Optimization of optics for a focusing DIRC

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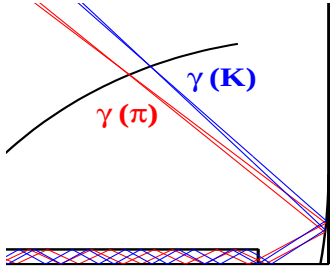
Challenges:

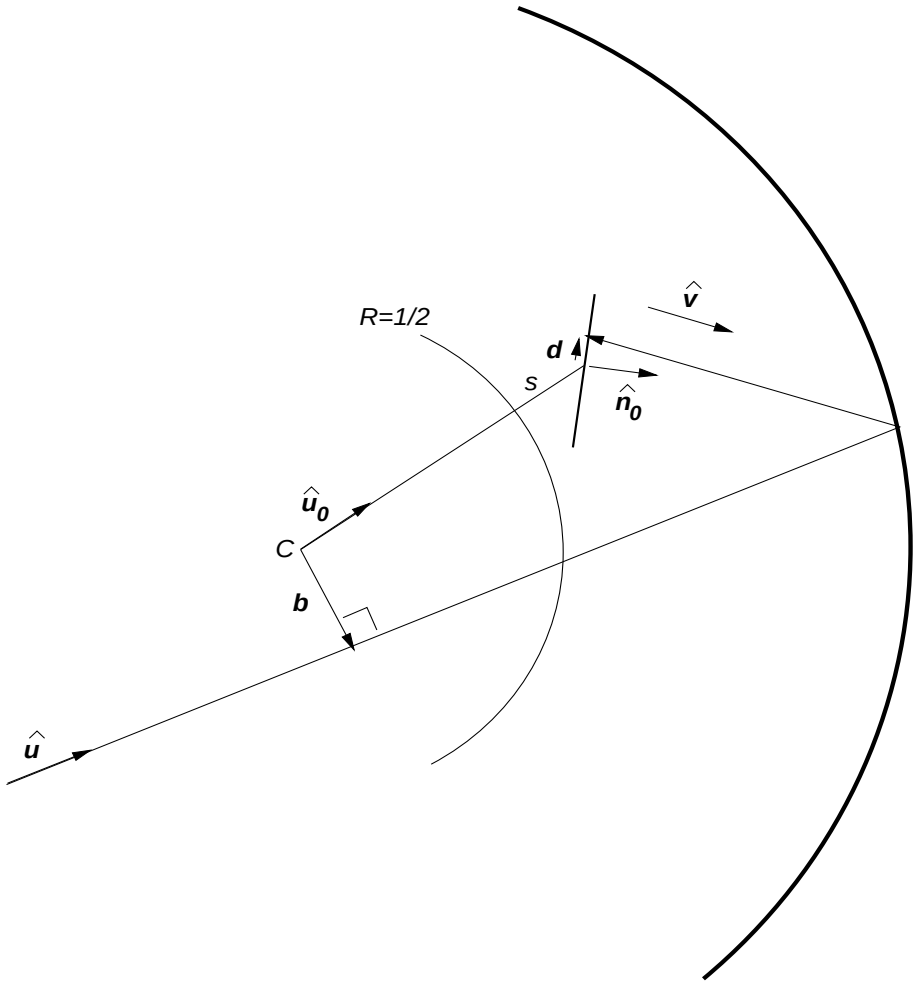
- *parallel light rays make large angles w/r/t central axis of mirror, i.e., they are not paraxial. Focal surface is displaced from $r_M/2$, and the amount of displacement depends on **k***n ⇒ image is smeared*
- *a spherical mirror images onto a focal sphere (modulo aberration above), but detector surface is planar ⇒ image is smeared*
- *π/K ring separation in mm improves with increased focal length of mirror, and bar end-mirror distance, but this increases the size of focusing system*
- *timing is easier to resolve/use with wide bars, e.g., TOP counter; but photon acceptance for a spherical mirror can decrease. Also: can wide bars be (affordably) polished to optical tolerance?*



