Machine Detector Interface

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Outline

- MDI issues
  - Detector acceptance
  - Final Focus elements
  - Backgrounds
    - Synchrotron Radiation
    - Beam particle
    - Luminosity
  - Other (heating, HOM, vacuum, …)
- Summary
- Conclusion

MDI issues

- Up to now, the factories have been lower energy machines (<~10 GeV) with very high beam currents (>1 A)
- However, all present and new *ee* machines are essentially factory designs
- *eP* designs have many of the *ee* MDI issues because of the electron beam with extra complications added in from the hadron beam (i.e. more neutrons)
- An addition, current and future *ee* machines are aiming for higher energies and unprecedented luminosities

MDI concerns stem from factory designs

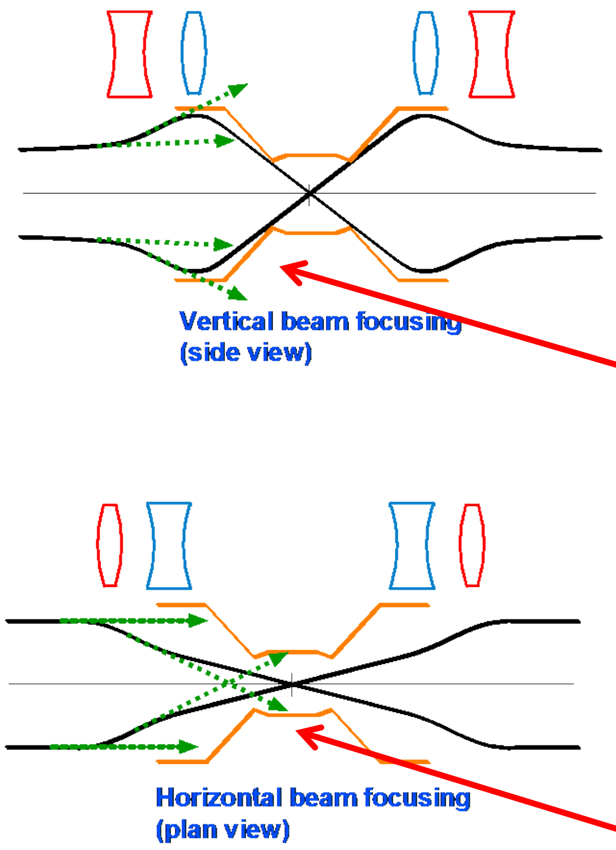
- Detector acceptance
  - Final Focus elements are as close to the IP as possible
  - Low angle detector acceptance is reduced
    - For the new *eP* collider designs forward acceptance becomes a critical item forcing accelerator design changes (JLAB with JLEIC and BNL with eRHIC)

Synchrotron radiation sources

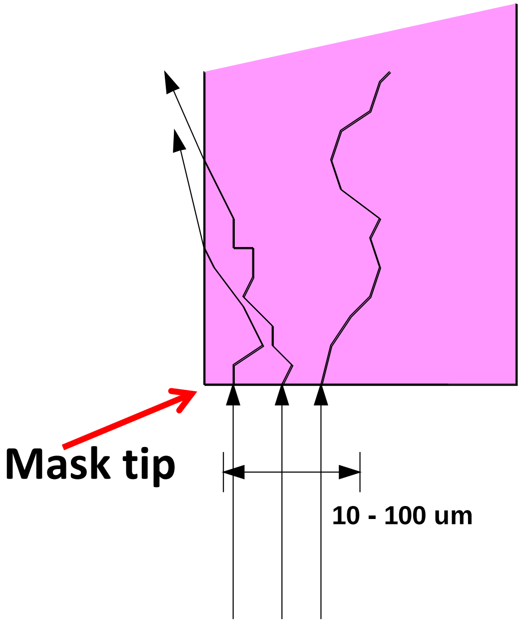
- Close final focus elements mean stronger magnetic fields
  - SR from the FF magnets (quadrupole radiation) becomes an important detector background
  - FF magnets close to the IP mean less space to design masking solutions
  - In addition, the downstream FF magnets have to be protected from the upstream FF SR (especially if they have cold bores)

