RICH1 Challenges for Upgrade II

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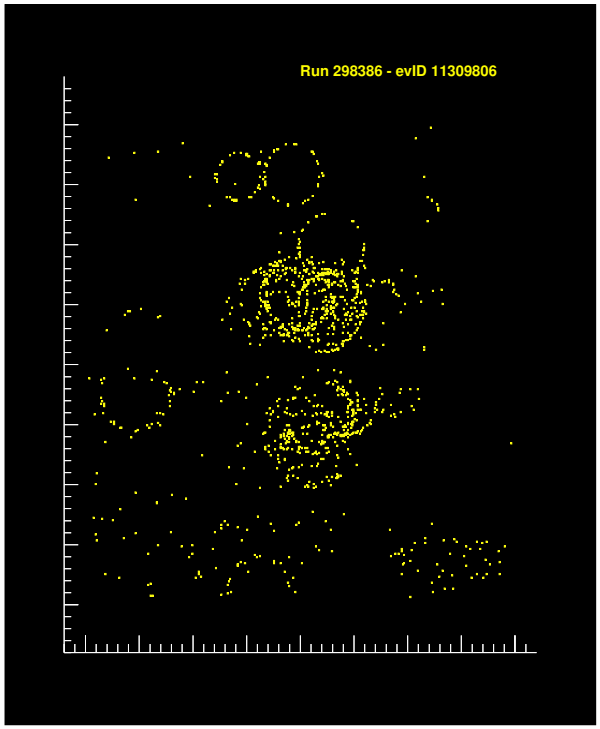
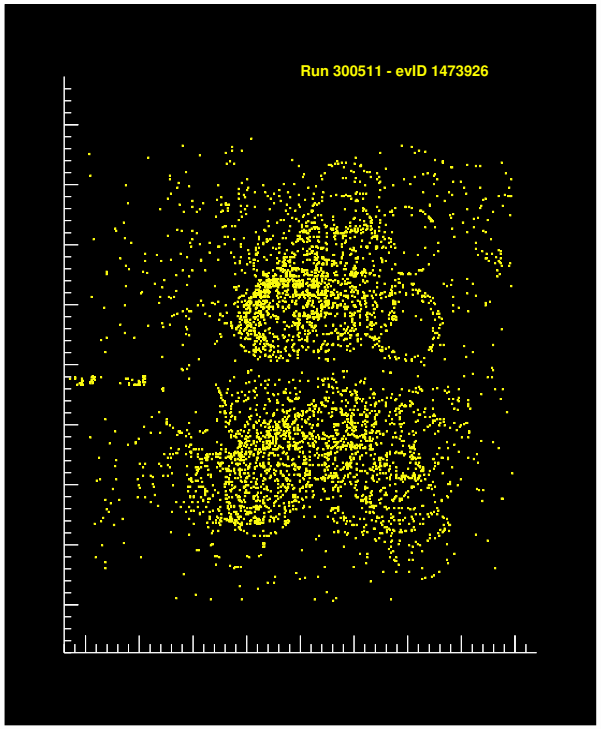
RICH1: the challenge

Evolution of the occupancy with the current optics in RICH1

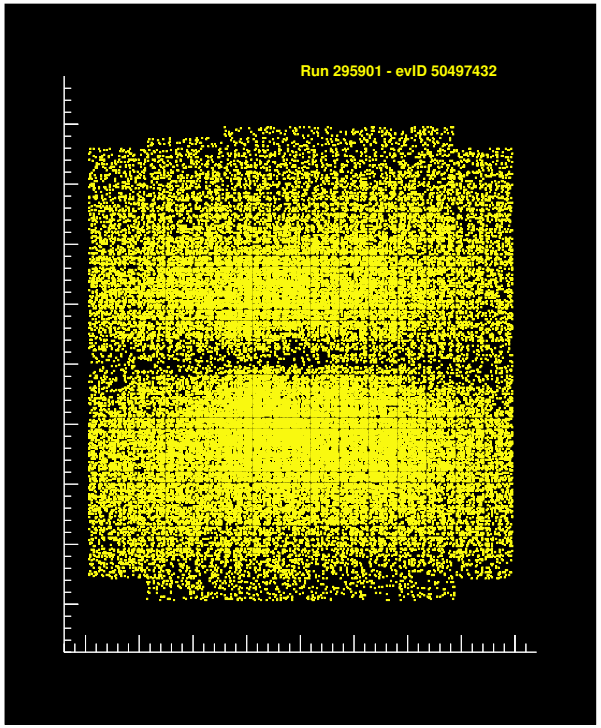
Low occupancy
(∼Run1 conditions)