Optical error

$$\boldsymbol{d} \;=\; \frac{1}{(\hat{\boldsymbol{n}}_{\mathbf{0}}\cdot\hat{\boldsymbol{v}})}\,\hat{\boldsymbol{n}}_{\mathbf{0}}\times\left[\frac{1}{2}(1+2s)(\hat{\boldsymbol{u}}-\hat{\boldsymbol{u}}_{\mathbf{0}})\times\hat{\boldsymbol{v}}\;+\;\left(\frac{b^2}{1+\sqrt{1-b^2}}-2s\sqrt{1-b^2}\right)\hat{\boldsymbol{u}}\times\boldsymbol{b}\right]$$

$$\hat{\boldsymbol{v}} \;=\; (1-2b^2)\hat{\boldsymbol{u}}\;+\;2\sqrt{1-b^2}\,\boldsymbol{b}$$

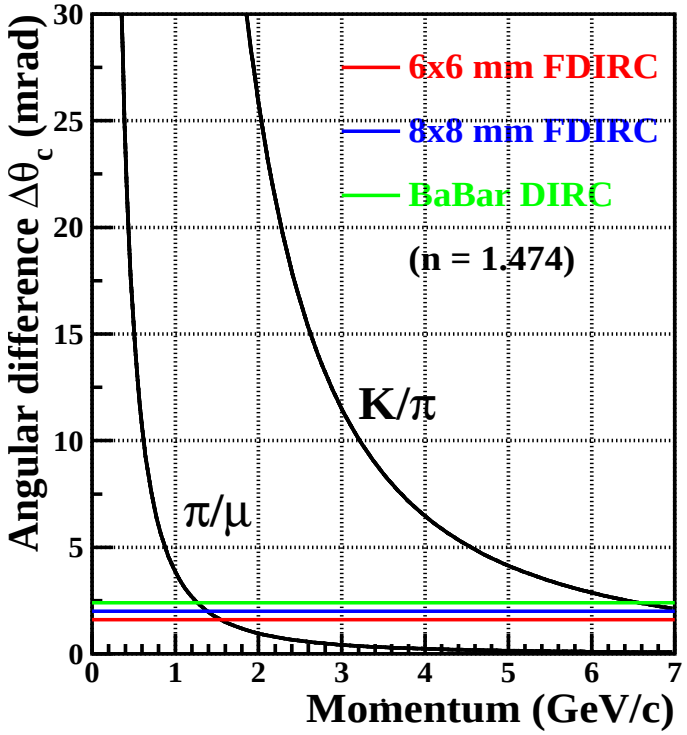


Note: R_M=1, and d depends on b (the magnitude of $\boldsymbol{b}$)

