Considerations about luminosity measurement and IR layout

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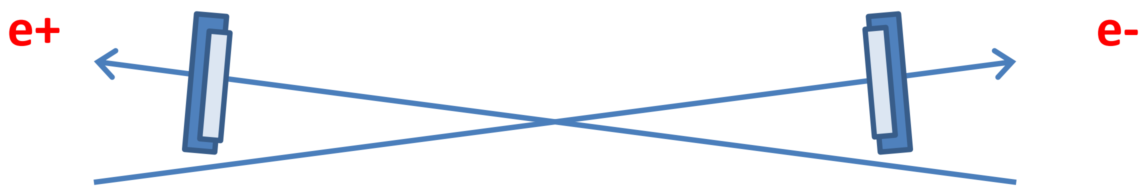
Luminosity measurement specifications (I)

1. luminosity monitor is typically a silicon-tungsten sandwich calorimeter, 20cm thick (25 X_0) able to locate and measure E_beam electrons/positrons

2. Requires two detectors, one on each side of the IP
   Need to be covering a range of angles
   around the outgoing electron (A-side) and positron (B-side) beams
   Need precise tight fiducial volume and loser fiducial volume selection is
   {tightA $\cap$lose B + tight B $\cap$lose A} -- this reduces impact of beam parameters



3. luminosity is

$$L = \frac{N_{\text{Bhabha}}}{\sigma_{\text{Bhabha}}},$$

4. cross-section for Bhabha scattering e+e- → e+ e- at small angles is

$$\sigma = \frac{1040\,\text{nb GeV}^2}{s}\left(\frac{1}{\theta^2_{\text{min}}} - \frac{1}{\theta^2_{\text{max}}}\right).$$

this requires small and very precise value of θ_{min}

Luminosity measurement specifications (II)

4. difference between $\theta_{min,\ tight}$ $\theta_{max,\ tight}$ as well as between
$\theta_{min,\ loose}$ and $\theta_{min,\ detector}$
must allow containment of shower, > one Molière radius in the calorimeter. (1cm)
all of which becomes very difficlt to do if detector is too close to IP

5. all of this also becomes difficult when trying to get closer than the angle betwen the incoming and outcoming beams (30 mrad)

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FCC-ee Luminosity Calorimeter Layout Study

Assumptions:

1. Distance between IP and quads: $L^* = 2.0$ m;
2. Beam crossing angle: 30 mrad;
3. Closest approach of luminosity calorimeter to center of beam line: 40 mm;
4. Maximum scattering angle of luminosity calorimeter: 140 mrad (8°);
5. Precise fiducial region starts 25 mm from calorimeter edge (Moliere radius: $\sim$15 mm);
6. Luminosity calorimeter depth: 20 cm;
7. Need space between luminosity calorimeter and quadrupole for machine equipment: Study three scenarios where calorimeter face is at z=1.0 m, 1.3 m, and 1.5 m, respectively.

What the luminosity monitor has to do

1. provide high statistics relative normalization for the machine adjustment and fast feedback

100nb of cross-section leads to 0.3% precision in one second.

probably easier to

2. provide relative normalisation for the points on the Z line shape for m_Z and Γ_Z measurements.