Secondary SR sources

- The new and current machines have higher energy beams or higher beam currents (or both!)
- This means that SR intensity and energy spectra are higher than before in almost all cases
- Blocking the SR sources from directly hitting the detector (mainly the central beam pipe) is the first step
- But then secondary radiation (one bounce and/or tip scattering) becomes the dominant source of SR background in the detector (also backscattering ala HERA)
- These secondary background sources can become quite serious in the new regime of high energy and high current beams



Photons generated from the final focus quadrupoles have to be masked away from the central beam pipe. The vertical focusing element is usually closest to the IP and easier to mask. The horizontal focusing magnet is farther back and must over-focus in order to compensate for the defocusing of the vertical focusing magnet. These photons are more difficult to mask.



Photons that strike near the tip of a mask have a chance to scatter through the tip and then hit the central beam pipe

Beam particle Backgrounds

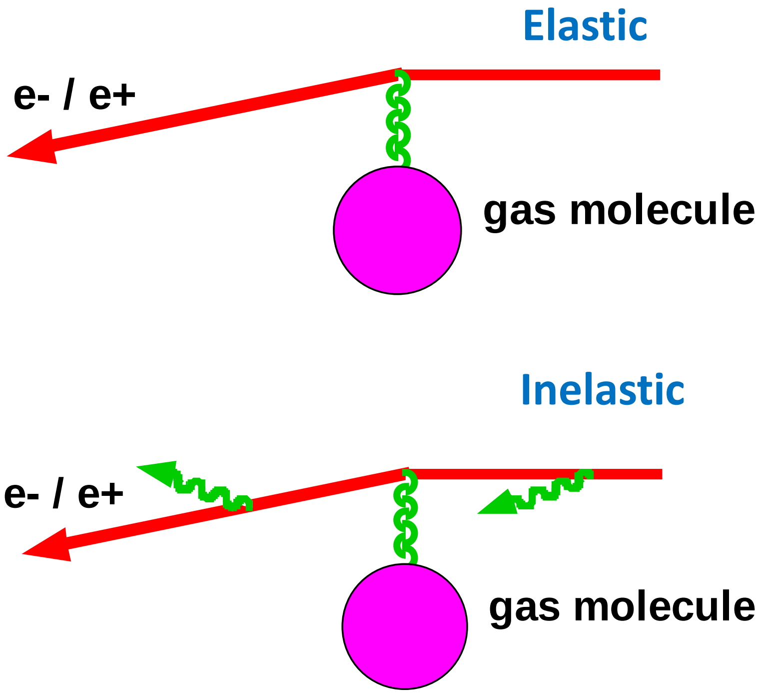
- There are several processes that need to be calculated that all involve backgrounds from a beam particle
  - Particle – particle interaction inside a beam bunch
    - Touschek
    - Inter-beam scattering (IBS)
  - These scattering events populate the high sigma region of a beam bunch with particles that tend to get lost in the IR because the beam beta functions are largest in the final focus magnets
    - Careful beam tail collimation at places outside of the IR are needed

Beam Beam

- Beam-beam tune shift also puts beam particles into the high sigma regions
  - Collimation should help this but one must watch the beam lifetime
- Luminosity lifetime
  - This is essentially the above point again.
  - Beam particles are shoved out into the high beam sigma regions
    - Top up injection needed