Angular resolution

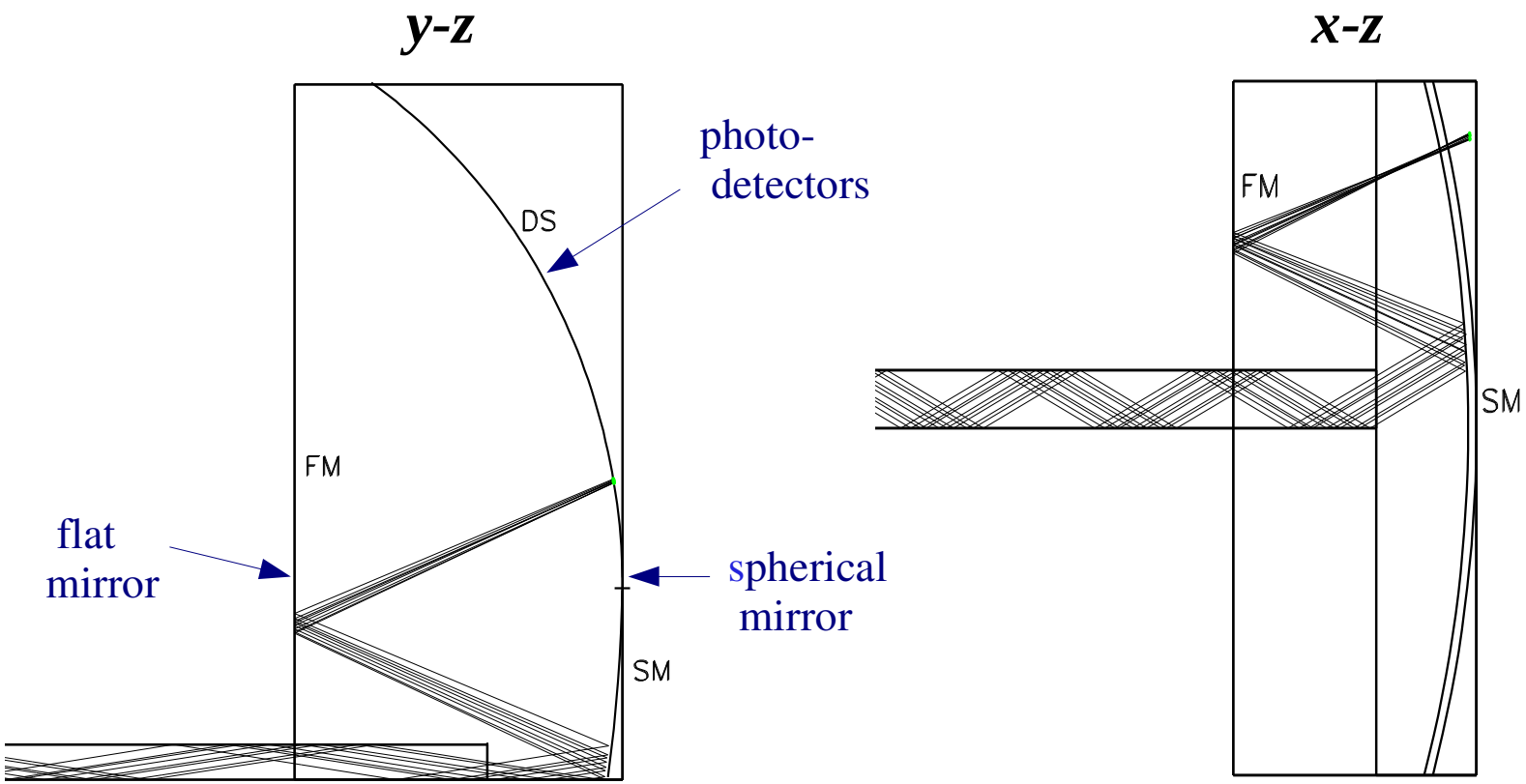
$$\sigma_\theta(\text{tot}) = \frac{\sigma_\theta(\text{uncorr.})}{\sqrt{N_\gamma}} \otimes \sigma_\theta(\text{correl.})$$

	BaBar DIRC (mrad)	Focusing DIRC (mrad)
PMT pixel size	6.4 (28 mm)	5 (6 mm)
bar thickness	4.1 (18 mm)	~ 0
transport along bar	2–3	2–3
chromatic dispersion	5.4	5.4 ($\rightarrow 1$)
track	1	1
total uncorrelated ($N_\gamma \approx 25$)	9.6	~ 7 (5.8)
correlated (tracking, alignment)	1.6	1.6
Overall	2.5	2.1 (2.0)