Typical event in Run3



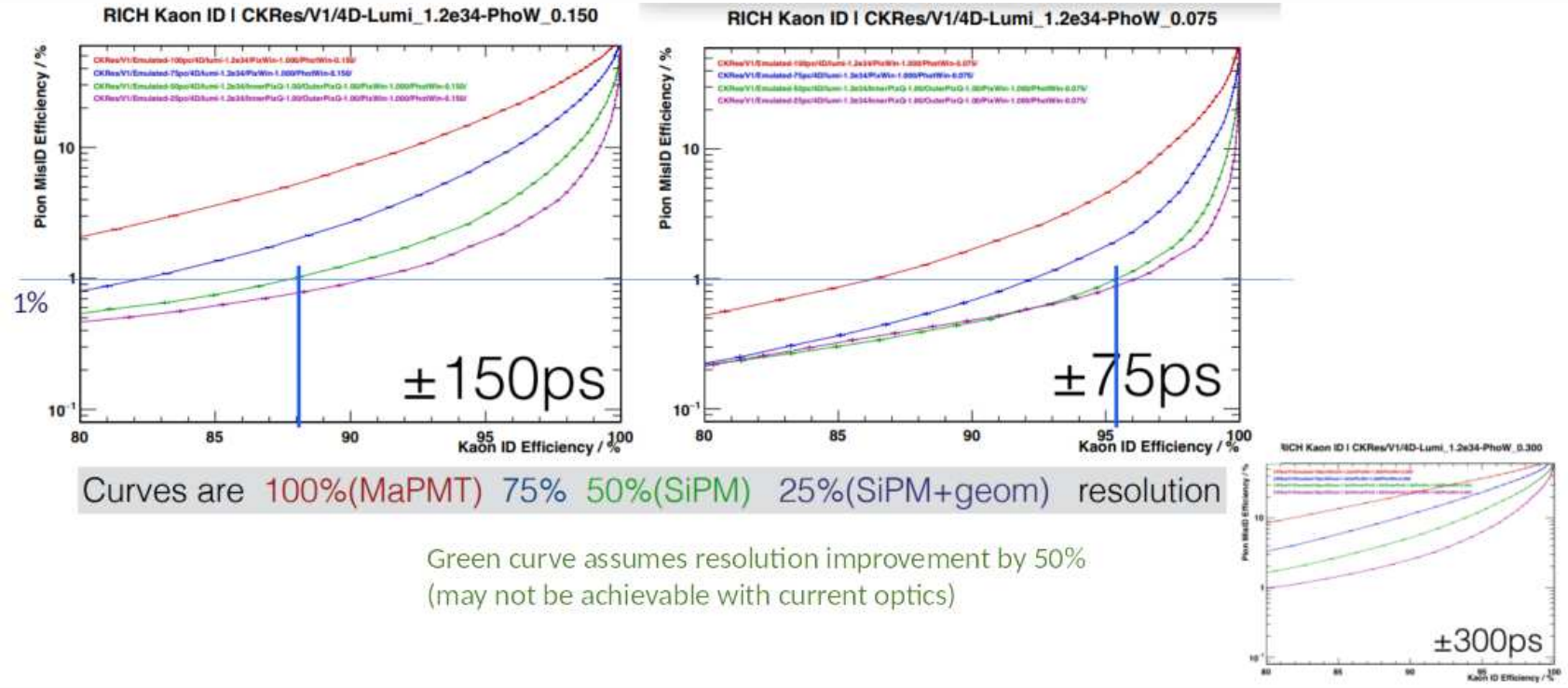
Expected occupancy in
Upgrade II



Performance with current optics

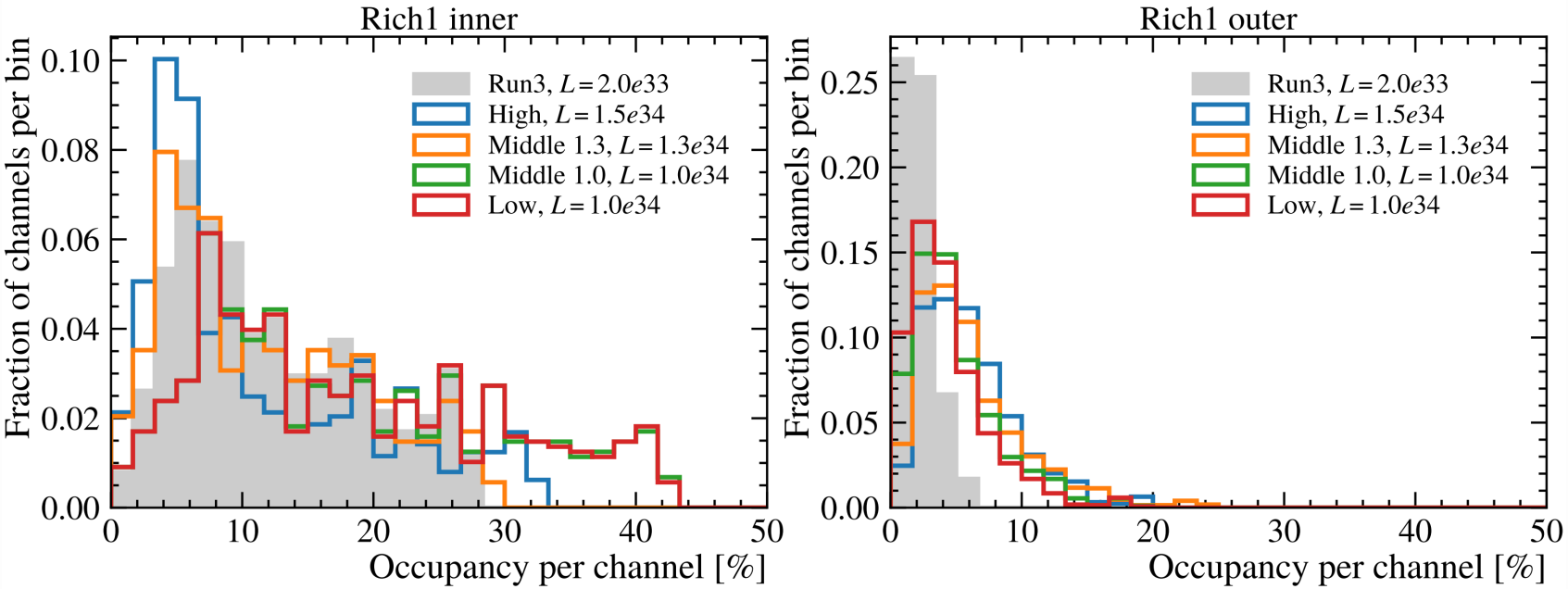
First studies performed:

- introduction of timing
- Cherenkov angle resolution improvement

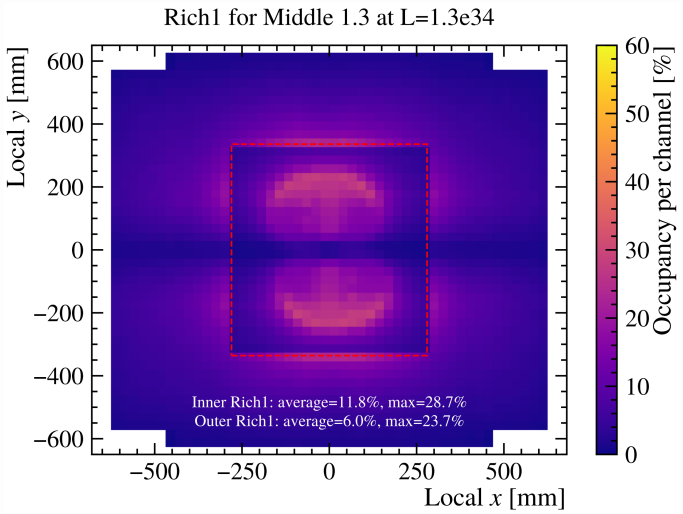


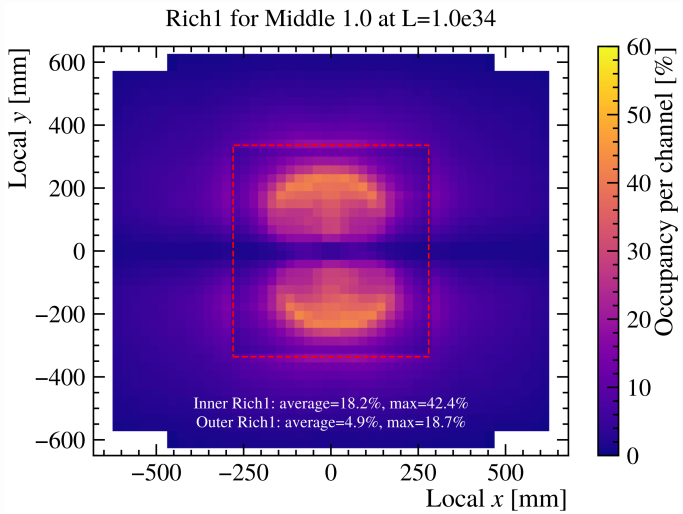
⇒ improvement of the optics to reduce occupancy is needed