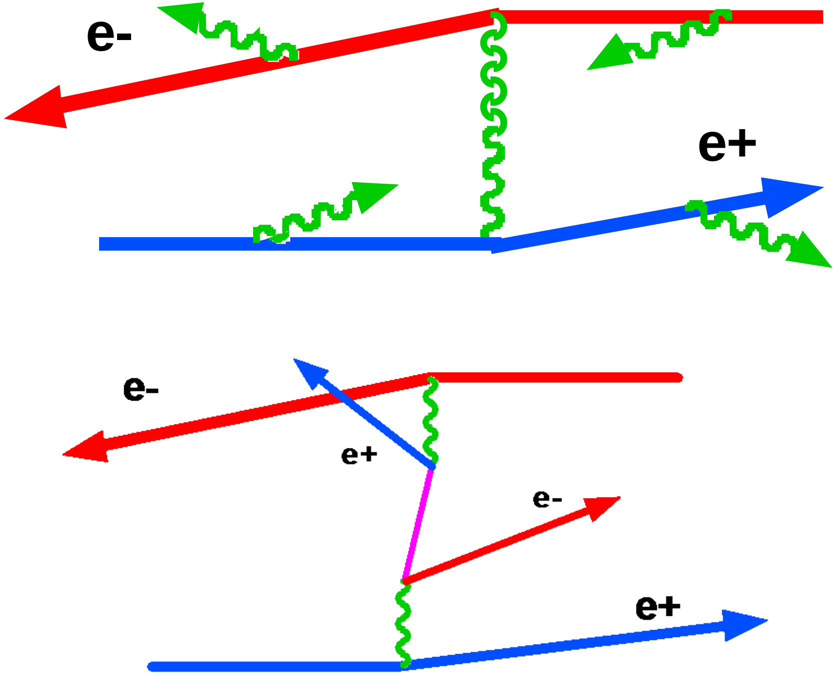
Beam-gas particle bkgds

- Beam particle interaction with a gas molecule
  - Coulomb scattering (elastic)
  - Beam-Gas interaction (inelastic)
    - A carefully constructed collimation scheme is needed to minimize these backgrounds
    - Also as good a vacuum as possible around the ring and especially upstream of the detector



Luminosity backgrounds

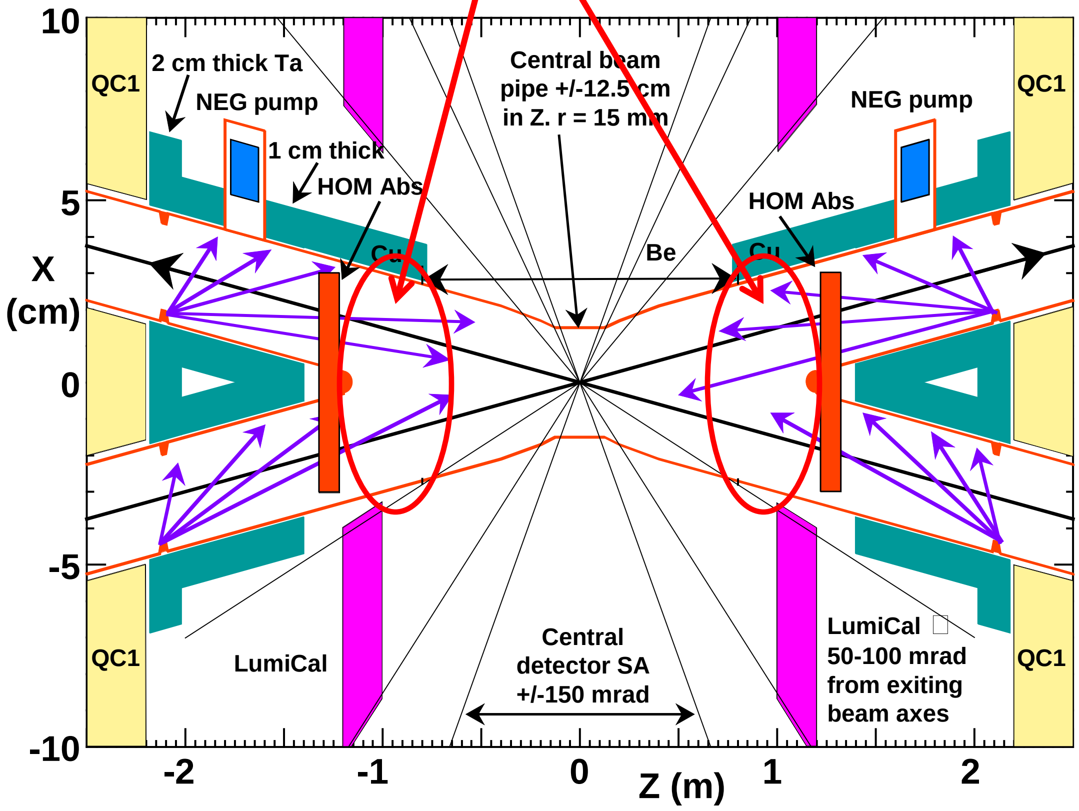
- The B-factories were the first to encounter significant backgrounds from luminosity
  - Radiative Bhabhas
    - Low angle γs and off-energy beam particles
  - Two-photon e^+e^-
    - Sets the inner radius of the beam pipe
- These bkgds increase with increasing luminosity