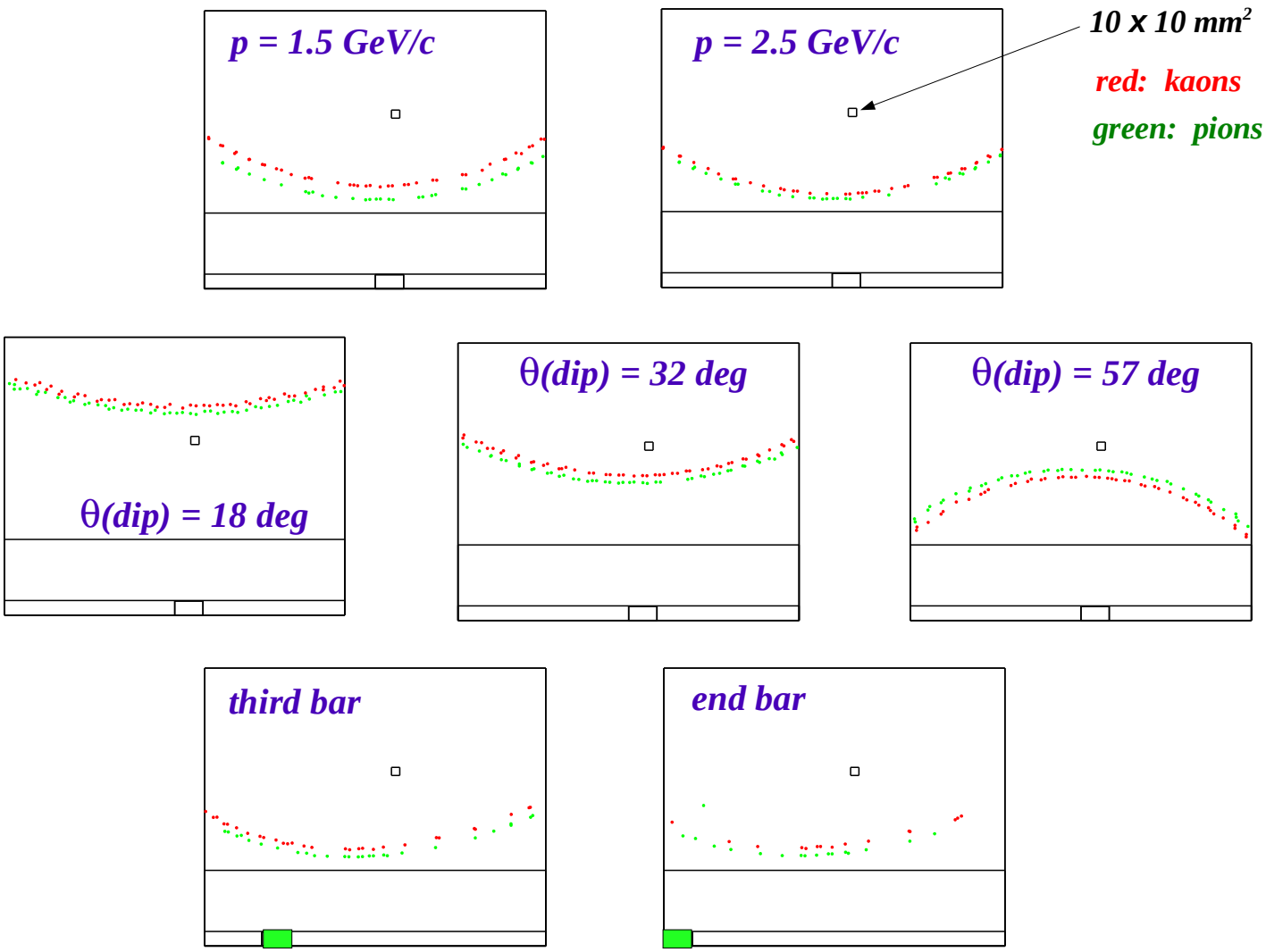


Simulation

Alexey Drutskoy design specs:

