dRICH Optics

– Status, Issues & Plans –

Christopher Dilks

GD/I Meeting

30 January 2023

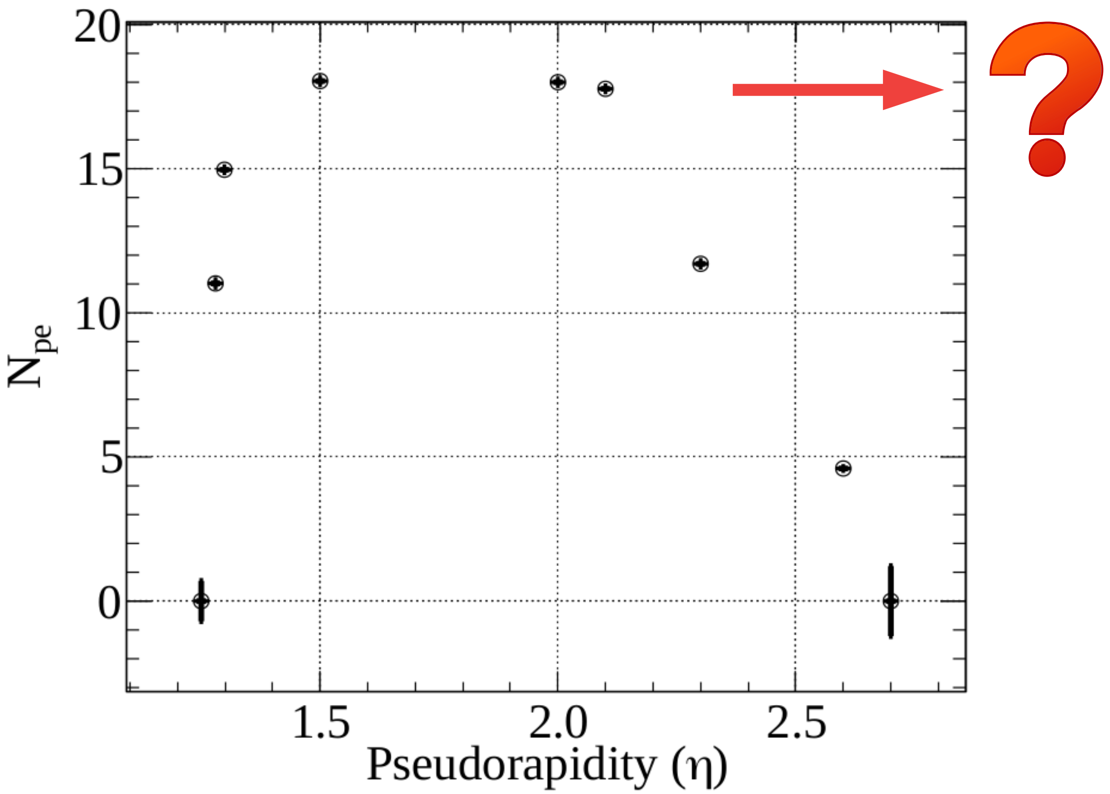
Acceptance shown at Collaboration Meeting

- 50 GeV pions
- Number of Photoelectrons (NPE) from gas radiator
- Acceptance limits:

  $1.3 < \eta < 2.3$

  $11.5° < \theta < 30°$

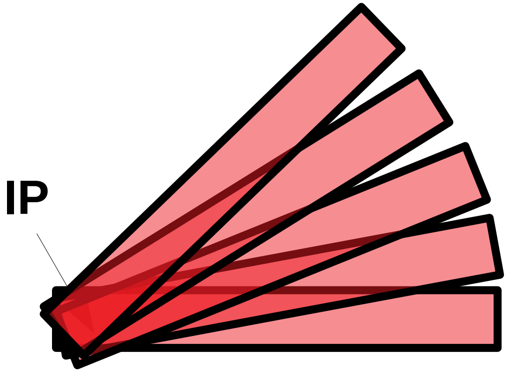
  Integrated over ϕ
- Optics could be improved…



Study from C. Chatterjee

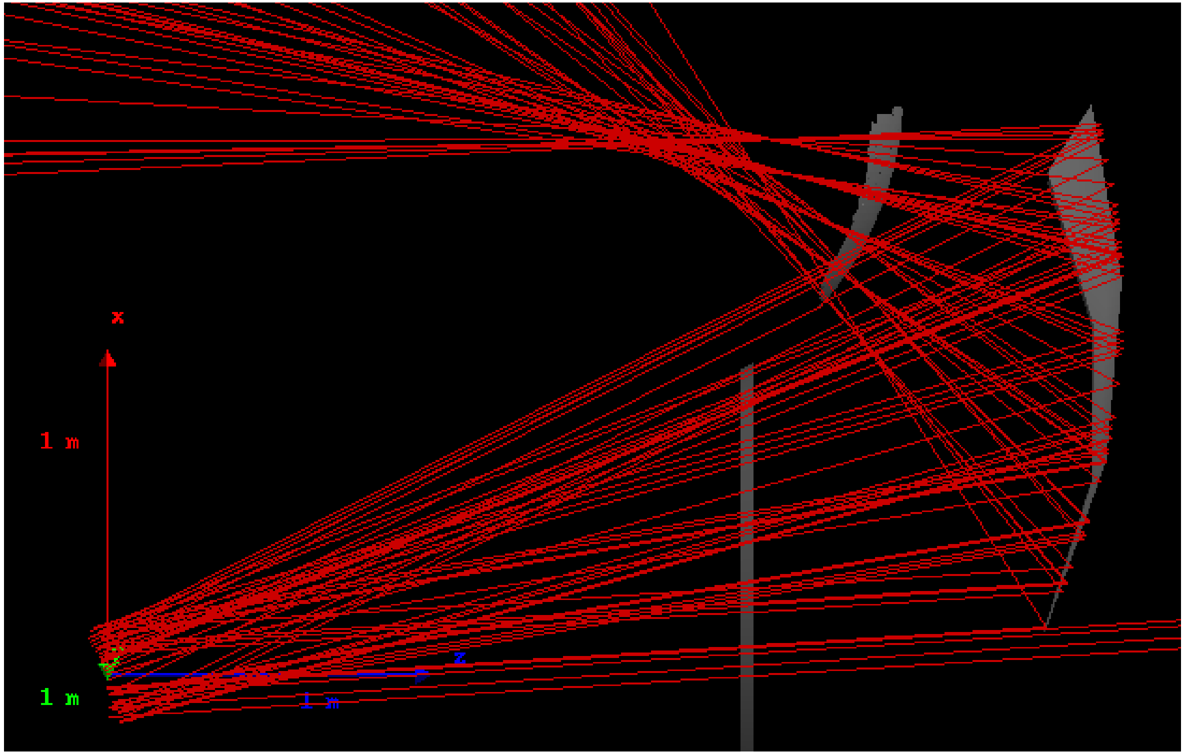
The optics we had in August 2022 …

- 5, wide collimated photon beams
  - Emitted from IP
  - Within full dRICH η acceptance, evenly spaced