Other MDI issues

- **HOM heating**
  - **This is always an issue especially for crossing angle or separate storage ring collider designs**
  - **There is always a place that has the largest inside volume which is where the low frequency HOM gets trapped**
- **Image current heating**
  - **The beam produces an image charge on the walls that travels with the beam. This image current has an I^2R power loss based on the resistivity of the wall which is a function of frequencies related to the bunch length**

HOM catchers in FCCee IR



The beam pipe in all designs with separate storage rings will have a section where the two rings combine into a single pipe and then split into separate beam pipes

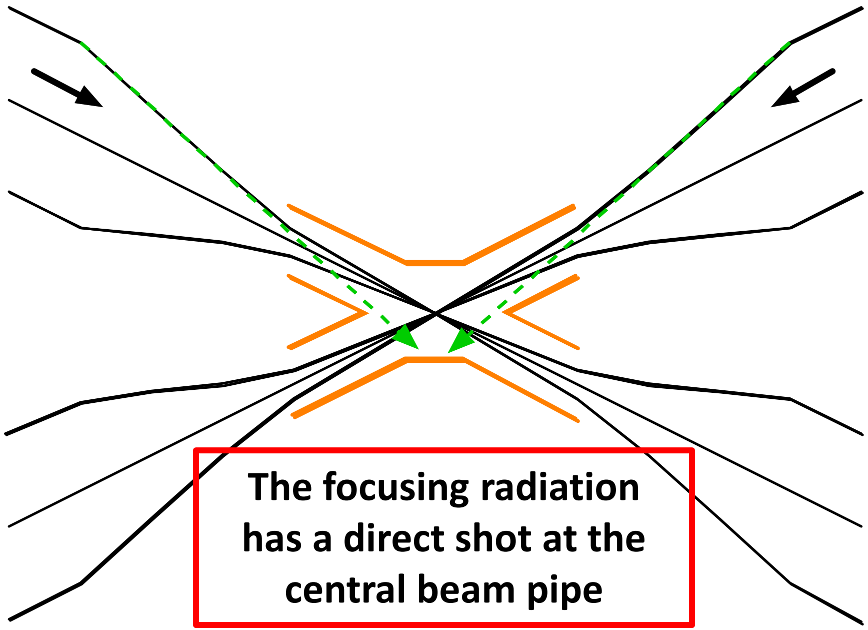
This needs to be checked for the CEPC RF region where we have different beam pipe paths for the Z and W compared to the Higgs