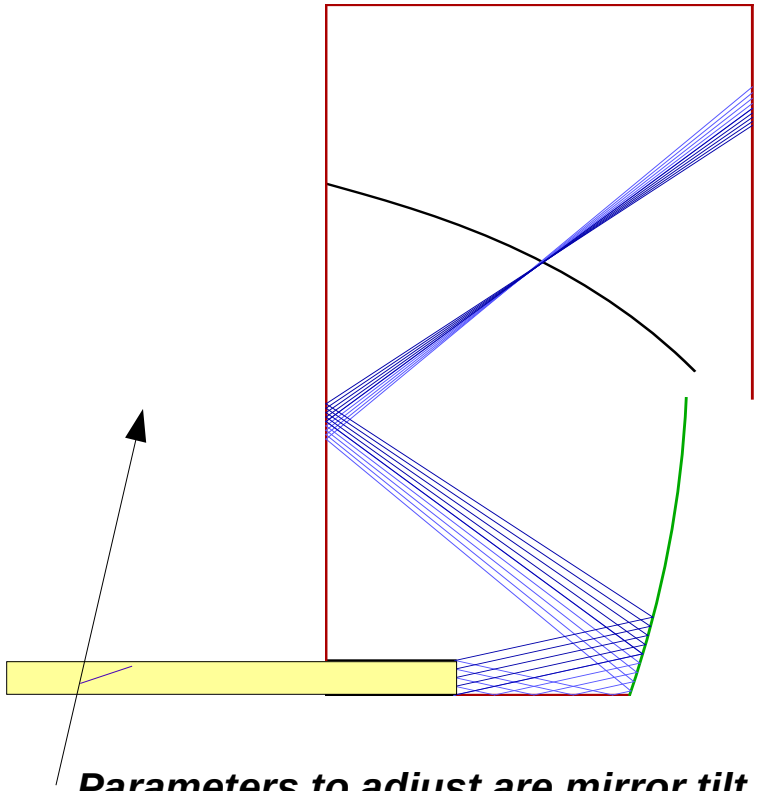


Simulated hits after transport, focusing



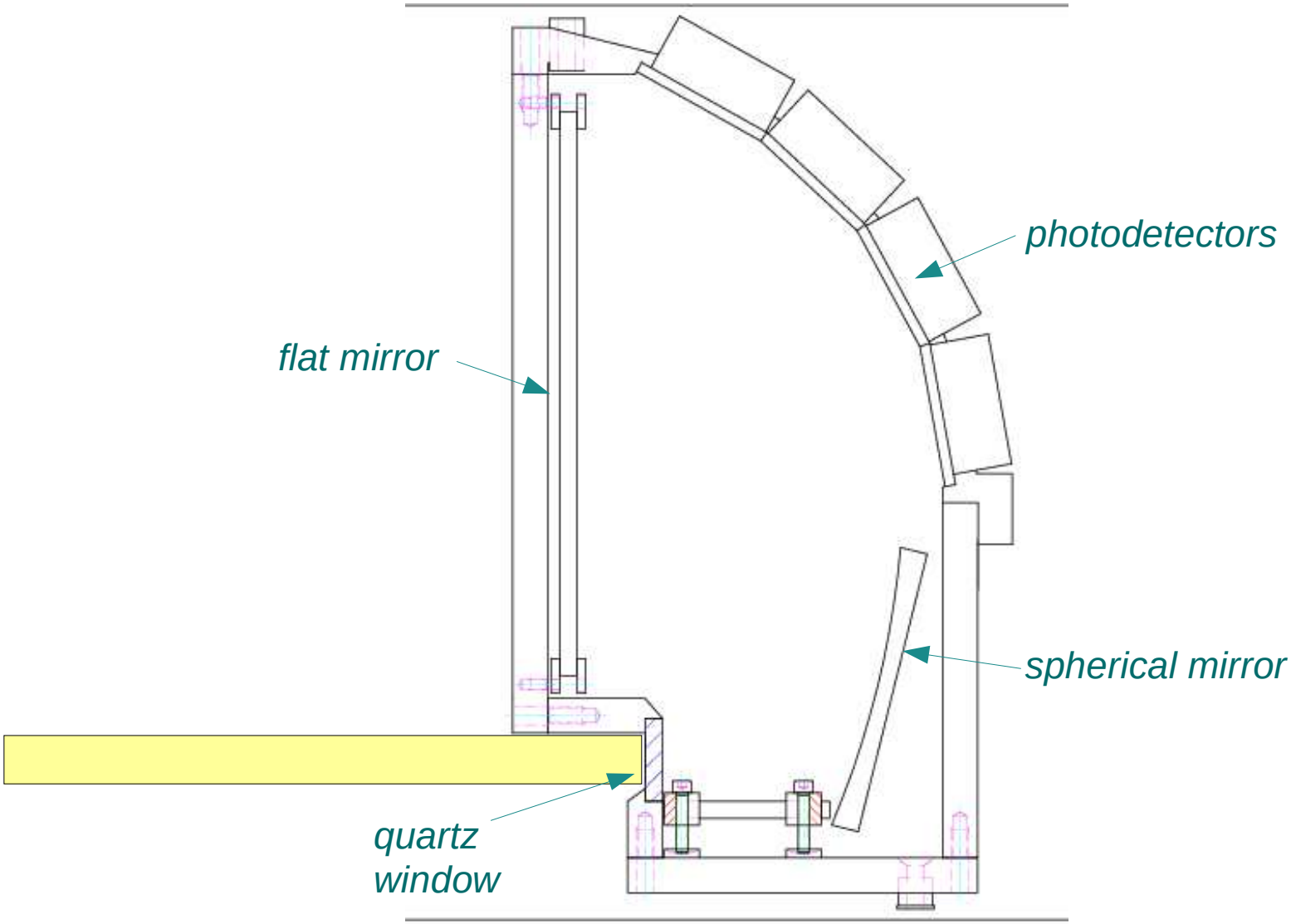
Ray tracing

ray tracing via Mathematica:

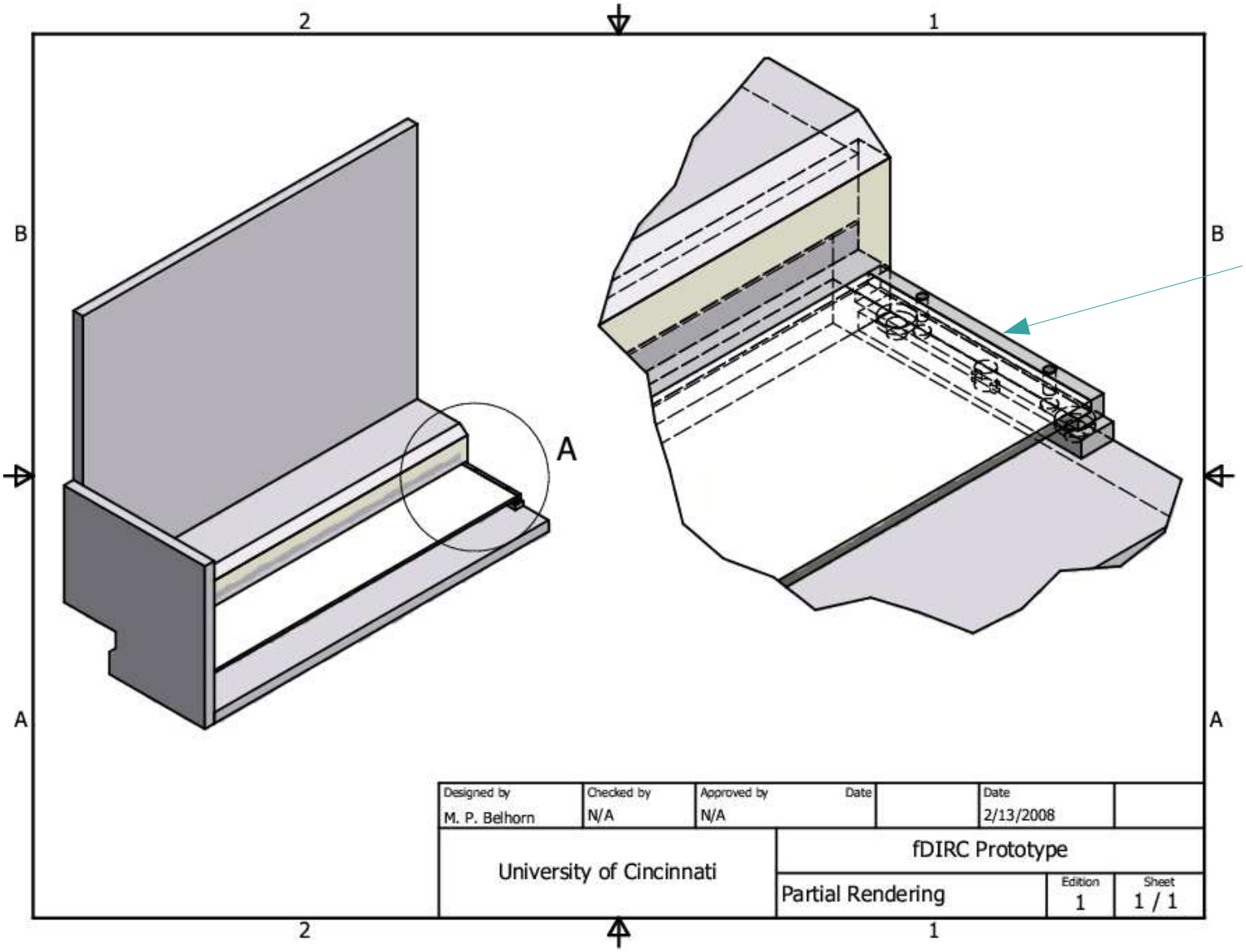


Parameters to adjust are mirror tilt and position, mirror focal length; Mathematica then draws focal surface