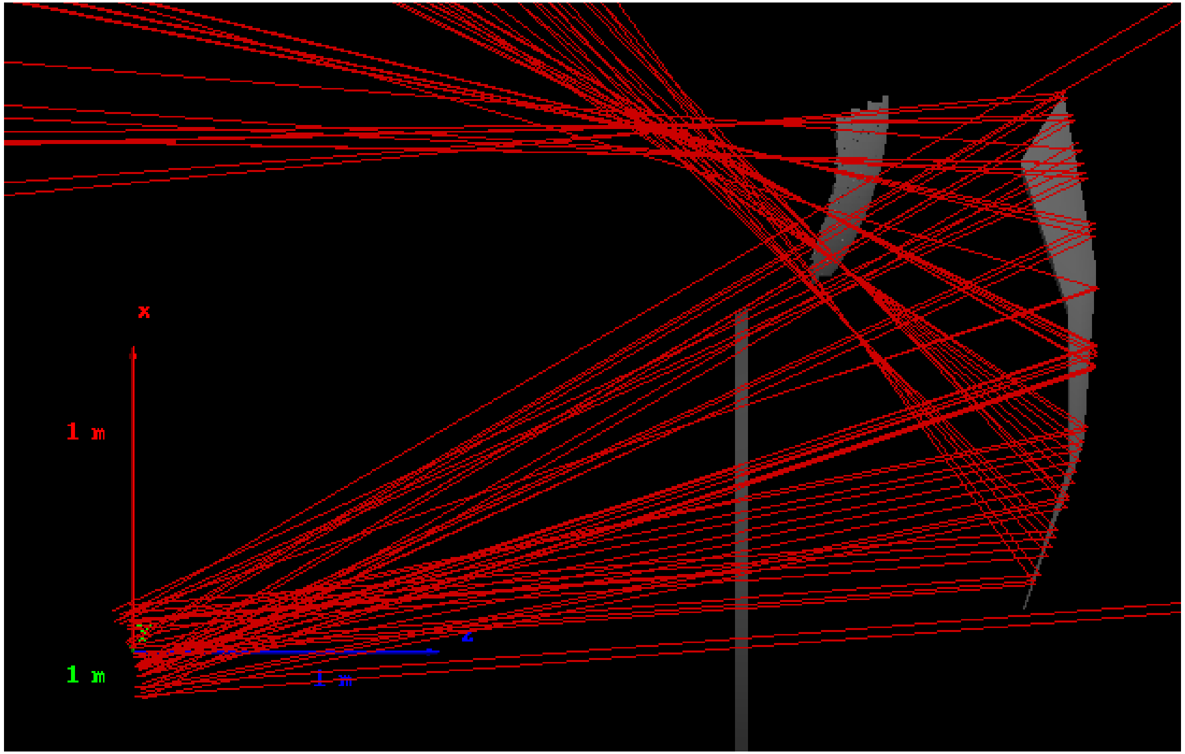


Parallel-to-point focal region to *approximate* the real Cherenkov focal region

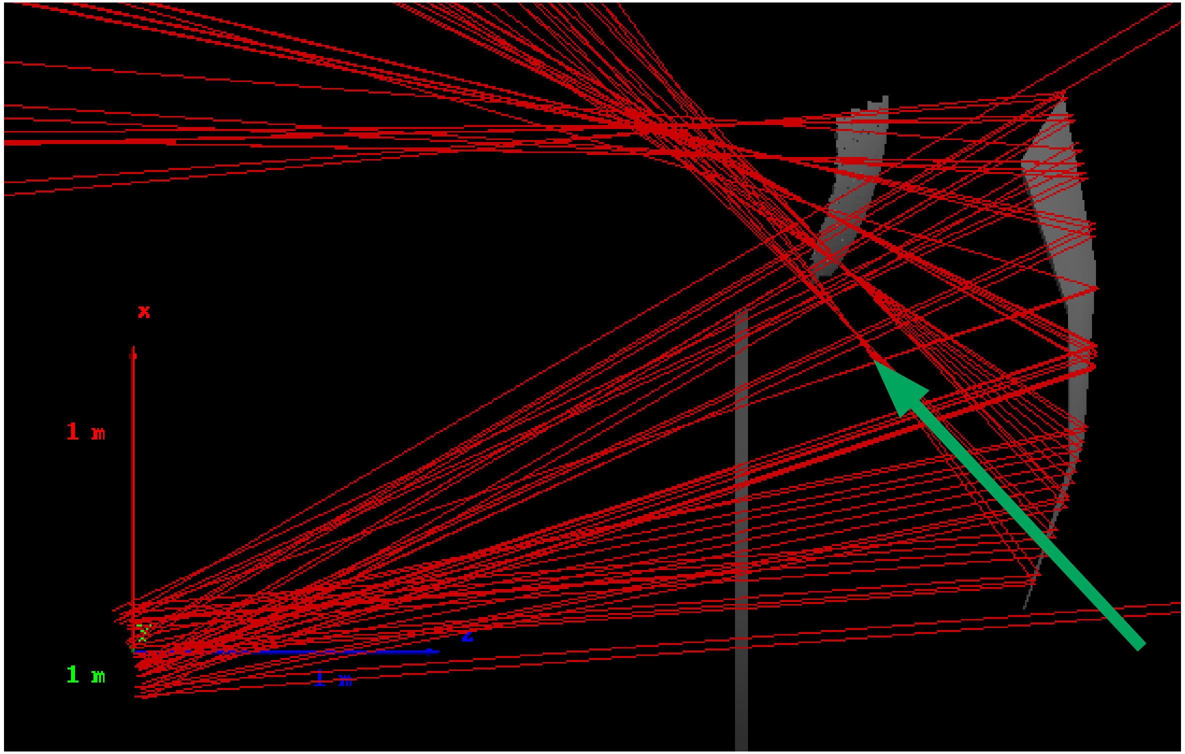
Tuned in https://github.com/eic/epic/pull/24



… vs. what we have now



… vs. what we have now



- Oversight, lost in last minute geometry changes prior to October campaign
- Importance of continuously testing *everything* during rapid development

High η misses the sensors!