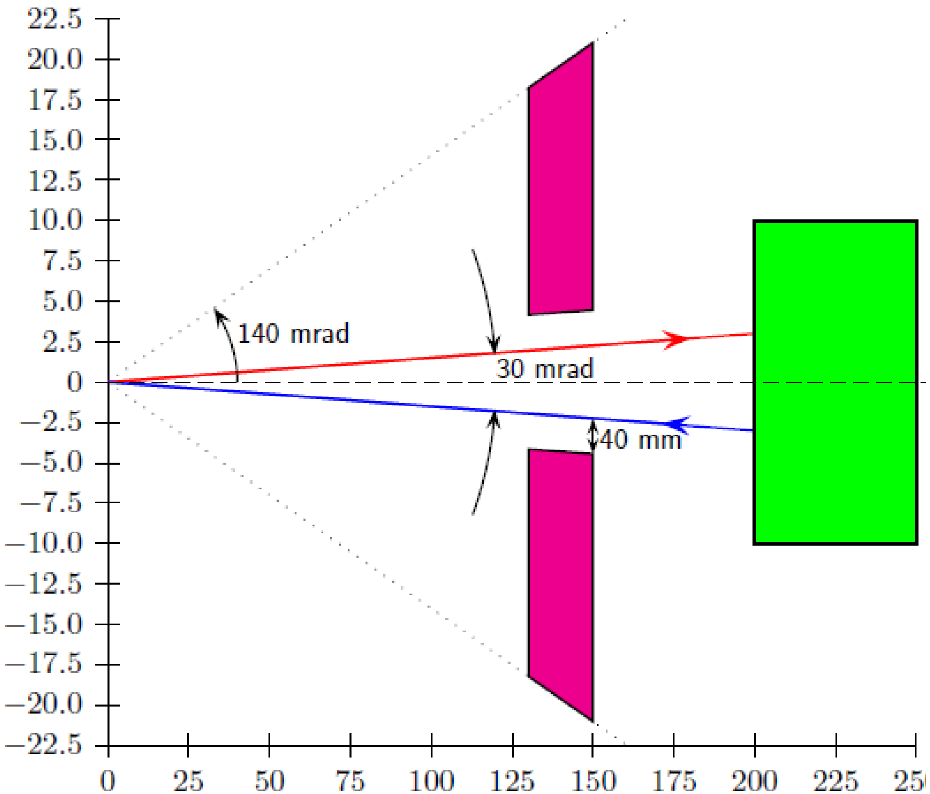
➔ peak cross-section for visible Z decays is ~30 nb ➔ . ***$\theta_{min, tight}$ < 50 mrad***

3. need very precise cross-section measurements for absolute cross-section determinations.

e.g. the measurement of
- Z peak cross-section (10^{12} Z)
- WW pair cross-section (10^7 events)
- ZH cross-section (10^6 events)
- ttbar (10^6 events)

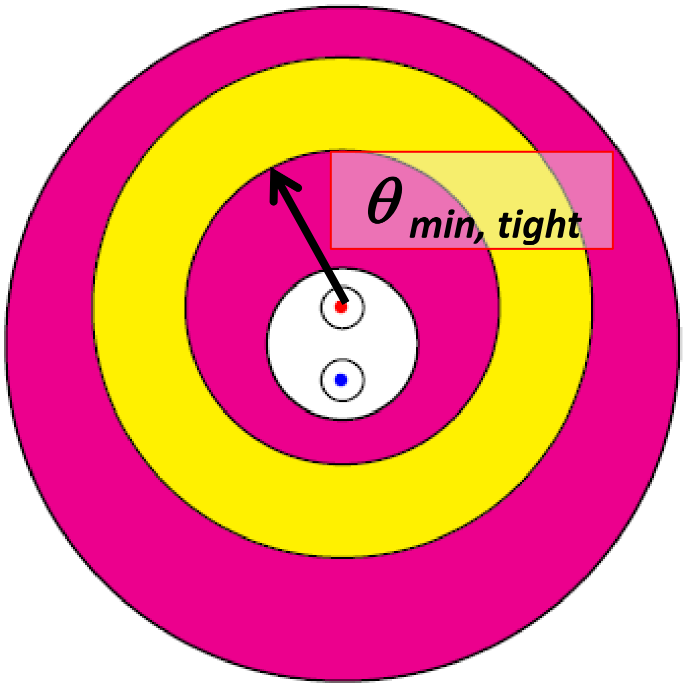
compare to theoretical precision of (now 6 10^{-4} hope 2 10^{-4}) aim 10^{-4} on cross-section

THIS might be easier for a larger angle detector.



Figur 1: rz view

transverse view



face view, indicating outgoing beam (red) and the precise (tight) fiducial volume in Yellow

NB: The performance will be helped if the inner radius can be smaller.
(what is the size needed for the beam pipe at 1-1.5 m distance from the IP?)