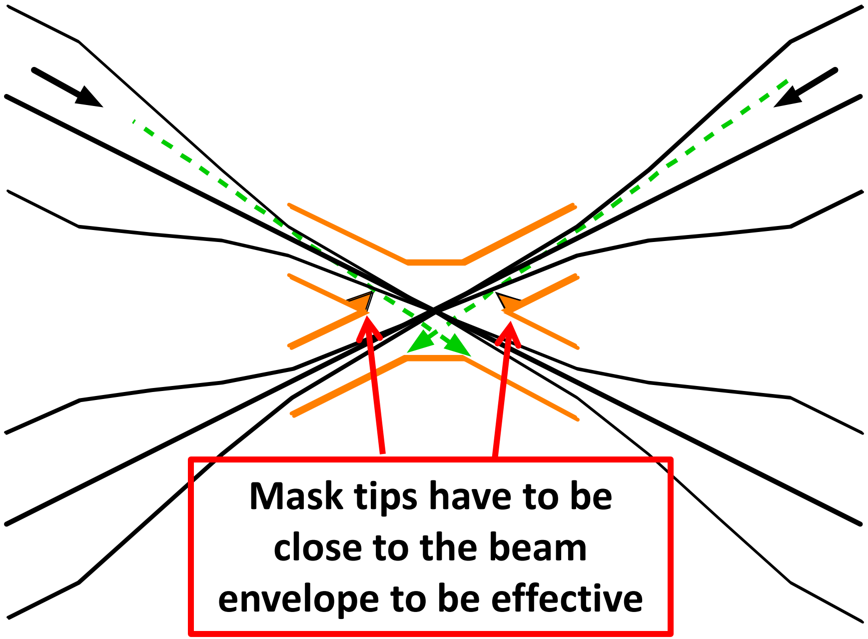
More other MDI issues

- Vacuum pressure
  - As low as reasonably possible upstream of the IR
  - The beam pipe from the last collimator to the IR must have very good vacuum as all gas interactions in this region will tend to crash into the detector (a bend magnet can help – especially BGB but Coulomb can still be a problem)
- Injection backgrounds
  - Continuous injection can double and perhaps triple the integrated luminosity compared to a coast and fill method (luminosity lifetime) but then one needs to make sure the detector can survive with continuous injection