What to do next

- **Restoring full η acceptance: easy**
- **Getting good focus across all η: difficult**
  - *impossible* with a single spherical mirror (per sector)
- **Need to also improve sensor placement to better match the actual focal region**

Brute Force Optimizer: better than nothing…

- **Scan the parameter space, hoping to find a reasonable region**
- **Start with a coarse, 5-dimensional lattice**
  - Sensor sphere center (z,x) and radius (r) + mirror focus tunes (z,x) which steer the focal region
- **Choose the "best" option(s)**
  - chosen "by eye", since performance characterization is not (yet) connected to this optimizer; looking for:
    - Small ring resolution
    - Maximum acceptance; sensors are not blocking the Cherenkov cones
    - Photons are close to normal incidence on the sensors
- **Repeat with a finer lattice near this "best" region, until we converge with reasonable optics**

This was the technique in August; repeat it <u>now</u> to correct the η acceptance

(or just tune it by hand)

Implementation serves as an <u>entry point</u> for smarter optimizers

Aerogel Radius

Component	Sub-Component	WBS	Length (cm)	Inner Radius (cm)	Outer Radius (cm)	Offset from Center (cm)	Physical Start (cm)	Physical End (cm)
Dual RICH		6.10.04	120	15.0	185	195	195	315
	Detector Section		*100*	*15.0*	*185*	*215*	*215*	*315*
	Aerogel Section		*20*	*15.0*	*110*	*195*	*195*	*215*

from Menagerie

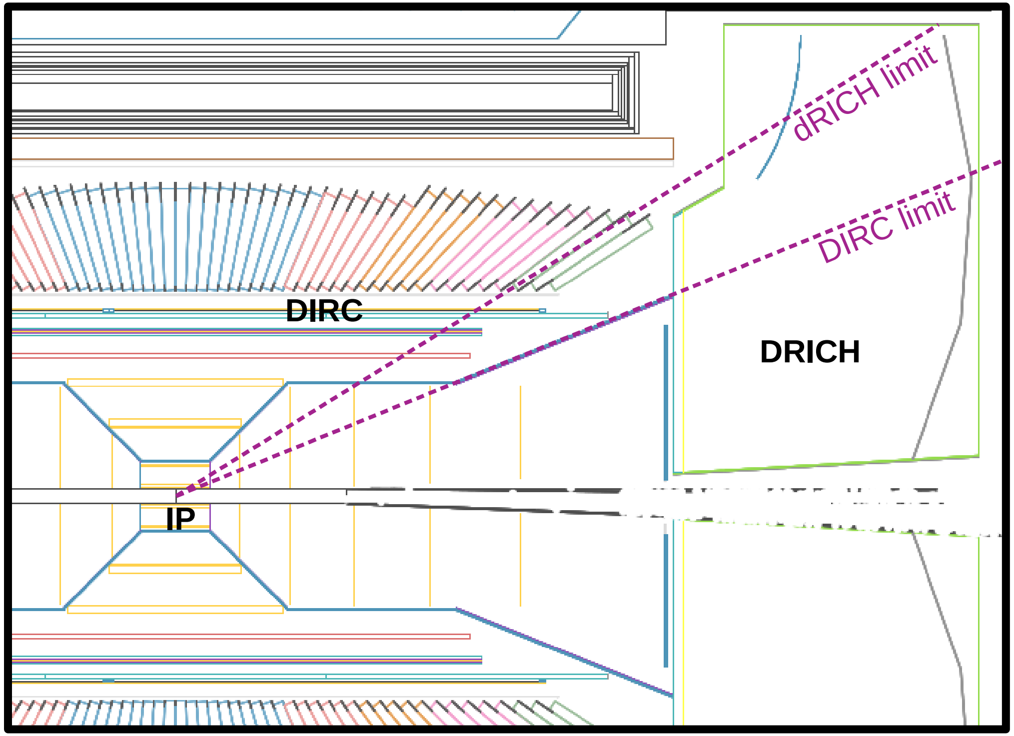
Do we really want aerogel radius at 110 cm?

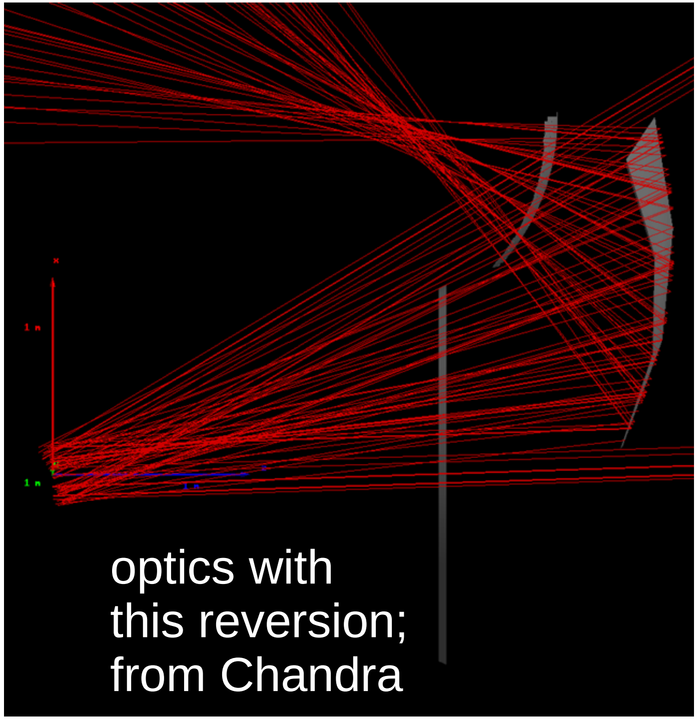
- Inconsistency between DD4hep aerogel radius and menagerie noticed in October; changed DD4hep 95 cm → 110 cm https://github.com/eic/epic/pull/217
- It's possible this change was the culprit for our sudden loss of acceptance at high η: the optics were simply not re-tuned well enough to compensate for this change