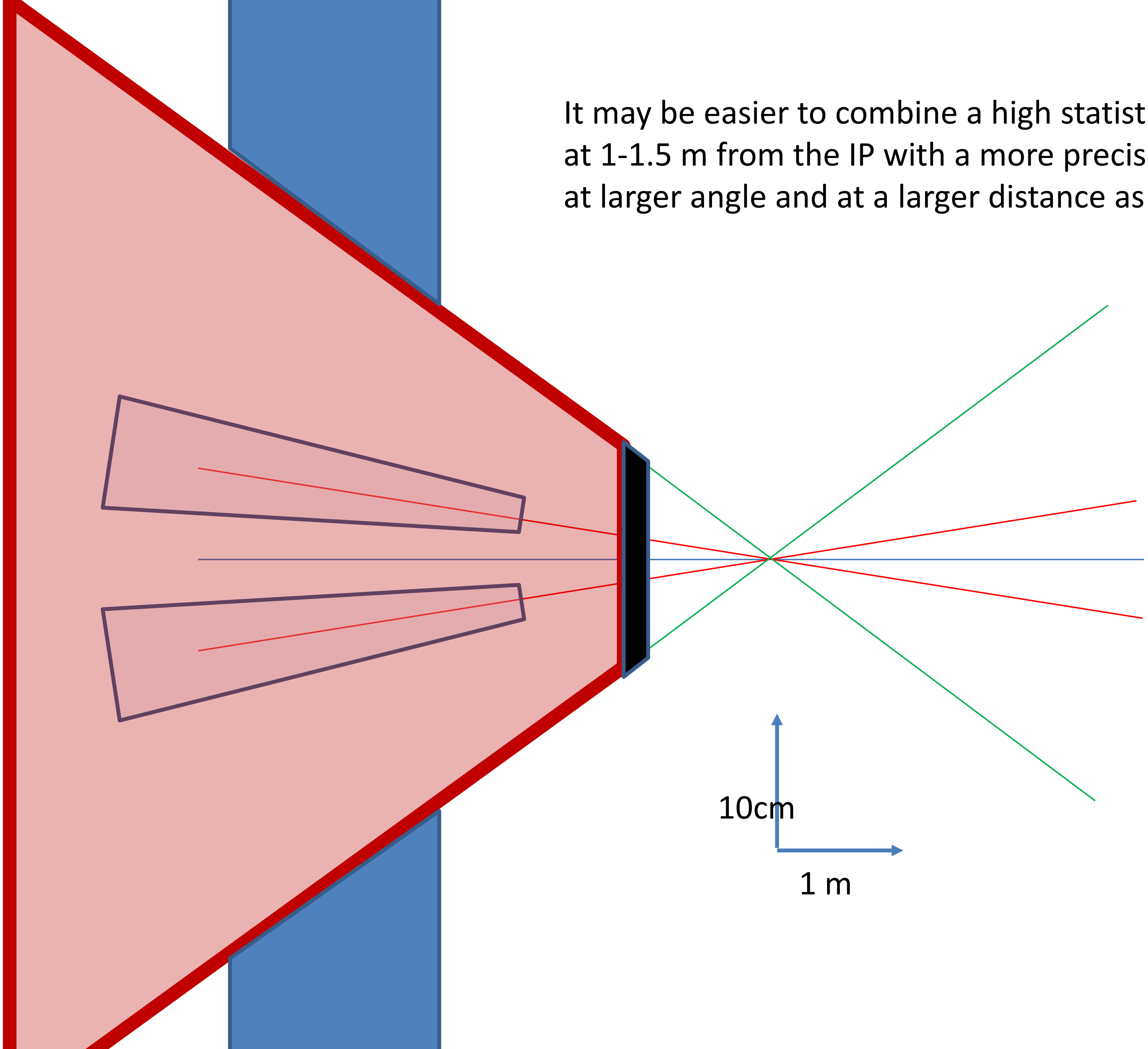
Note: it is very difficult, in this situation of placing the luminosity monitor in front of the quadrupoles, to get the 10^{-4} accuracy.