Crossing angle masking

- **A large crossing angle makes shielding the central chamber from direct SR hits more difficult**
  - **SuperKEKB has the largest crossing angle of 83 mrad**





Engineering issues

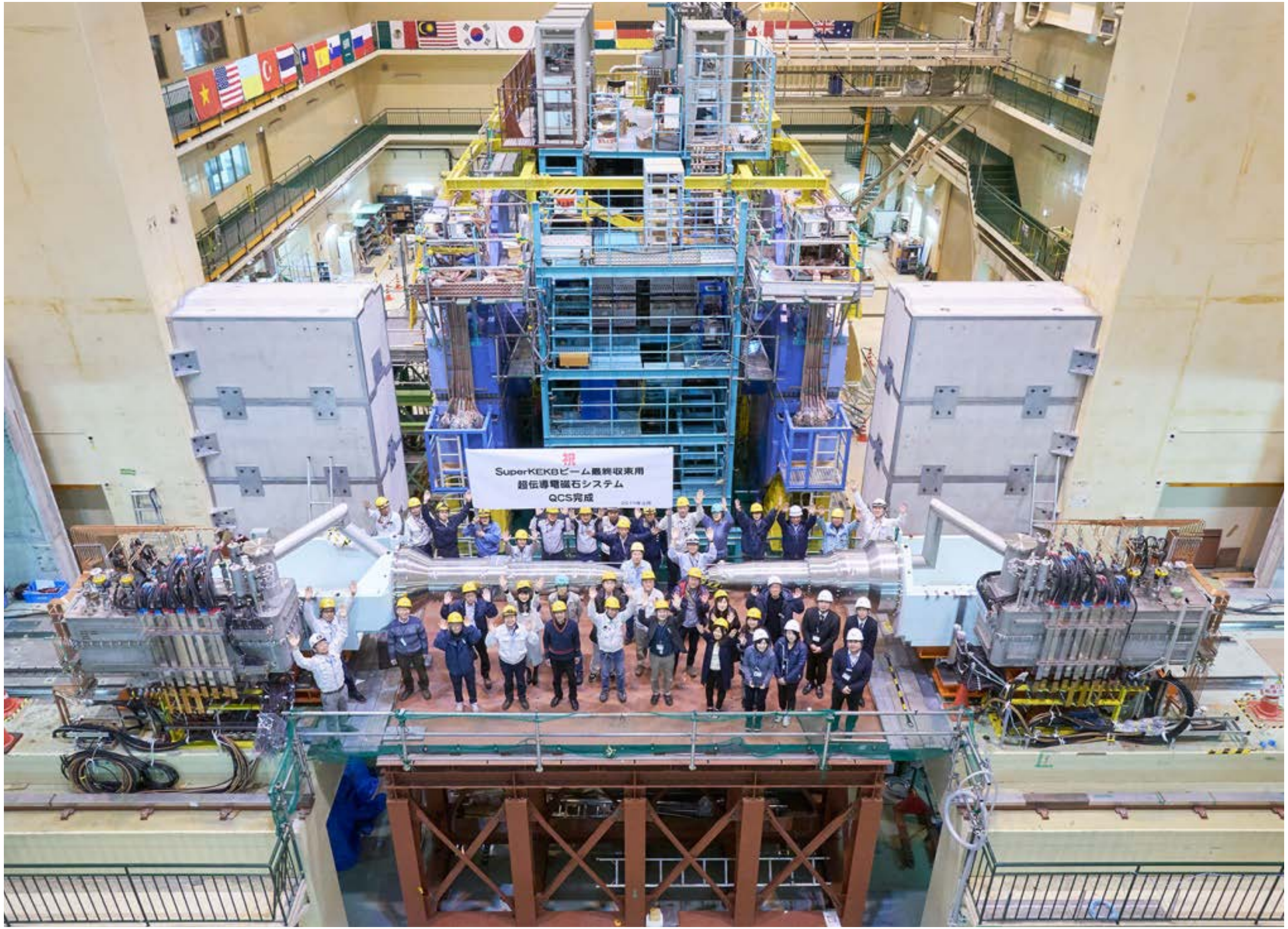
- Central beam pipe
  - Detector prefers zero RL material
  - Must be cooled (adds to RL)
  - High Z coating on the inside
    - Needed for SR soft photons?
    - How thick (5-10 um)?
      - Be is essentially transparent to all x-rays above 0.5 keV
    - What element (Cu, Ag, Au)?
    - Impedance to the beam if no coating?
      - Also extra heating into the Be