Aerogel Radius

- Consider reverting this change: 110 → 95 cm
- Overlap of DIRC and dRICH aerogel (?)
- Adds room for services

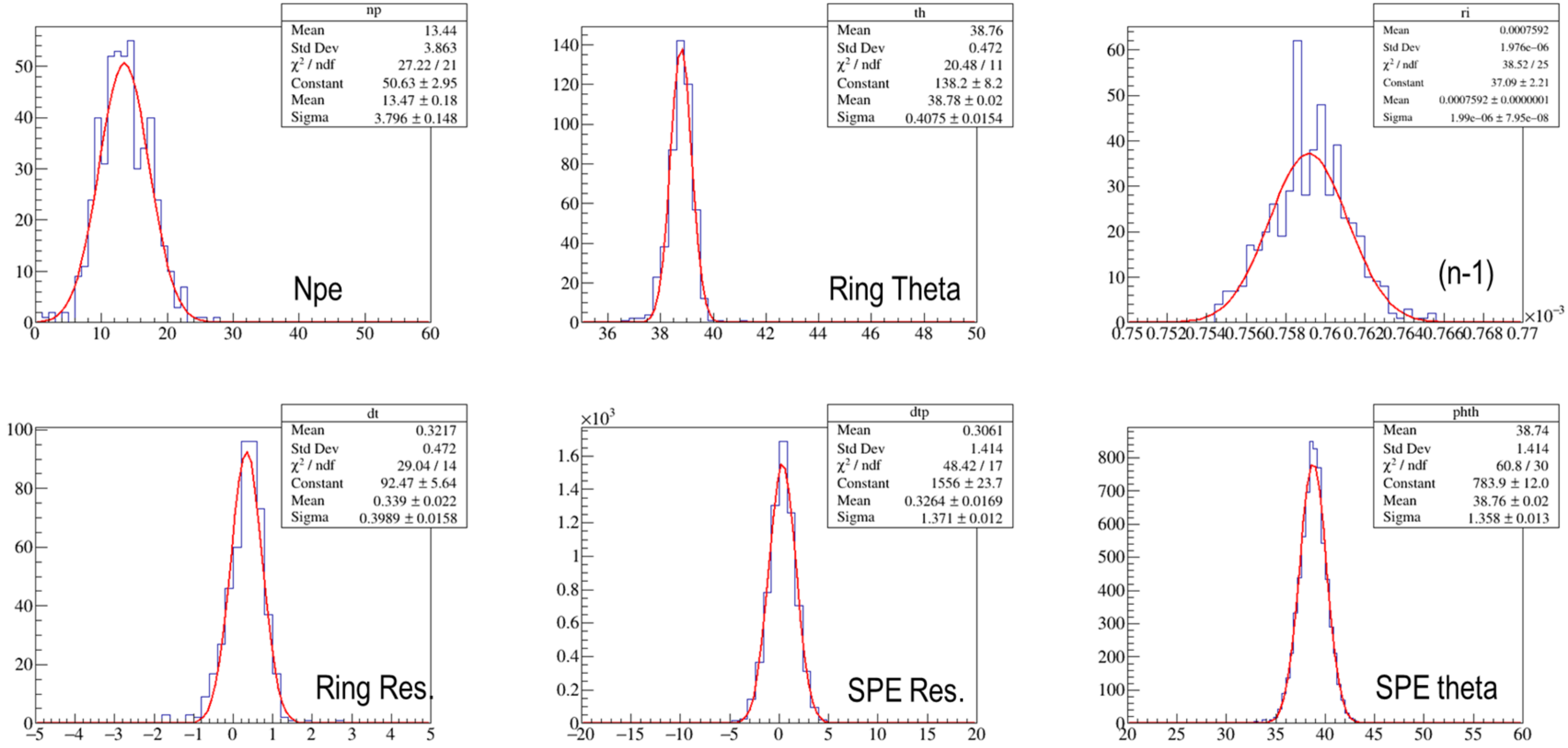
Aerogel radius currently at 110 cm (at entrance)
Magenta dashed lines for projective reference





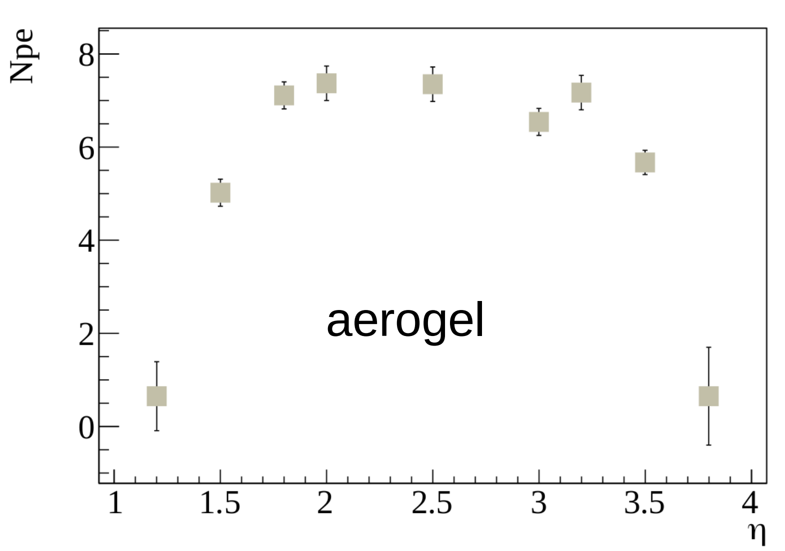
High η (gas)