➔ **require accuracy of 2-3 microns on inner radius!**

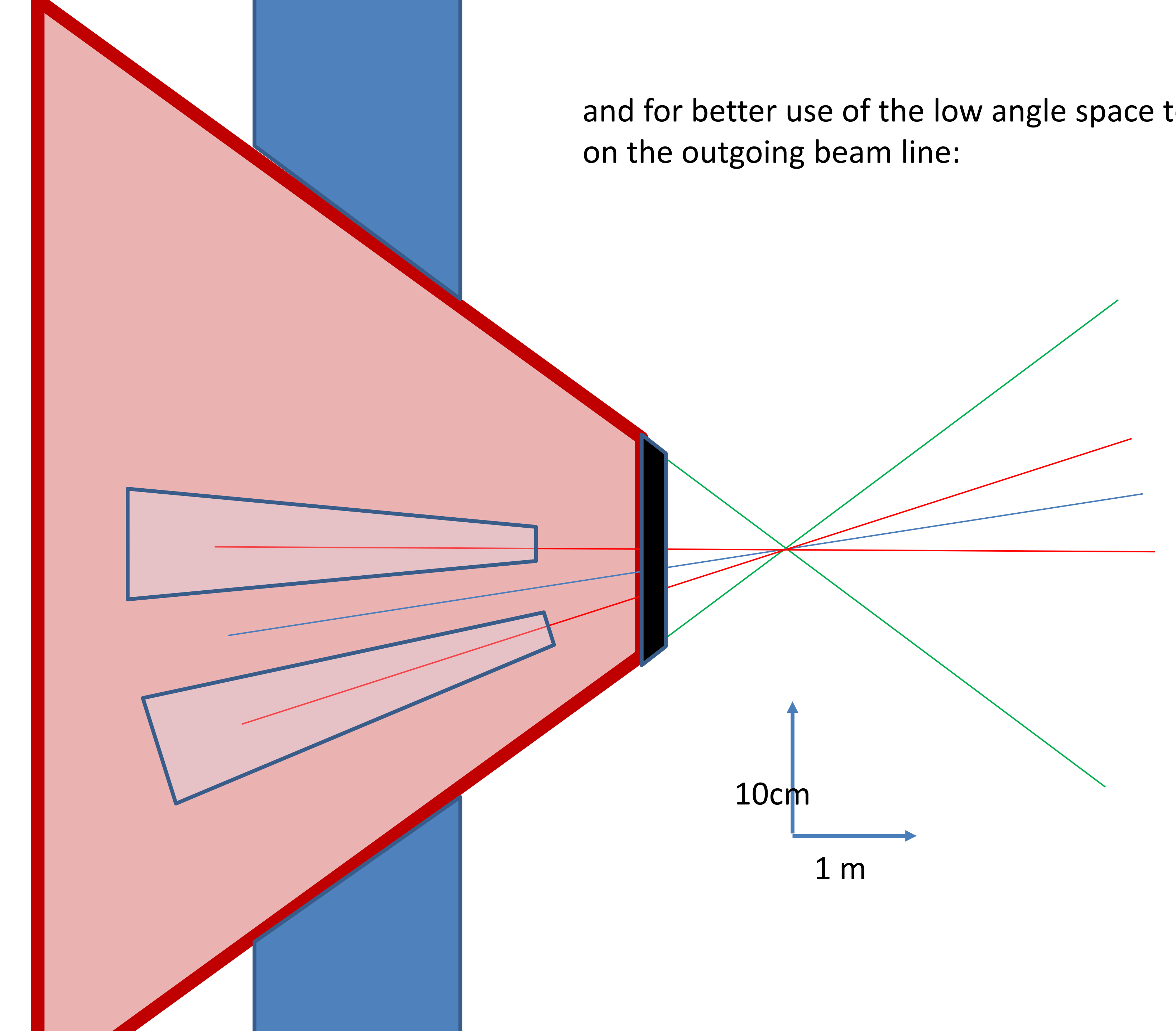
z_{front} mm	r_{min} mm	r_{max} mm	θ_{min} mrad	θ_{max} mrad	σ nb	δz_{front} μm	δr_{min} μm	δr_{max} μm
1000	75	105	75	105	11	50	-1.8	5.0
1300	80	143	61	110	23	65	-2.7	16
1500	83	168	55	112	31	75	-3.1	26