RICH1 occupancy



- concern about peak occ in Middle 1.0 and Low
- possible solution: reduce granularity in inner region from $2 \times 2\,\text{mm}^2$ to $1.4 \times 1.4\,\text{mm}^2$ $\Rightarrow$ cost increase

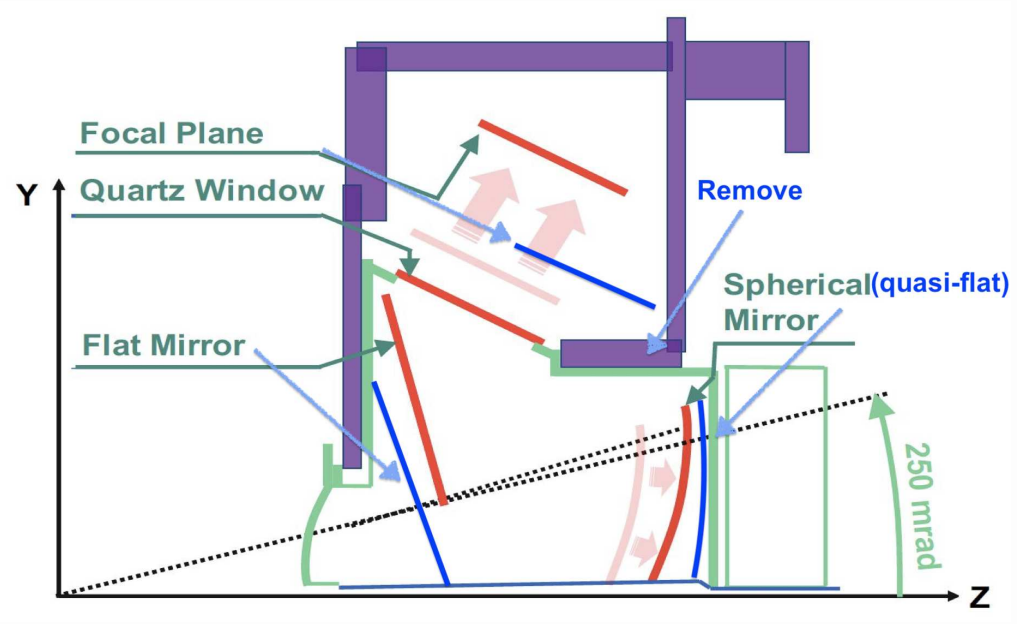




$\Rightarrow$ study of different geometries to distribute photons on the focal plane

Framework TDR design

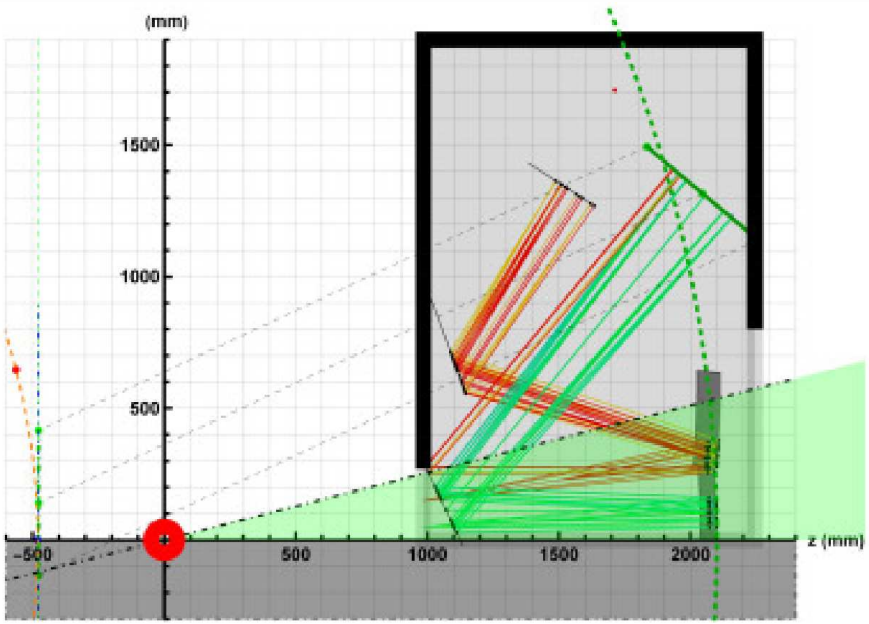
- move flat mirrors in the acceptance ⇒ requires R&D on carbon fibre flat mirrors, light-weight supports and with good resistance to radiation ⇒ improve emission point error
- further increase in spherical mirror curvature radius ⇒ reduced occupancy and decreased pixel error
- shift QE towards the green ⇒ improve chromatic uncertainty
- reduce pixel size



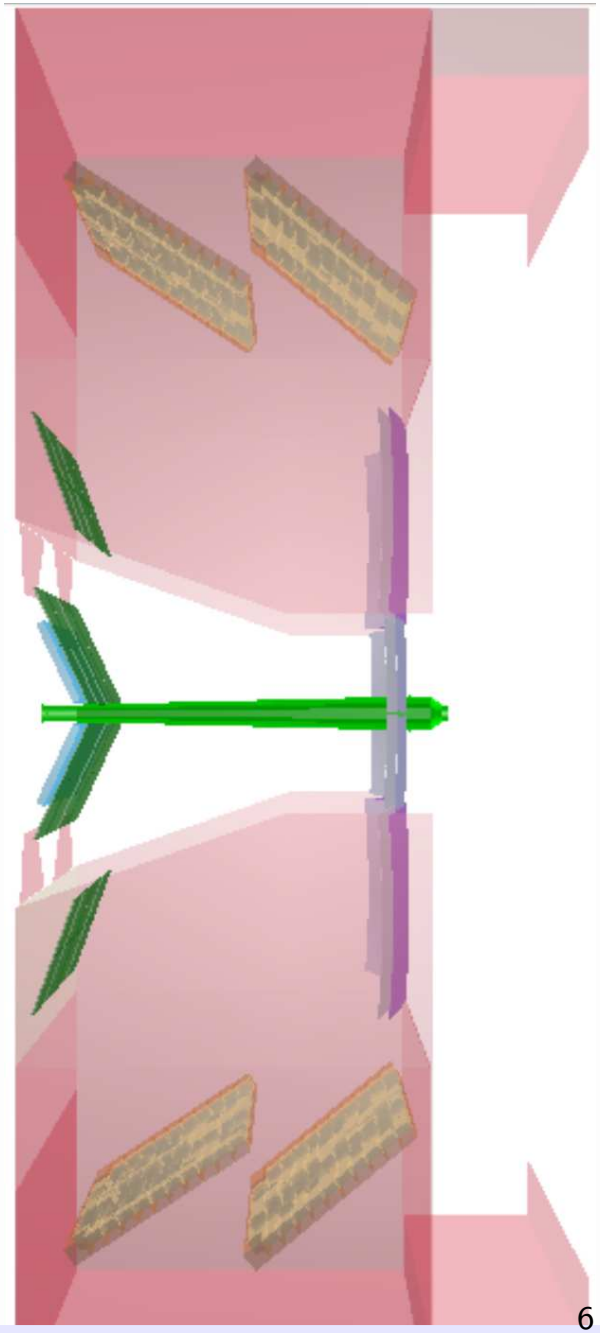
Configuration		Overall [mrad]	Chromatic [mrad]	Emission pt. [mrad]	Pixel [mrad]	Yield
RICH1	MaPMT	0.80	0.52	0.36	0.50	63
	SiPM	0.40	0.11	0.36	0.15	47
	SiPM & geometry	0.22	0.11	0.12	0.15	34

