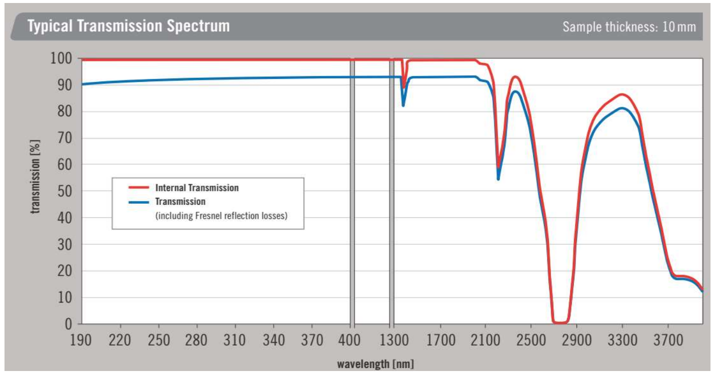


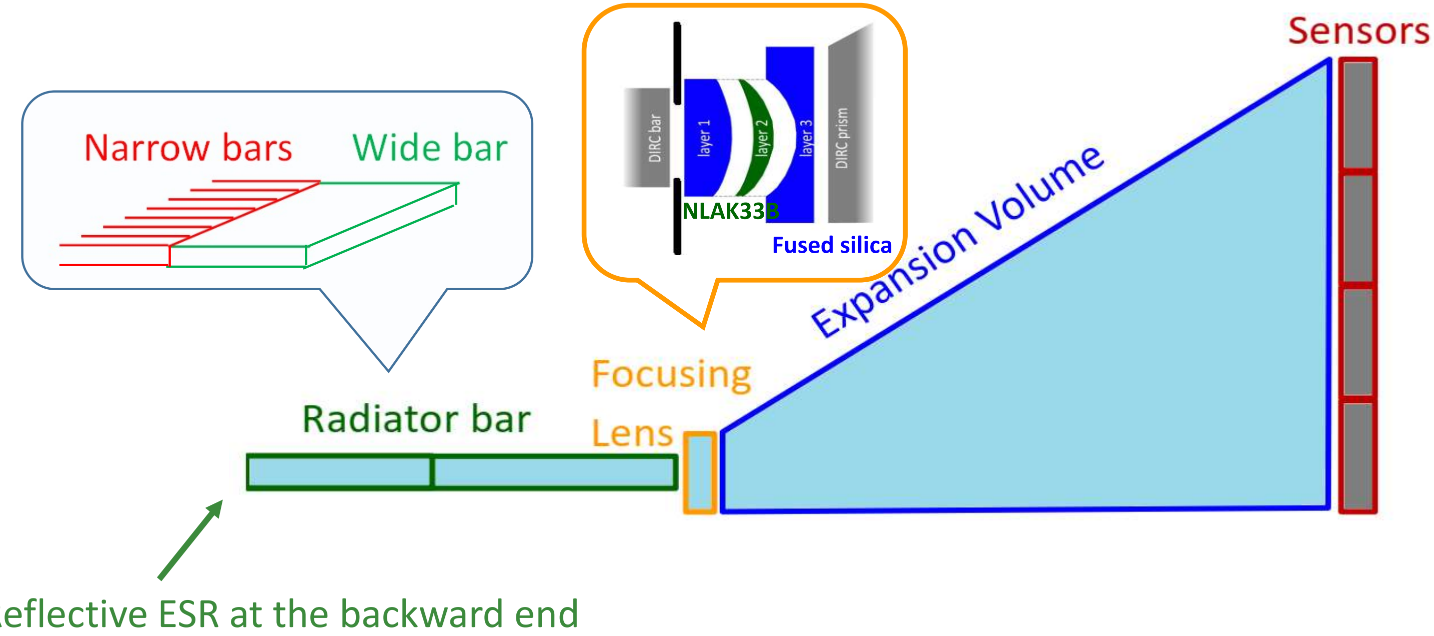


- Light output measurement:
  - No reflection for new strip with 2 grooves
  - Red: new strip + 1.0mm Kuraray fiber
  - Blue: new strip +1.5mm Saint-Gobain fiber
  - Black: new strip + 1.5mm Kuraray fiber