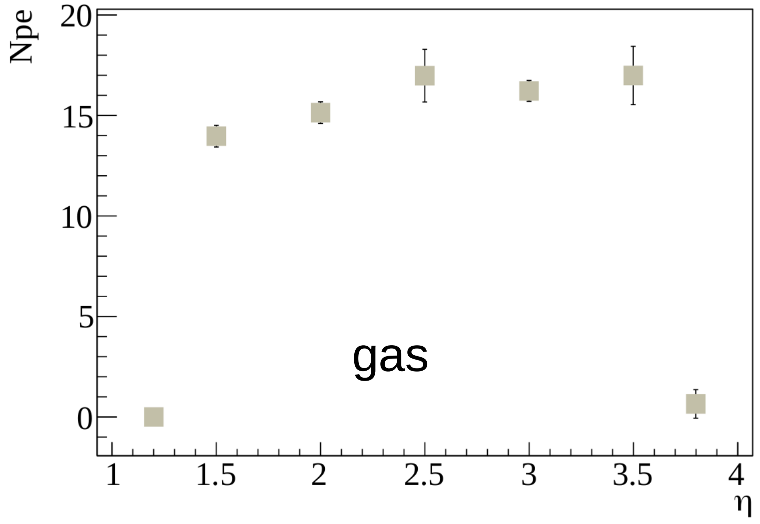
Study from Chandra
Reduce aerogel radius 110 → 95 cm
Thrown 30 GeV pions, **at η=3.5**



Updated acceptance

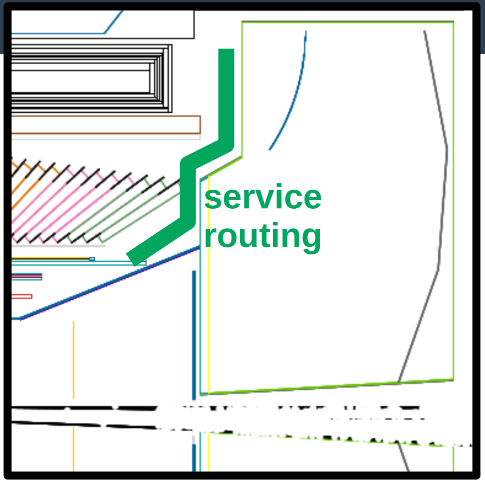
- 10 GeV pions
- Number of Photoelectrons (NPE)
- Low NPE for aerogel (?)



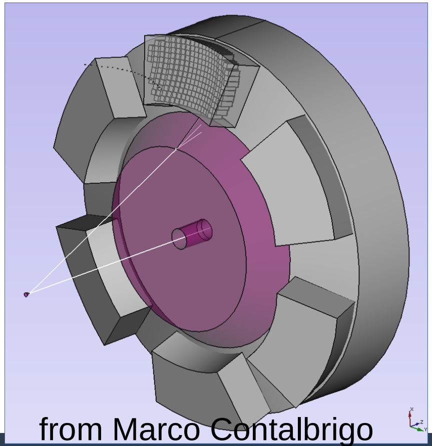


study from Chandra

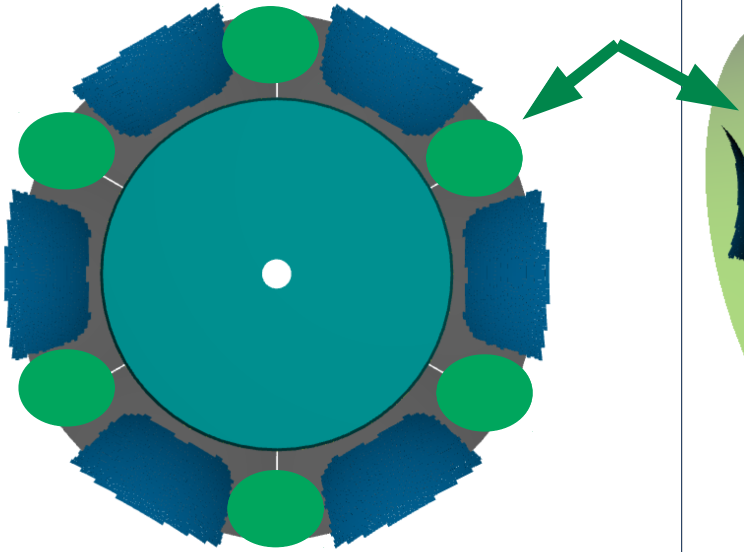
Utilizing Dead Space between Sectors

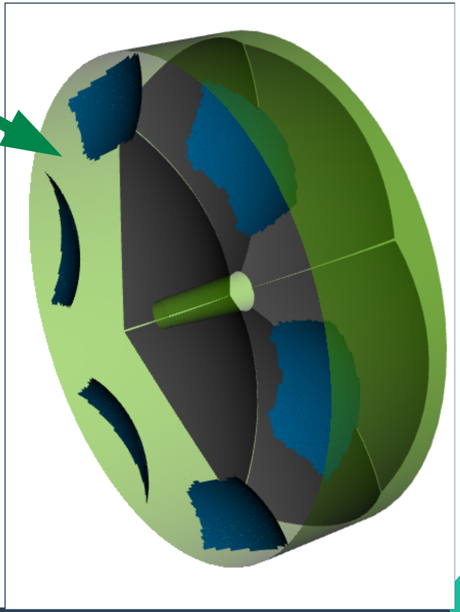


- What if we want larger aerogel radius
- What if we want to place the sensors less “in the way” of the initial Cherenkov cones?
- Use empty azimuthal space between sensors, where we expect no reflected Cherenkov photons, to route services
- Extrude sensor regions into existing service gap?