Alternative design

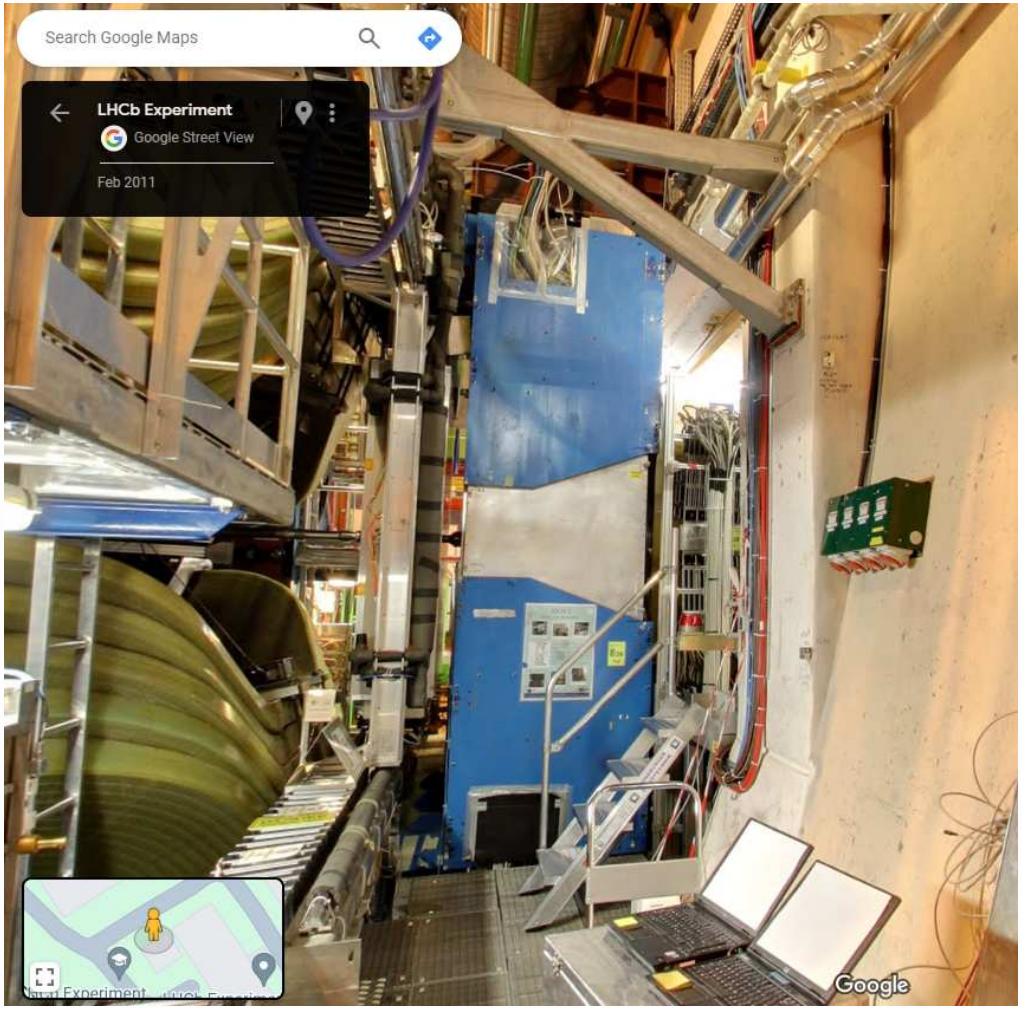
- split optics and photon detector plane
- lower reduction in photon yield and larger radius of curvature
- need to implement and study reconstruction for this option
- need to investigate engineering aspects (mounting of photon detector planes and mirrors...)

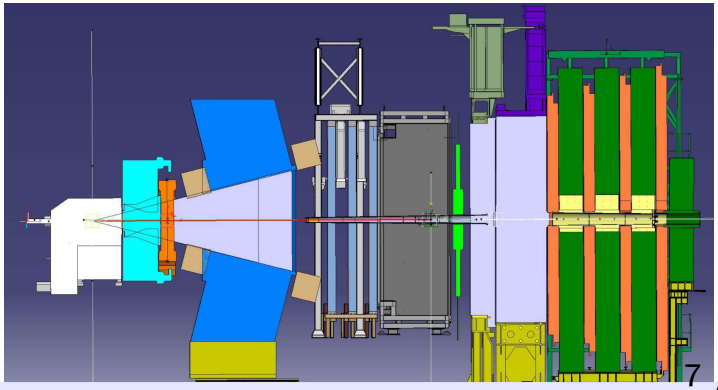


In both cases the study of the space available in the cavern is crucial: larger radius of curvature implies moving the photon detector panels further away from the beampipe