Usually must have high Z shielding just outside of the central beam pipe

Engineering Issues (2)

- Assembly of the IR central parts
  - FF quad cryostats
  - Central beam pipe
  - Central tracker
- Space will be needed to do this
- Vibration control
- Magnetic forces

SuperKEK is about to start up and has had to solve these concerns

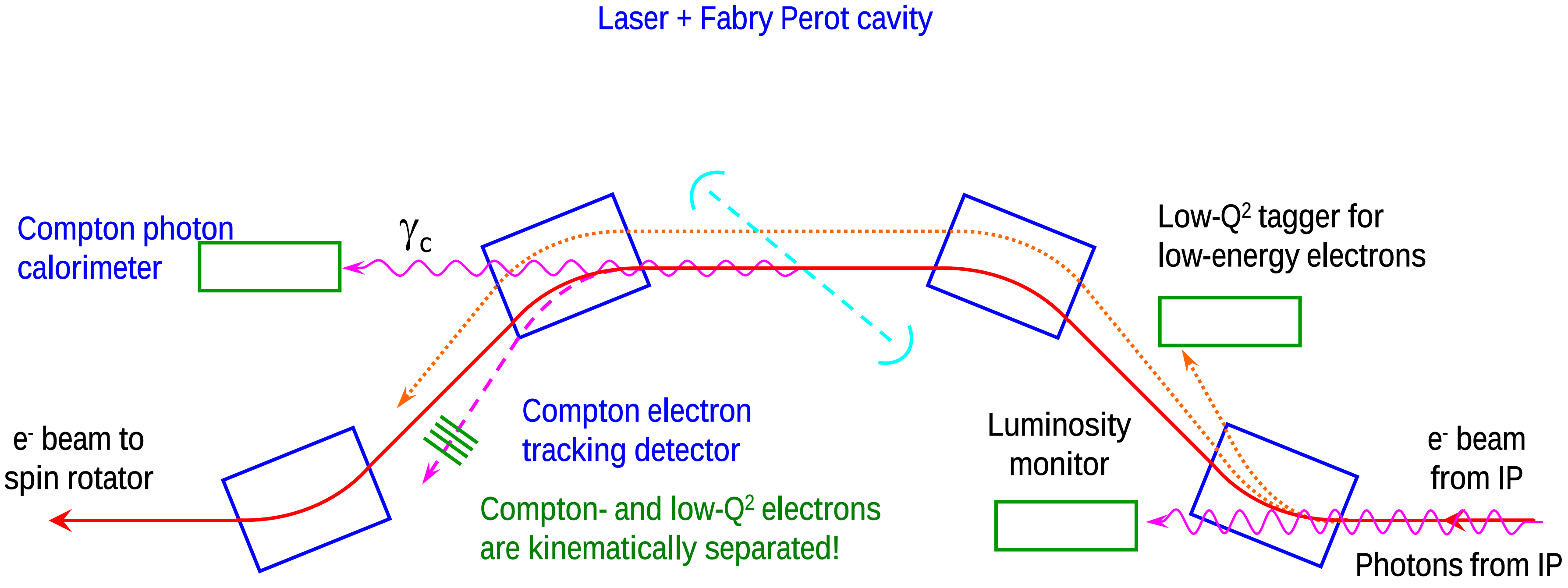


Notice the Massive Monsters these cryostats are

Polarimeter

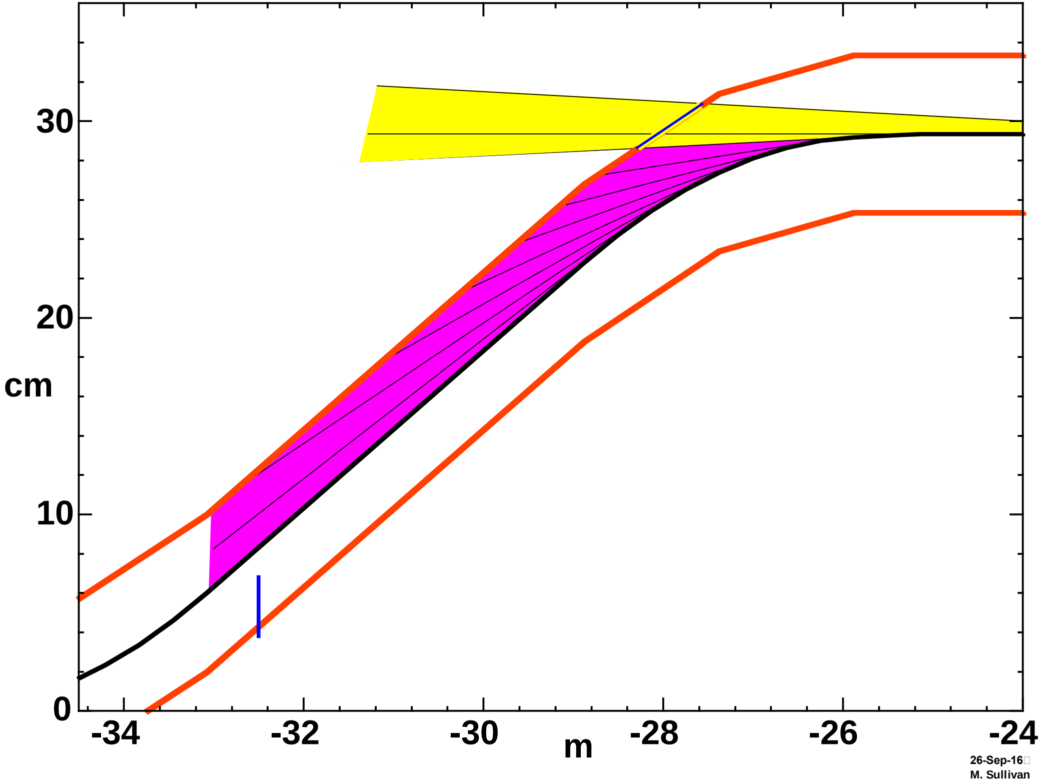
- Detector people want to insert a polarimeter to measure beam polarization
  - Involves a dipole magnet (how strong?)
    - Must be soft or Compton photon detector will be buried in SR photon flux from the bend magnet
    - In addition, the electron detector can also be easily buried by SR scattered from the beam pipe downstream of the dipole but upstream of the electron detector