from Marco Contalbrigo



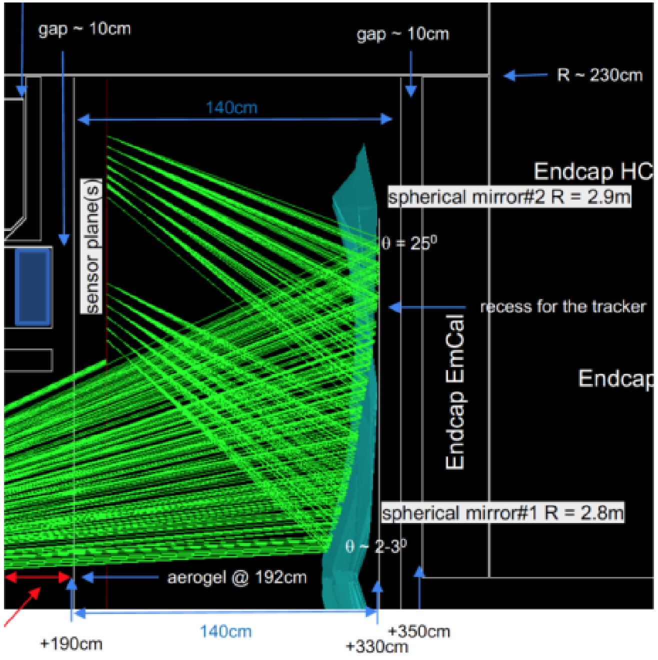


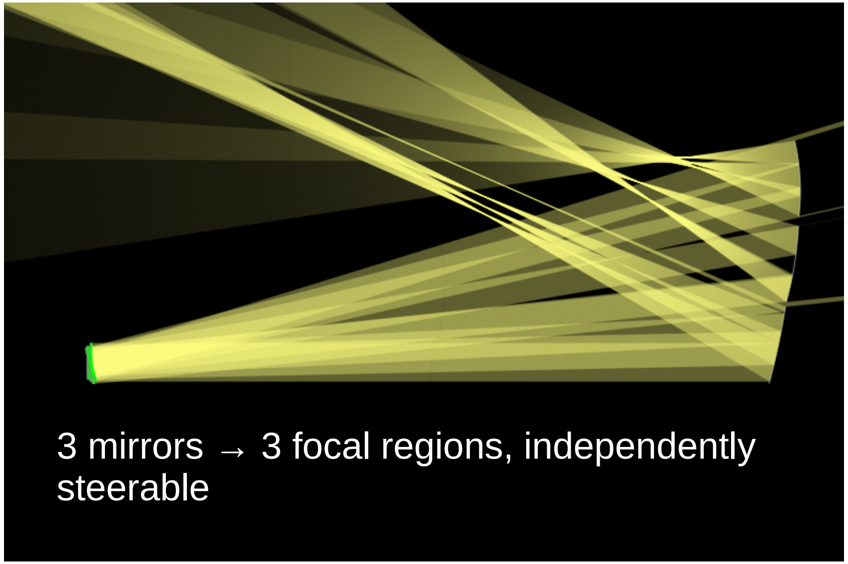
Trade-Offs to Think About

- **Smaller aerogel radius**
  - need overlap with DIRC at low momentum
  - allows for larger focal region, which would need relatively more sensors
- **Larger aerogel radius**
  - need smaller focal region → less sensors
  - shorter gas-path length at high η, from the mirror angle needed to tighten the focal region → loss in NPE in a critical region for PID

Multiple Mirrors → Sensor Placement Flexibility

Alexander's Dual Mirror study:



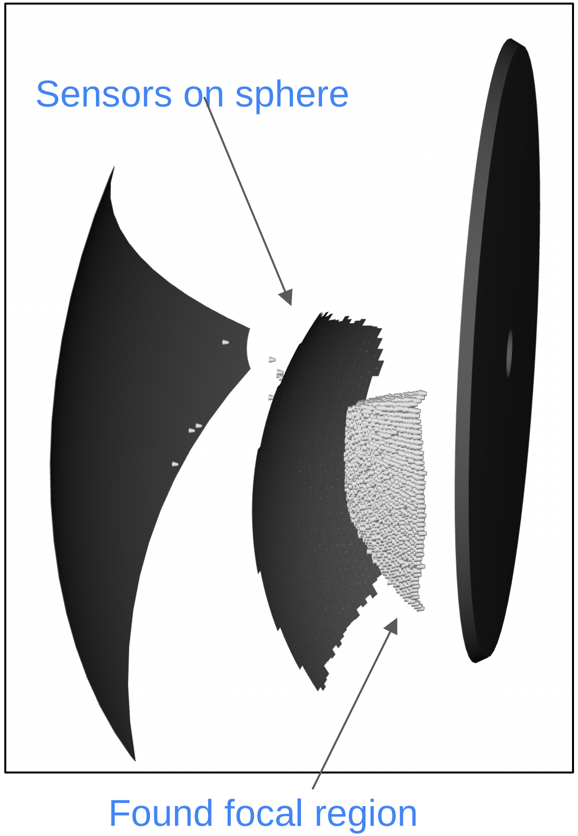


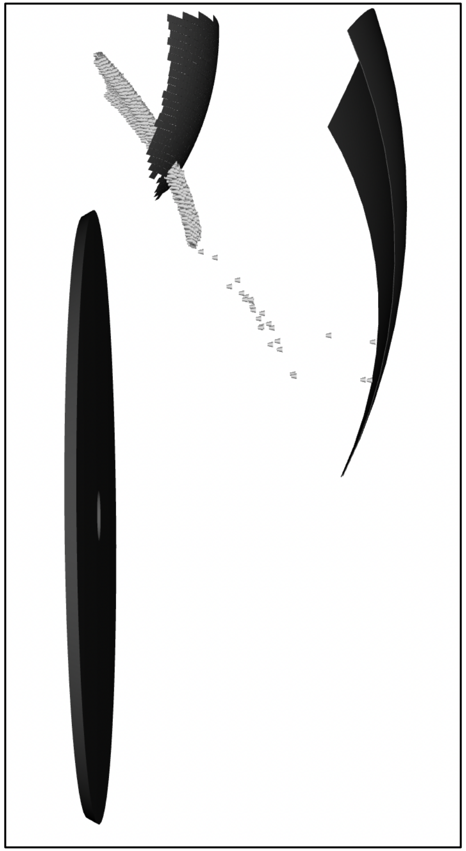
toy ray optics simulator:
https://ricktu288.github.io/ray-optics/simulator/

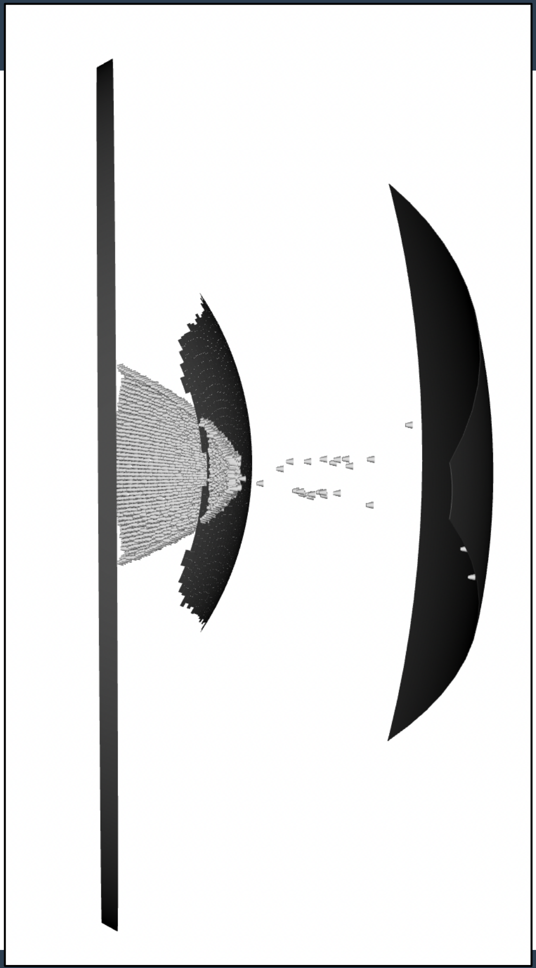
Use mirrors with differing radii and centers to make our own focal region and mitigate spherical aberrations