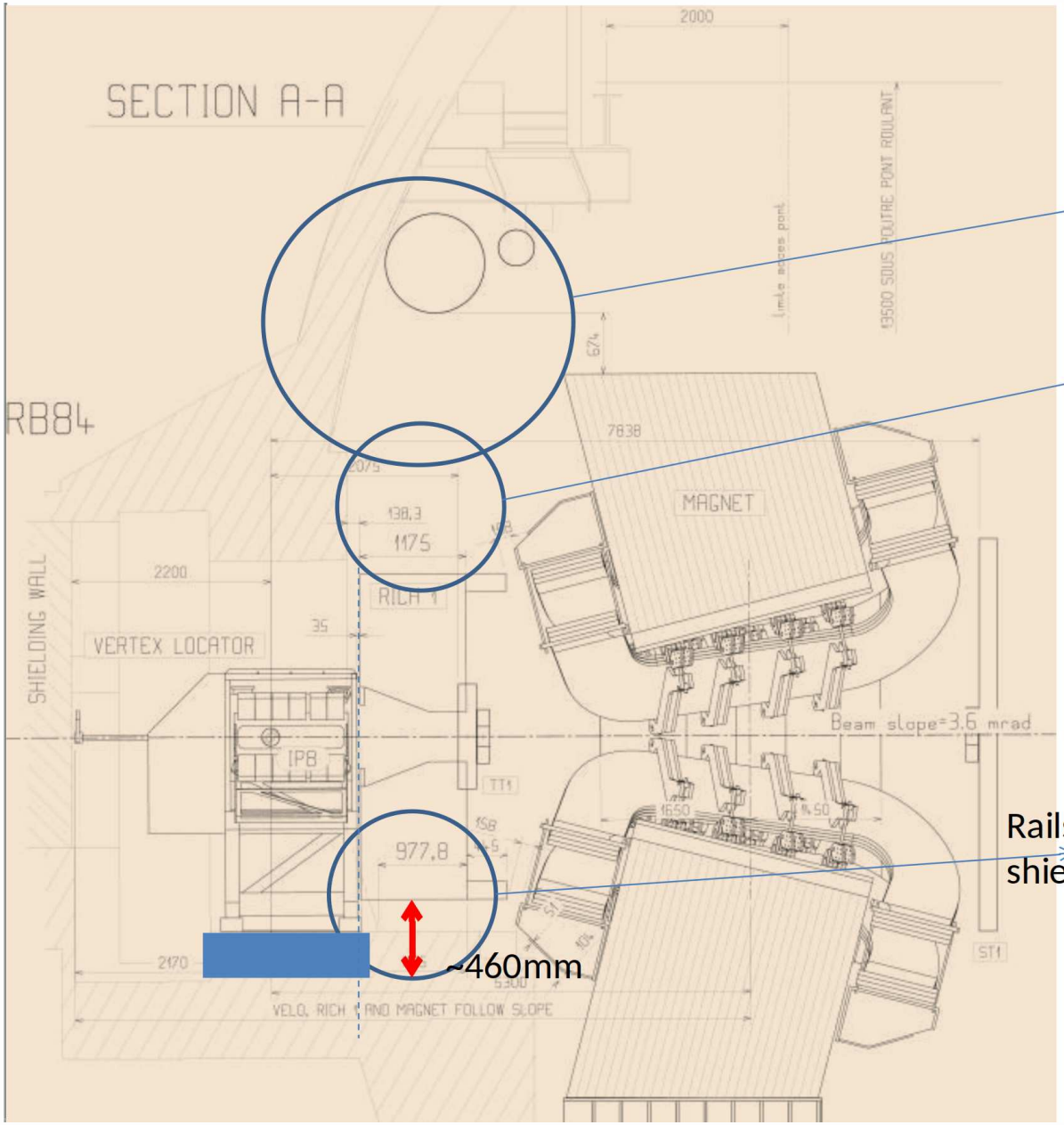
Envelope constraints along the z axis



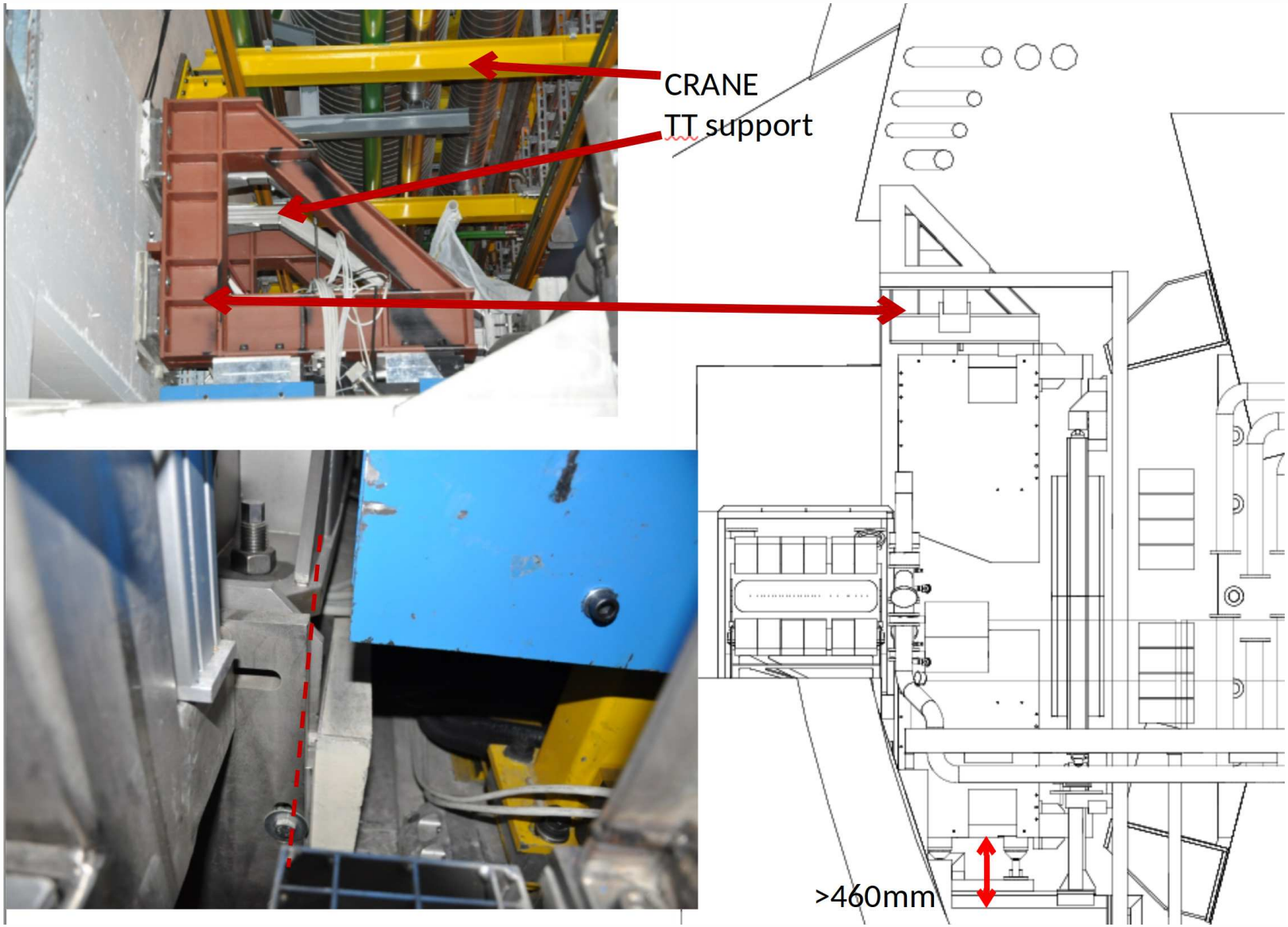


- tight constraint on the Velo side: shared interface upgraded only in case there will be a new Velo vessel
- tight constraint on the UT side: at the moment the UT is protruding in the RICH1 envelope