Next: DIRC Prototype Manufacture

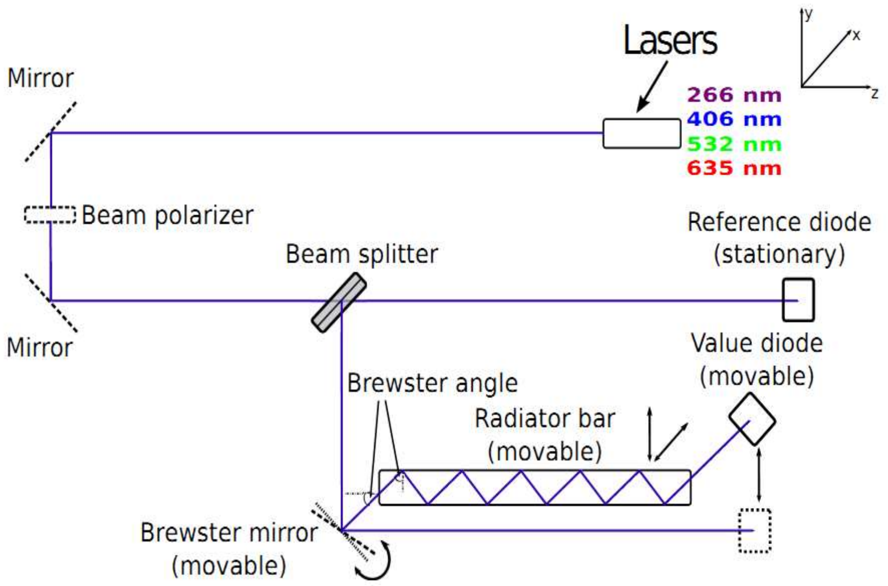
Radiator: 15mm x 36mm x 500mm, 10; 15mm x 360mm x 500mm, 1
Expansion volume: 240mm x 360mm x 300mm (Heraeus Suprasil UVL)
MCP-PMT: Hamamastu R10754
4 x 4 array, pixel size: 5.75mm x 5.75mm
Focusing: adjustable spherical multi-layer lens (Fused silica + NLAK33B glass)
various curvature radius & thickness (radius: 35-30cm, 25-20cm, thickness: 1cm, 1.5cm, 2cm, w/o pattern)

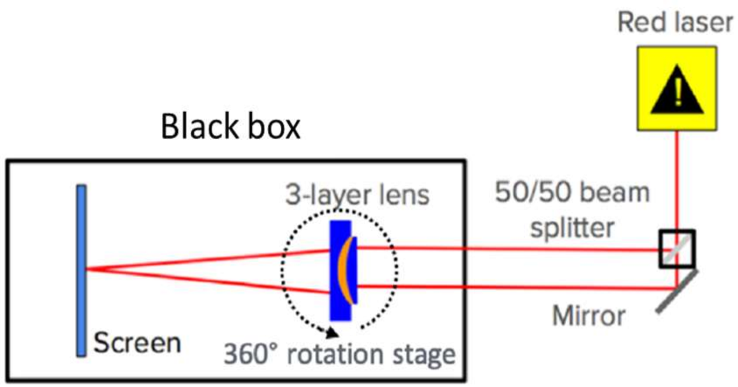




Next: Optical Performance Tests Setup

- To test optical characteristics of quartz radiator (including surface roughness, reflection coefficient, transmittance, etc.), four monochromatic light sources (covering the wavelength range of Cherenkov light) are provided by the laser.
- Through the optical beam spliter, the light beams enter the quartz at various incident angles.
- Two photodiodes (one serves as the reference) measure the light intensity changes at different incident positions and angles.





Summary

- **Barrel DIRC:**
  Simulated the DIRC performance with various geometry of radiator and focusing, optimize the design of DIRC module to achieve $\sigma_{\theta c}$ ~ 1mrad. Also developed 627ch readout electronics prototype.

- **Cosmic ray test:**
  Design & manufacture the cosmic ray platform for DIRC test

- **Next Step:**
  DIRC prototype manufacture & optical performance test

Thank you !