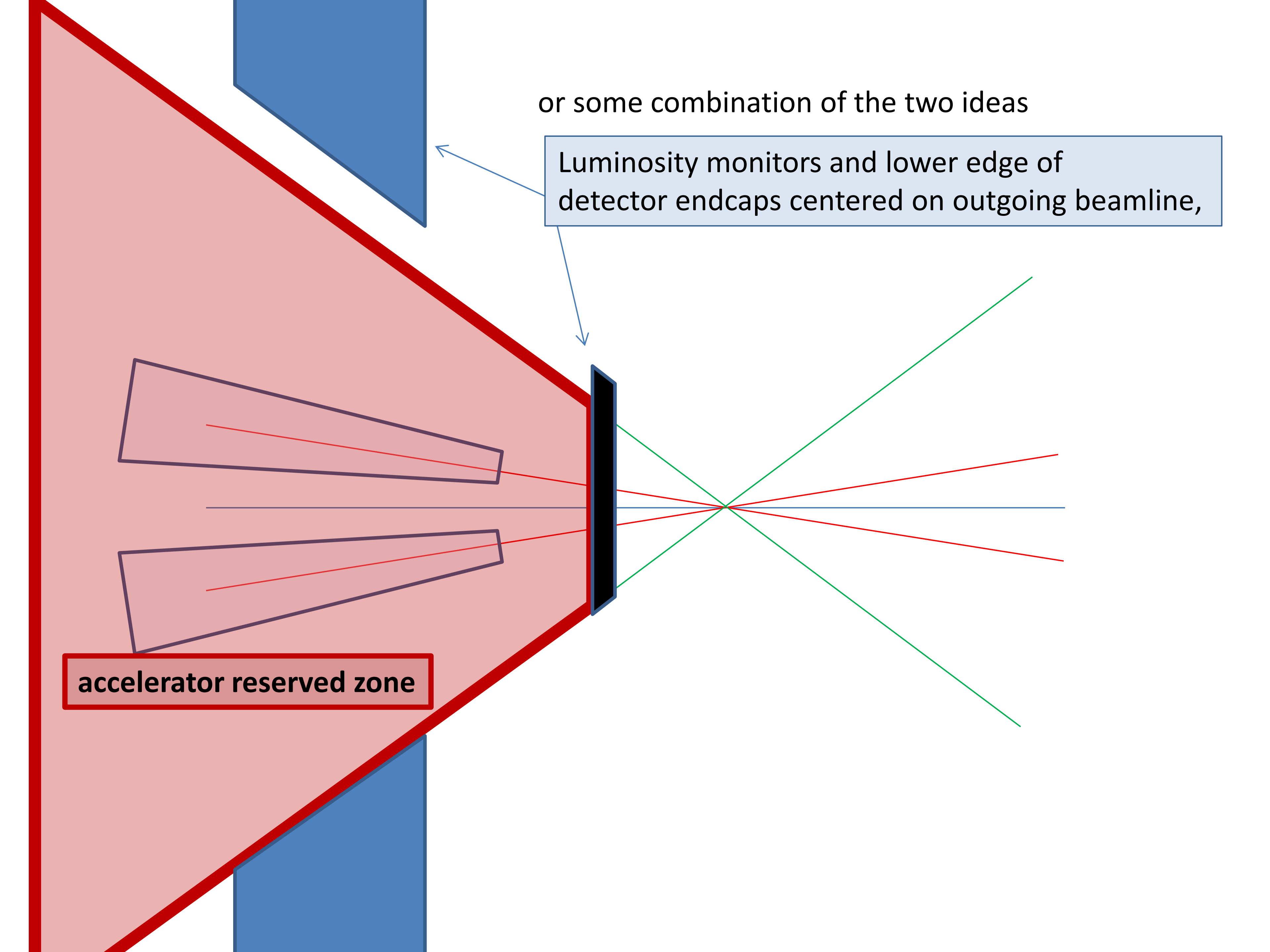
Tabel 1: Luminosity monitor scenarios studied. The last three columns give the shift in the parameter in question corresponding to an increase in acceptance of 10^{-4}.