Envelope constraints along the y axis

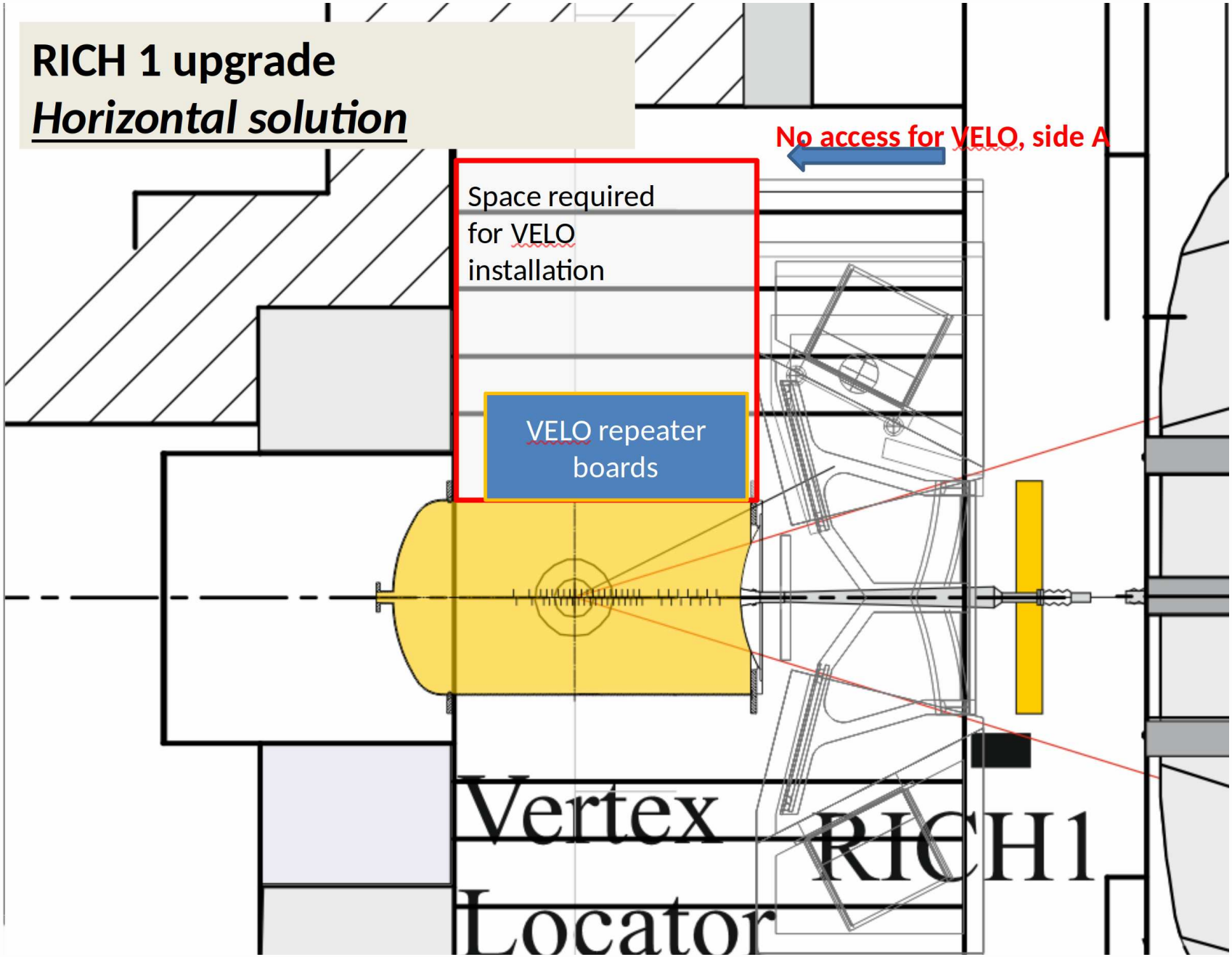


Envelope constraints along the y axis

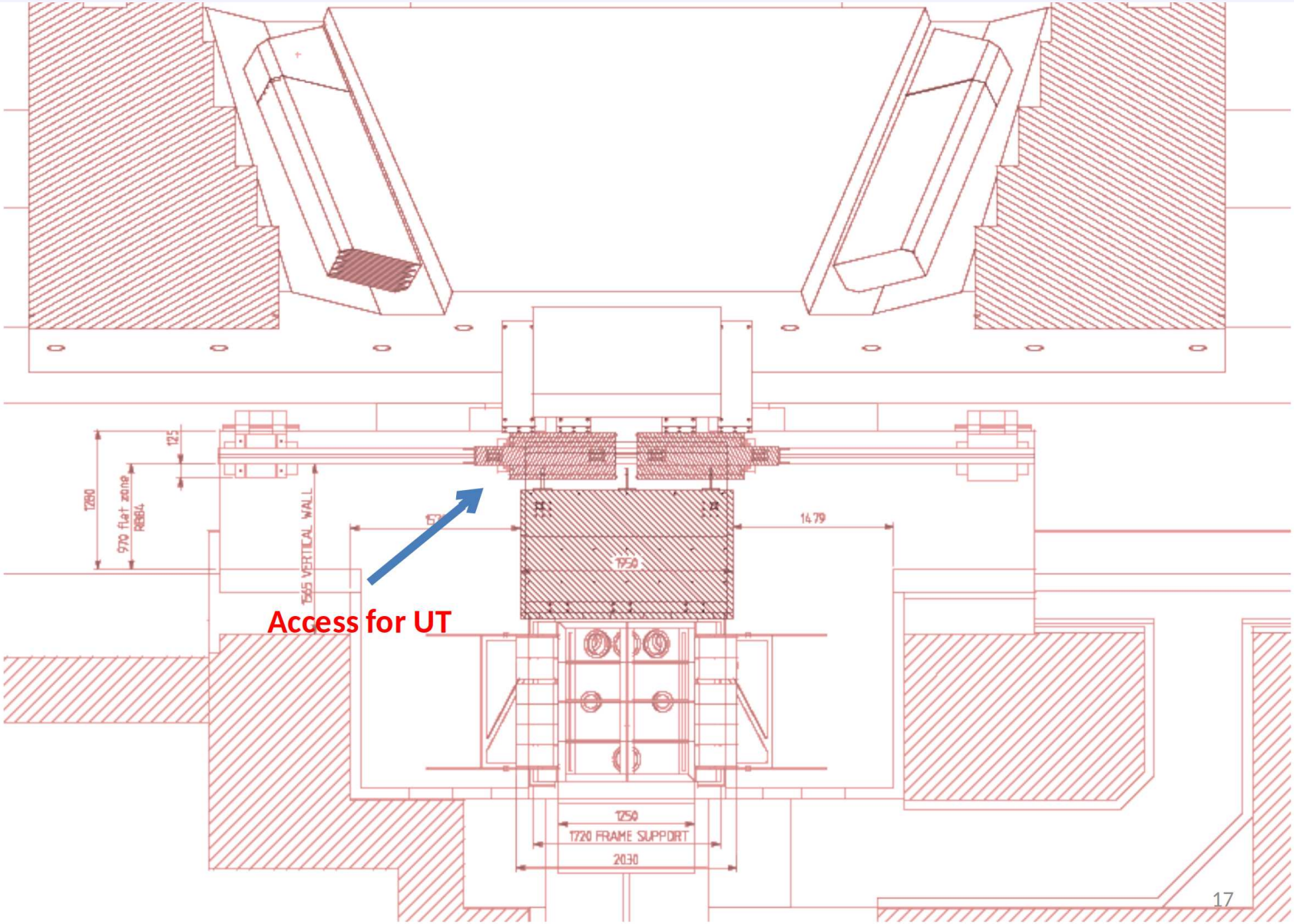


Very tight constraints both above and below RICH1: study of the removal of the magnetic shielding to gain more space for cryo and focal length