Prototype module (under design)



Prototype module (under design)



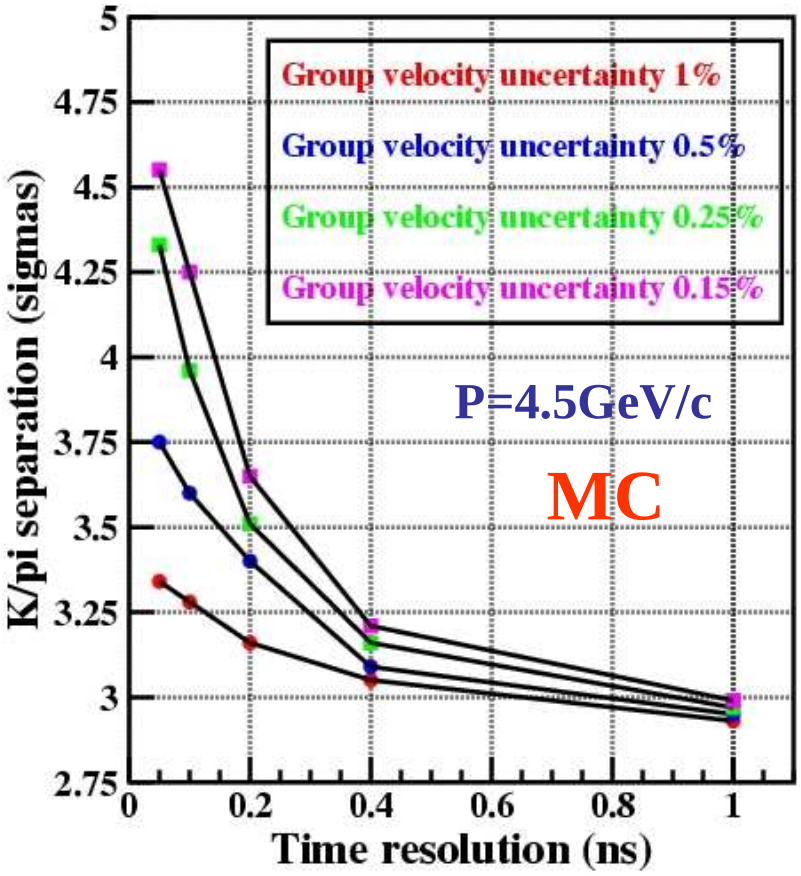
'kinematic' mount for spherical mirror (springs, fine set screws, alignment pin)

Timing measurement

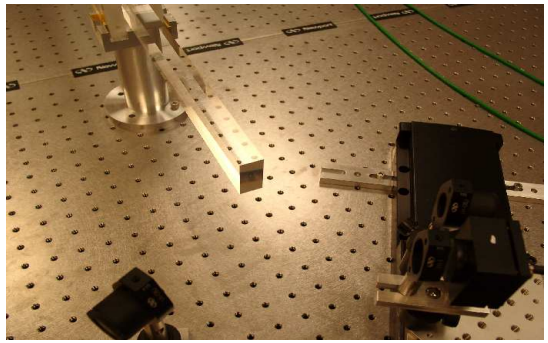
If group velocity is known with 0.5% accuracy and timing is measured with accuracy 50 ps, K/π resolution can be improved approximately from 3.0σ to 3.75σ.

Minor improvement if uncertainty in group velocity knowledge larger than 1%.

Difference between 50ps and 100ps PMT resolution is important only for uncertainty better than 0.5% (in case of proposed focused DIRC design).



Optics optimization



Summary:

- *work has begun on optimization studies, problem has become better defined*
- *need to calculate the magnitude of the spherical aberration error for mirror-detector arrangement being considered, compare to other errors on angular resolution*
- *adjust tilt of mirror, and offset s + angle of detector plane to minimize aberration while keeping photon efficiency high*
- *need to simulate the geometry, compare the smearing with the calculated aberration*
- *useful to make laboratory measurements (on bench or with beam) to confirm these errors, also verify photon yield obtained with a real device (glue, gaps, etc..)*