dRICH Focal Region Finder → Sensor Placement Guidance

from Connor Pecar







Implementation Strategy for Multi-Mirrors & Sensor Positioning

- We already have multi-mirror DD4hep geometry code from ATHENA
  - Update it for ePIC
  - Improve it, make it work
  - Tune the focus (by hand / brute force)
  - Then figure out where to put the sensors
- **Need a person who enjoys geometry and code to dedicate time and effort to do this**

PID Implementation

- **Indirect Ray Tracing (IRT)**
  - Juggler integration – done → "legacy support"
  - Migration to EICrecon underway → Everything written, now in a debugging phase
- **PID Task Force**
  - The dRICH is the *only* PID detector to use the ePIC software stack
    - And along with the pfRICH, these were the *only* Cherenkov PID detectors to seriously use the ATHENA software stack
  - Following algorithm independence:
    - Allows for sharing of algorithms with other subsystems, e.g. digitizers, track projectors, etc.
    - Braced for impact of reconstruction framework refactoring
  - Other PID detectors need to start joining the effort… with the caveats:
    - Respect higher priorities, e.g. pfRICH and mRICH studies are needed *now*, but probably should stay with the code that is already working for them
    - Respect that the PID detector *geometry* may not be quite correct and up-to-date for some PID subsystems… but we need reconstruction eventually anyway to help fix the geometry
    - Respect The Charge
  - Need the people power from each PID subsystem to do the algorithm implementation

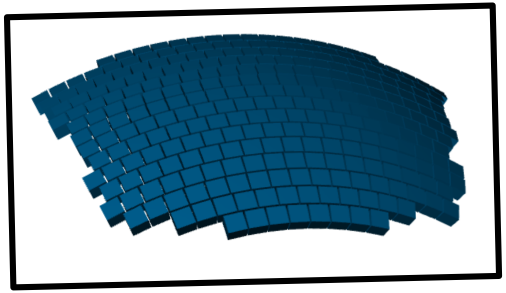
Summary and Outlook

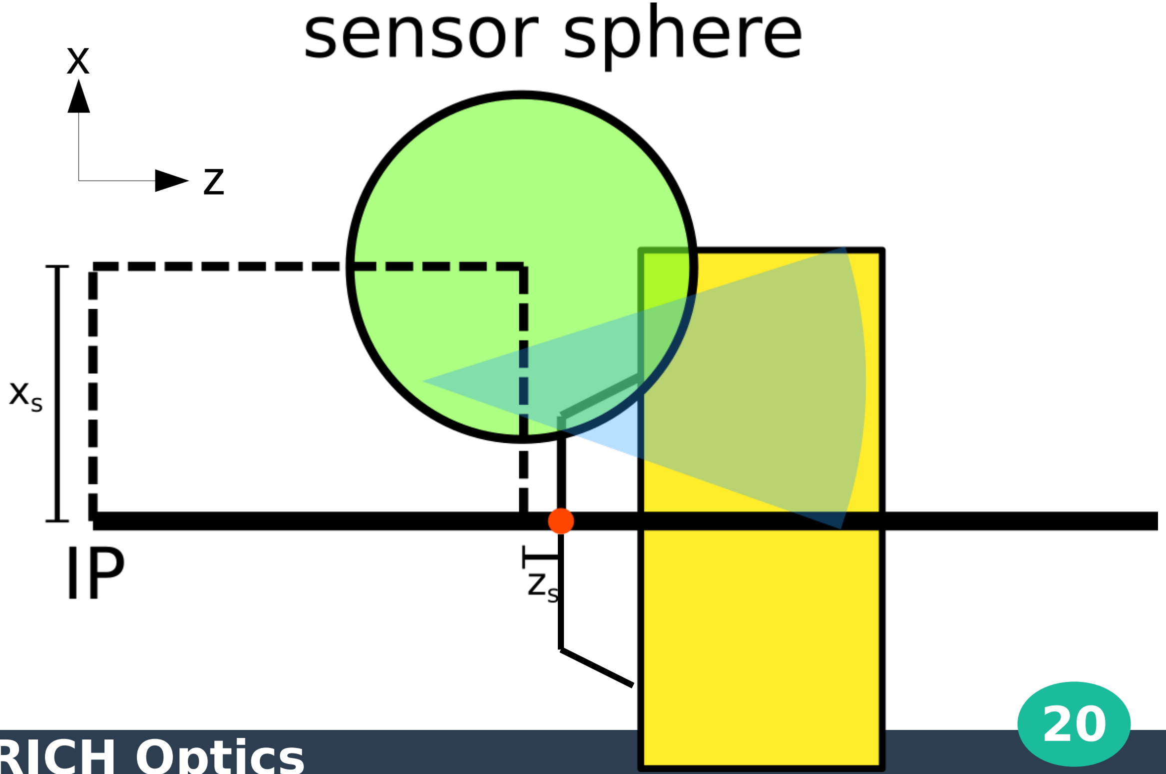
- **Optics issues**
  - Limited η acceptance → easy to resolve (solved), issue slipped under the radar
  - Good focusing across all η → much more difficult
    - Need multi-mirror configuration
    - Need to improve placement of sensors
    - Need to study the “actual” focal region (not just the parallel-to-point focal region “approximation”)
    - Need people power!
      - The tools are here, we need someone willing to use them, improve them as needed, and do the work