Envelope constraints along the x axis

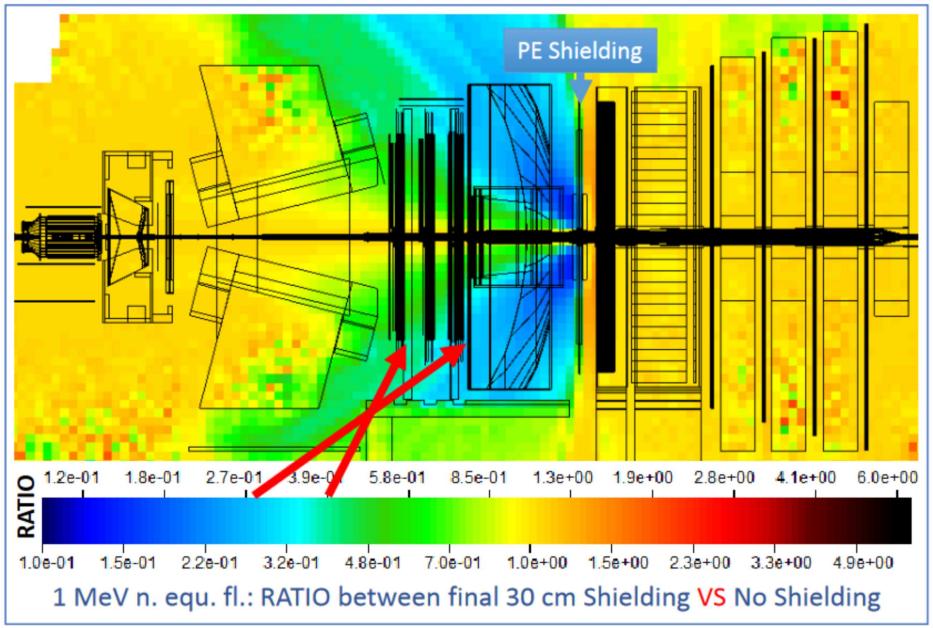


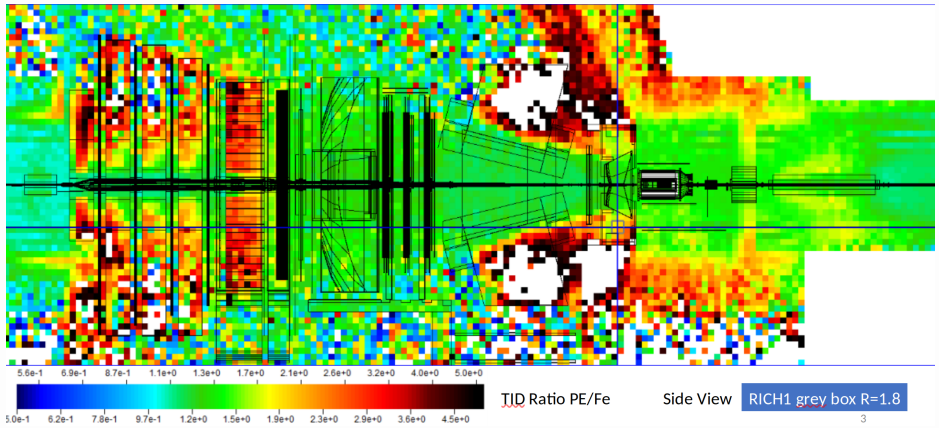
Envelope constraints along the x axis

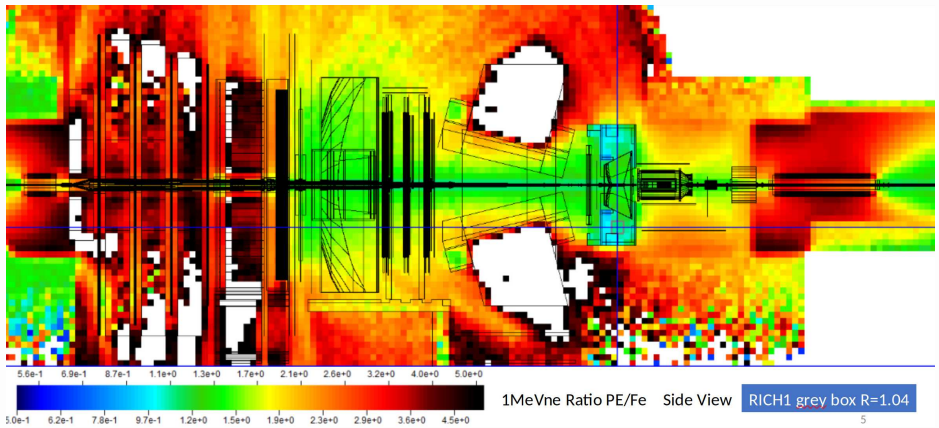


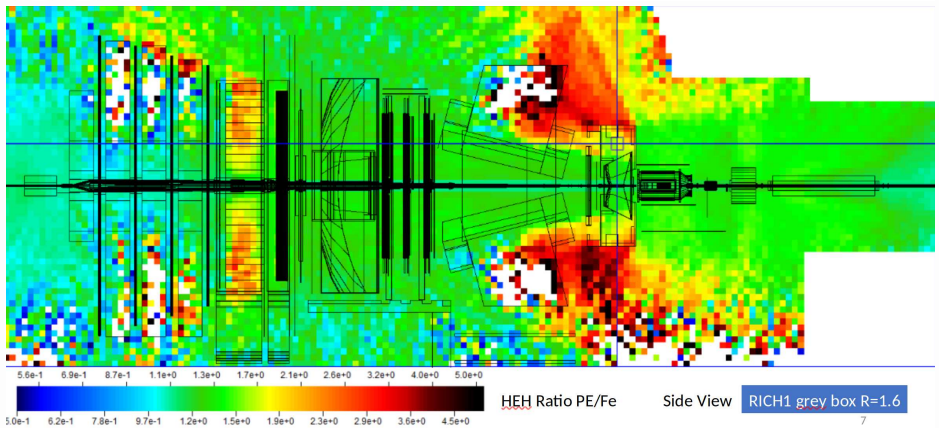
The RICH collaboration is also investigating the possibility of rotating RICH1 in horizontal position, as by original LHCb design: very tight constraints to allow access to Velo and UT on A and C-side

Radiation shielding





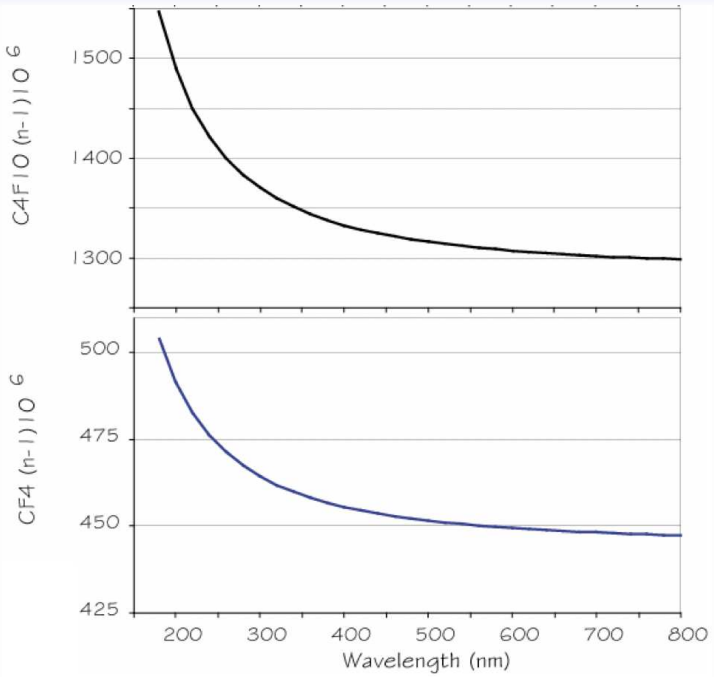




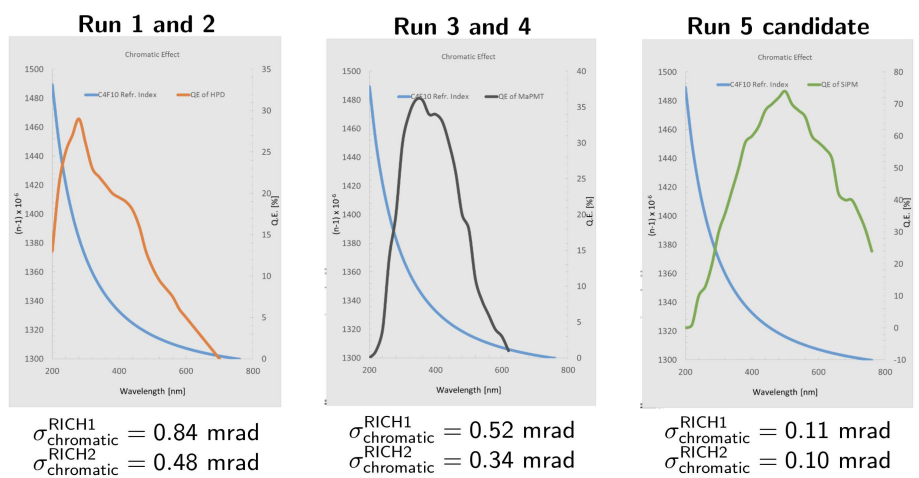
- preliminary studies on neutron shielding around photon detector enclosure performed by Matthias
- RICH2: shielding already coming from MT shield
- RICH1: no strong effect on 1 MeV neutron fluence equivalent, slight increase of the dose and the High Energy Hadron fluence levels in the detector

studies on other shielding materials ongoing and new FLUKA simulation needed (ratios between sim with different FLUKA codes)

Radiators



- fluorocarbon gases were chosen because of the relatively low chromatic dispersion
- C_4F_{10}: $n = 1.0014$ at 400 nm, gas vessel: $2 \times 3 \times 1\,\mathrm{m}^3$
- CF_4: $n = 1.0005$ at 400 nm, gas vessel: $100\,\mathrm{m}^3$
- the chromatic error depends on the convolution between the dispersion and the photon detector quantum efficiency (QE)