JLEIC polarimeter



JLEIC polarimeter

- They have a soft bend magnet for the Compton photon detector
- However, the fan (purple) is strong and deposits 35 kW of SR power (~10^{10} photons)
- 7 GeV beam 3A
- 10 GeV beam 0.7A

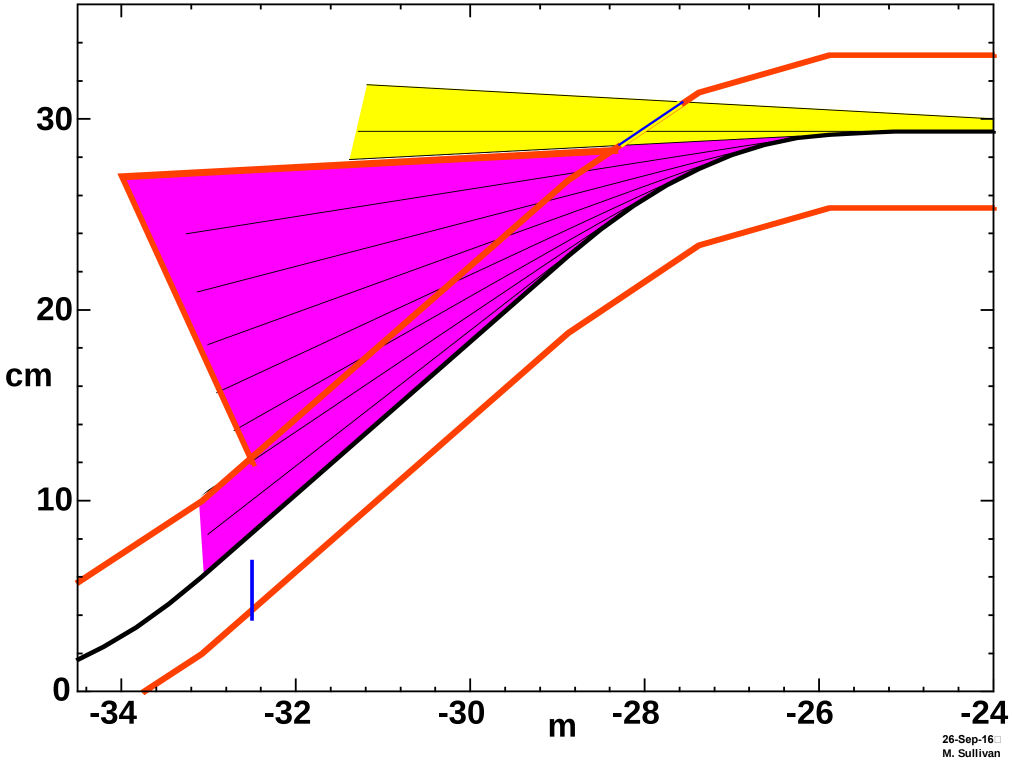


JLEIC polarimeter

- After some study we concluded that only solution is an antechamber beam pipe and a photon stop to absorb the SR power and photons

- Power density on the photon stop is still high but if sloped as shown then OK

- Lesson here is that polarimeter design must carefully check SR issues



Engineering details

- JLEIC polarimeter is an example of needing to check the details
- Need to try to itemize the requirements as much as possible in the CDR
- As much as possible try to explain why given selections have been made
  - What tradeoffs were considered

Summary

- The Interaction Region is one of the more interesting parts of an accelerator
  - There are many conflicting requirements that need to be optimally resolved
  - The accelerator needs to be able to produce the luminosity and the detector needs to be able to collect the physics

Summary (2)

- A good IR design should try to be as "flexible" as possible in order to "bend" and not "break" when slightly different running conditions or circumstances turn out to produce better machine and/or detector performance
- One needs to study around the chosen point for the IR design or in the large multi-parameter space near the design choices in order to find out where the "breaking points" are located

Conclusion

- First get a reasonably good IR design
- Then check for robustness
- Perhaps re-optimize
- Check again for robustness
- Keep iterating and rechecking especially after even small changes in the machine or detector occur