It may be easier to combine a high statistics detector at 1-1.5 m from the IP with a more precise one situated at larger angle and at a larger distance as such

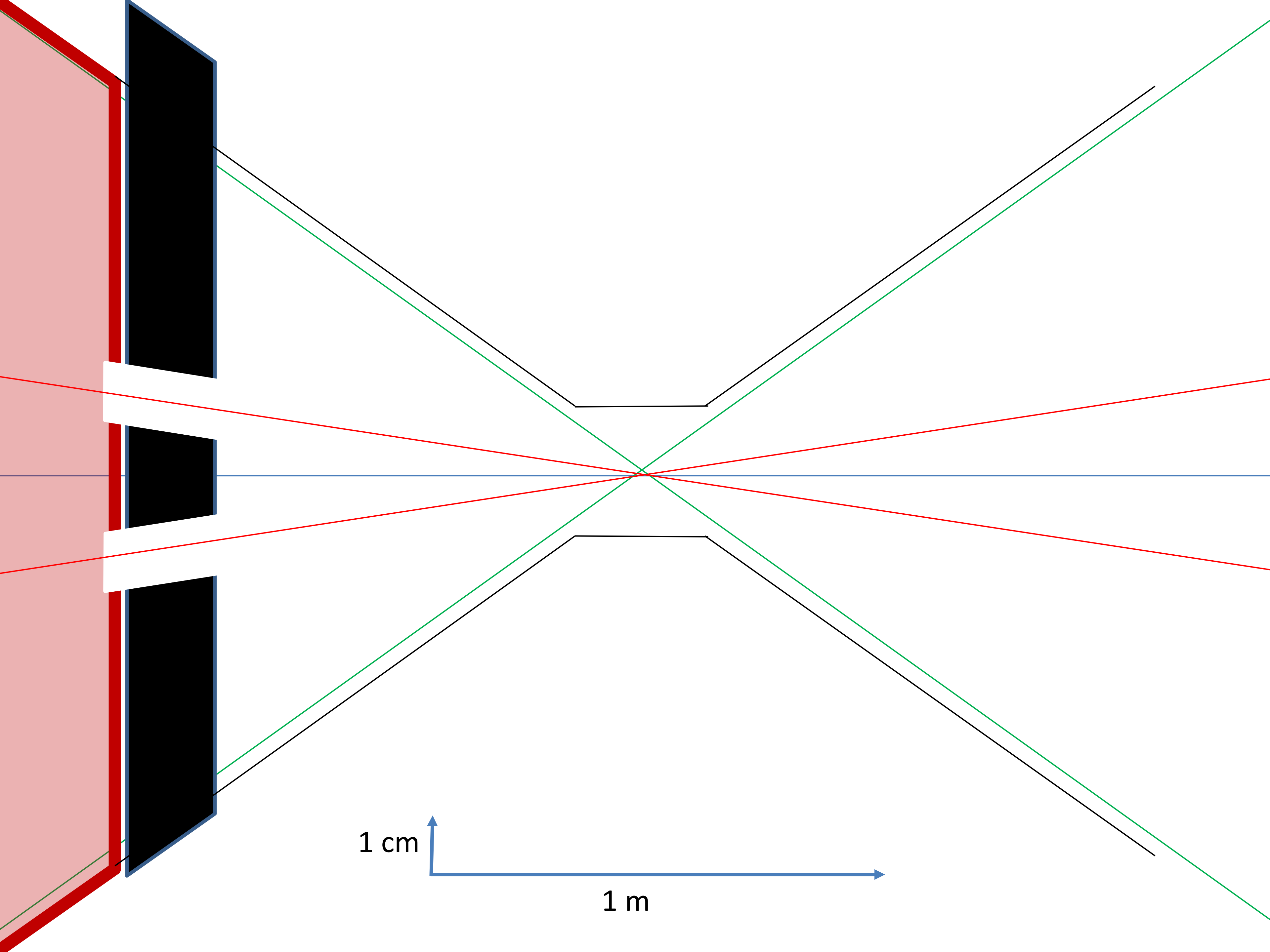


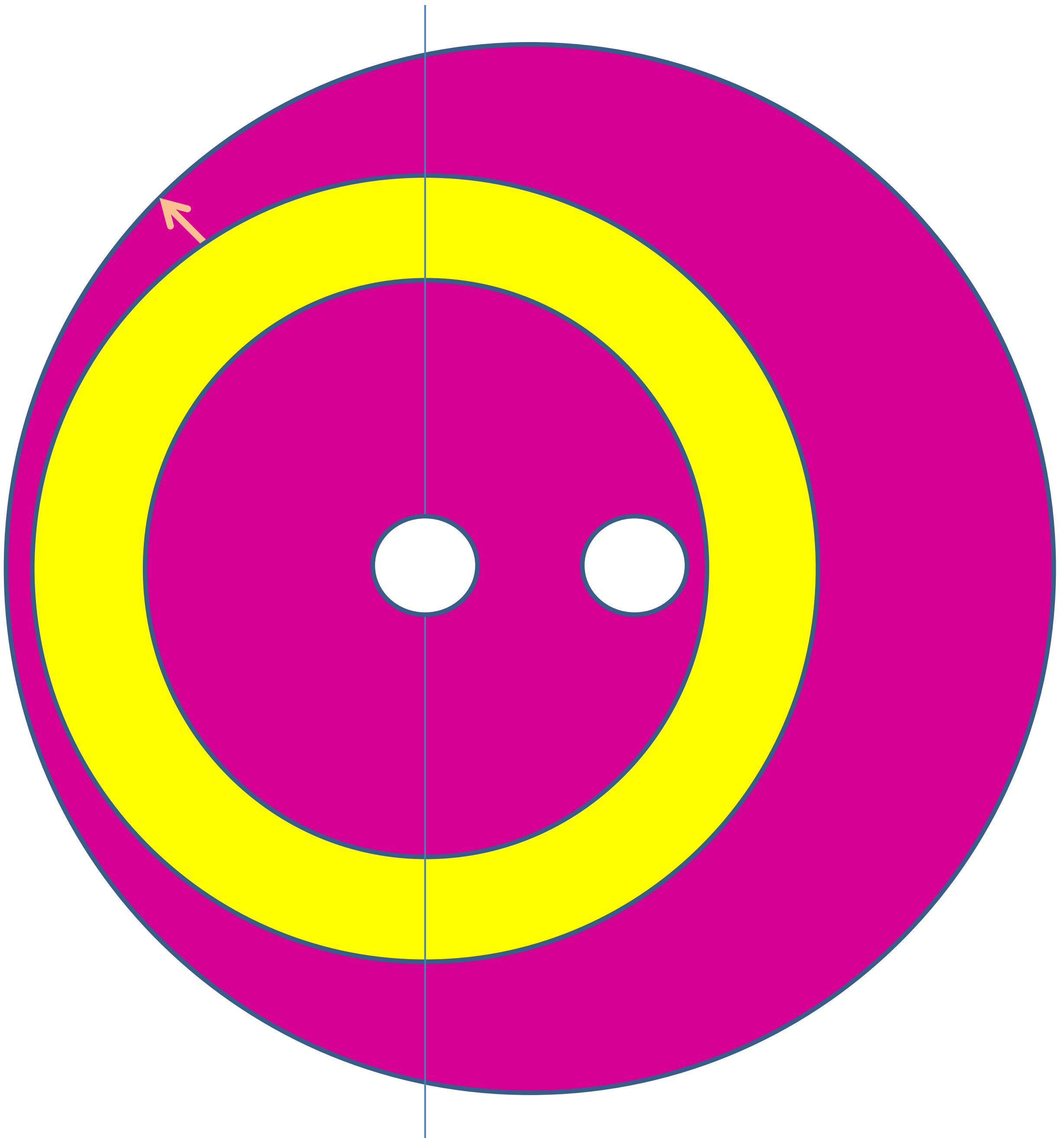
and for better use of the low angle space to center it on the outgoing beam line:

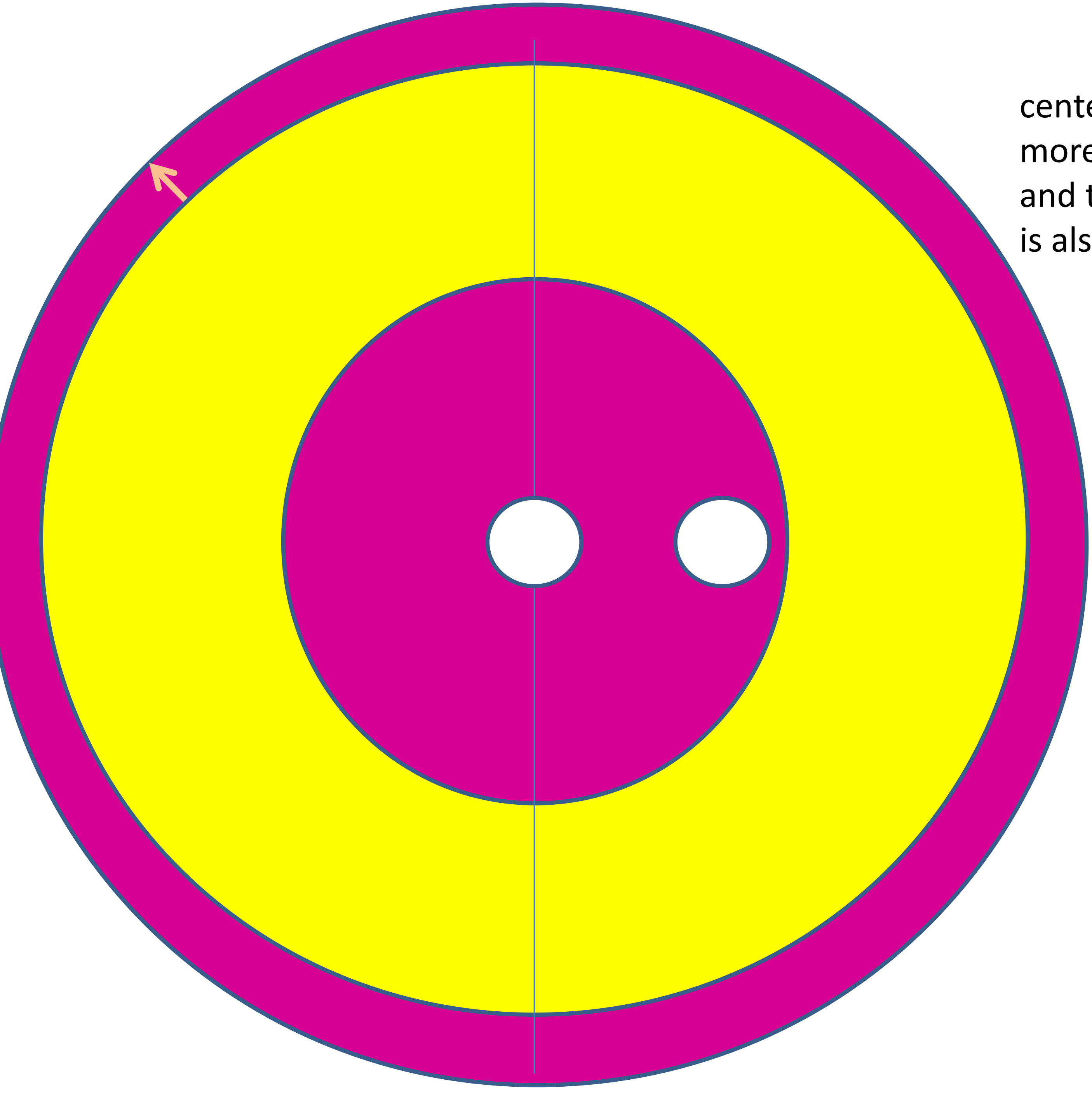




or some combination of the two ideas
Luminosity monitors and lower edge of
detector endcaps centered on outgoing beamline,
accelerator reserved zone


1 cm
1 m





centering on exit beam axis is
more efficient in space,
and the shadow on endcaps
is also symmetric.

Parameters to be defined

1. beam crossing angle
   NB spin tune of 103.5 = Z peak <-> angle of 0.01517 ~ 15mrad

2. safe beam pipe envelope at ~1m from IP

3. minimal space towards IP needed for quads and other beamline elements

4. angular cone supported by ‘accelerator reserved’ zone
to be negociated.

5. shielding (active, passive?) of beam against experiment solenoid field

THE IR design with beams crossing at an angle poses new issues of

- **-- magnet design**
- **-- physics**
- **-- optics**

MDI group has nice task in front of them!