$\sigma^{\mathrm{RICH1}}_{\mathrm{chromatic}} = 0.84$ mrad, $\sigma^{\mathrm{RICH2}}_{\mathrm{chromatic}} = 0.48$ mrad

$\sigma^{\mathrm{RICH1}}_{\mathrm{chromatic}} = 0.52$ mrad, $\sigma^{\mathrm{RICH2}}_{\mathrm{chromatic}} = 0.34$ mrad

$\sigma^{\mathrm{RICH1}}_{\mathrm{chromatic}} = 0.11$ mrad, $\sigma^{\mathrm{RICH2}}_{\mathrm{chromatic}} = 0.10$ mrad

- fluorocarbon gases have large Global Warming Potential
  $\mathrm{GWP}(C_4F_{10}) = 8500\ CO_2$,
  $\mathrm{GWP}(CF_4) = 7000\ CO_2$
  G. Hallewell's talk and B. Mandelli's talk at DRD4
- could replace CF_4 (n=1.0005) with CO_2 (n=1.0004): photon yield ($\propto 1 - 1/n^2$) marginally lower, but worse chromaticity
- intense R&D and studies needed to find alternatives to C_4F_{10}, matching its refractive index and allowing operations in the LHCb environment $\Rightarrow$ close synergy with DRD4
- R&D on metamaterials

Conclusion

- RICH1 design poses many challenges on optics, mechanics, photon detector, radiator
- effort from all areas of expertise in the RICH collaborations are needed to converge on the design
- studies needed for the road to TDR:
  - space available for cryo
  - reduction of radiation level in photon detector enclosures
  - study of photon detectors
  - R&D on light-weight mirrors

$\Rightarrow$ various open questions requiring a lot of effort from the RICH community at the moment!