backup

Parameterized Optics: Sensor Placement

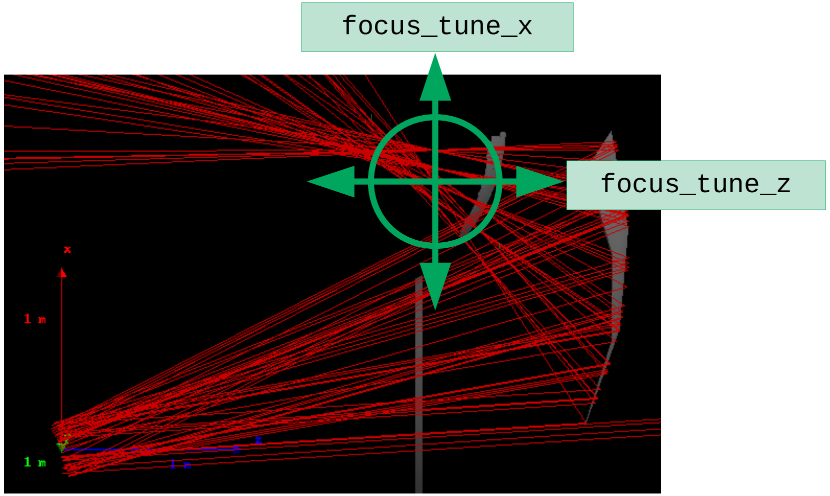
- **Sensor sphere**: sensors are tiled on a sphere
  - Not ideal; sensor positioning refinement under study
- 3 numbers:
  - Center position (z_s, x_s)
  - Radius r_s

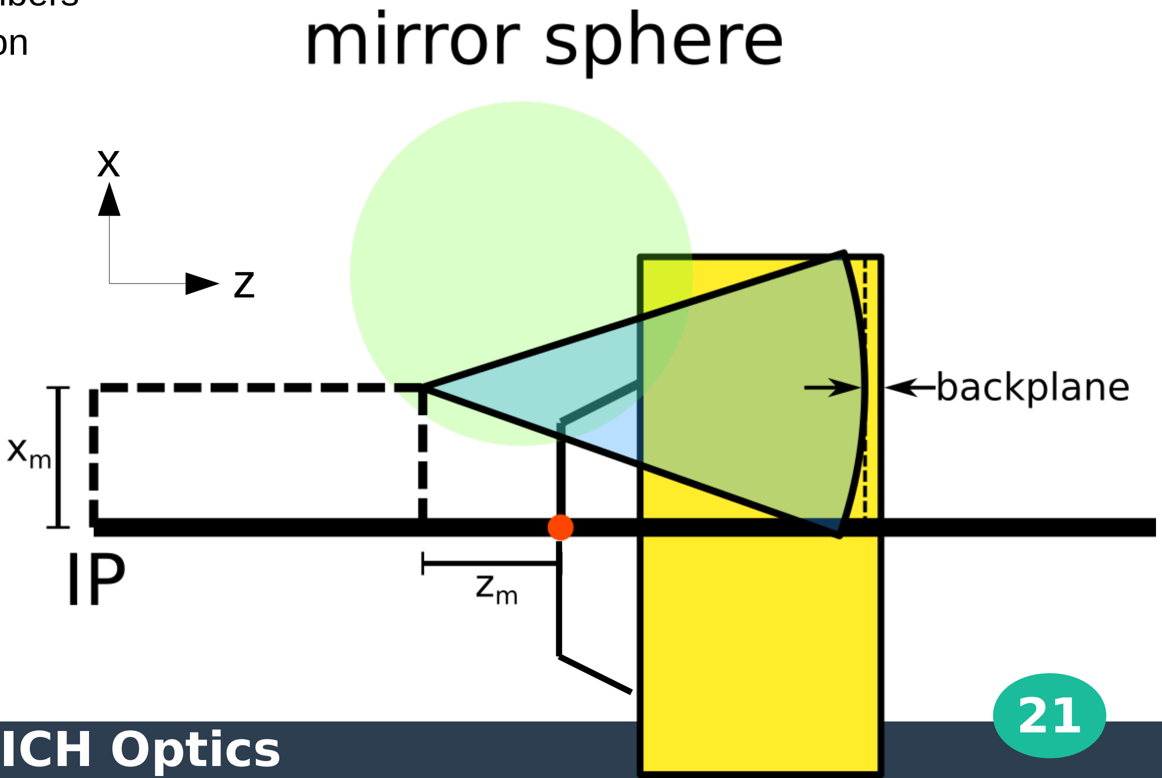




Parameterized Optics: Spherical Mirrors

- **Spherical Mirror**: similar to sensor sphere, need 3 numbers: center position (z_m,x_m) and a radius r_m
- In practice: reparameterize in terms of 3 other numbers
  - 2 focus tune parameters, to steer the focal region
  - A fixed backplane distance (see figure)





2x2 SiPM Modules

Readout modular unit and services

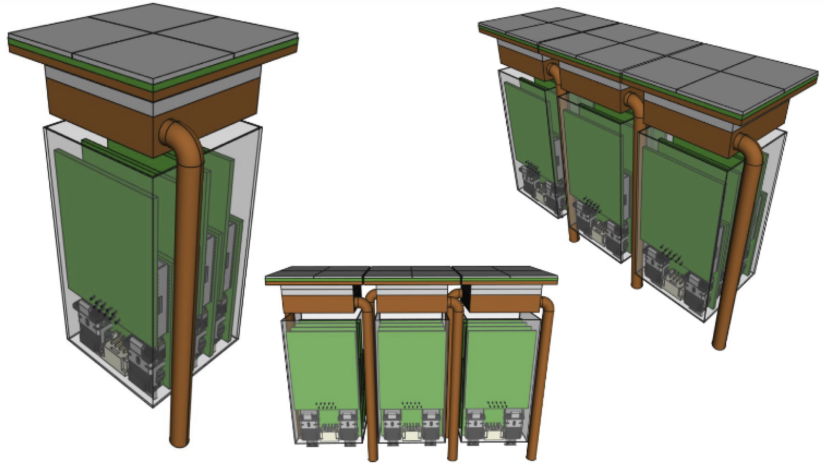


Figure from Marco Contalbrigo

- 20 cm behind the sensors
- Combined this reality with Connor’s focus finder → spherical placement of sensors is not ideal
- Need to take this into consideration along with the multi-mirror plan