IR Issues

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For the FCC workshop

Jan 31, 2018

Outline

- Introduction and MDI machine parameters
- Current beam pipe design
  - Features
- SR background calculations
  - Results
    - Top
    - Z
- Other IR concerns
  - Engineering constraints
- Summary and conclusions

MDI machine parameters used

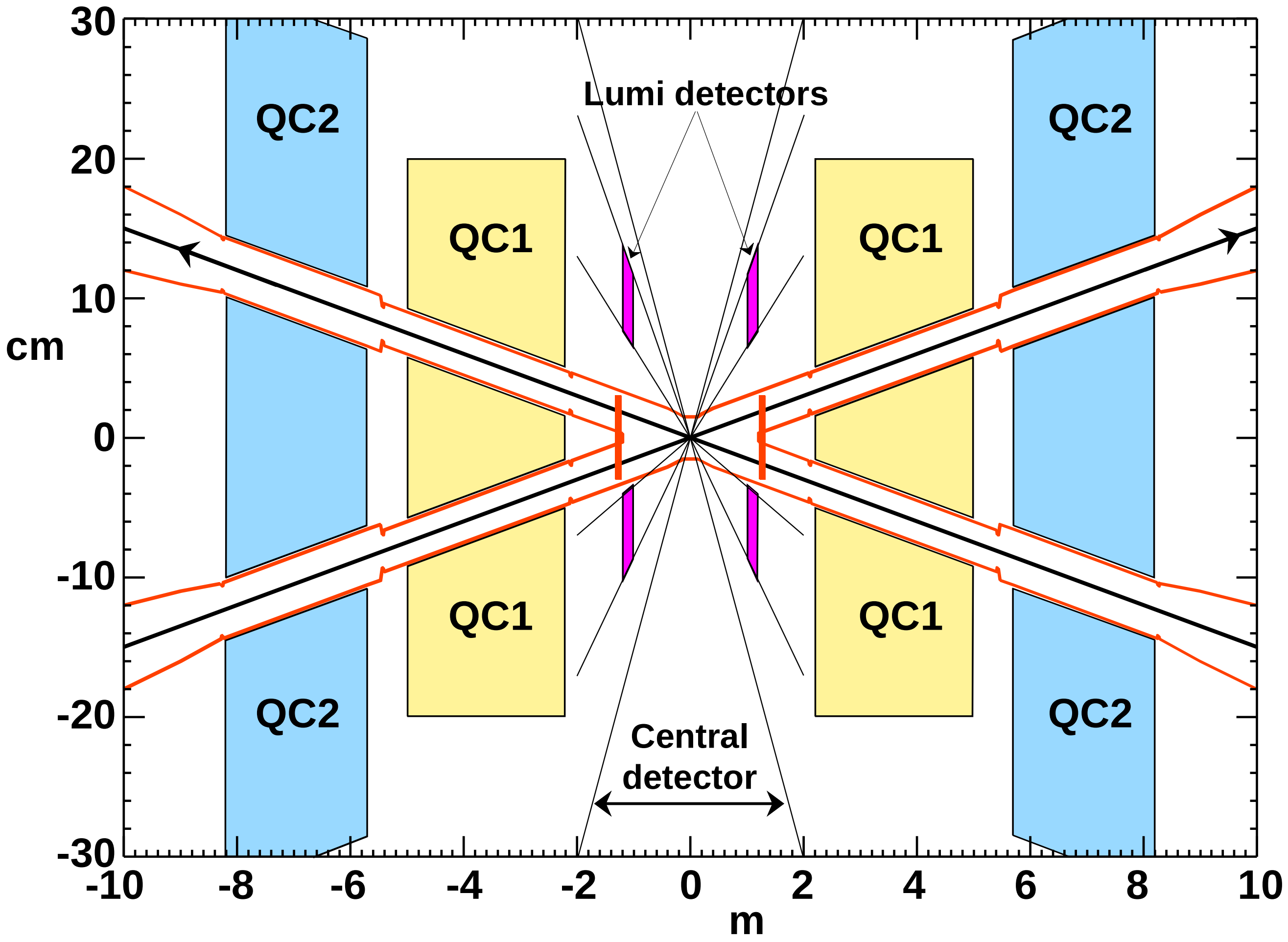
	Z	WW	Higgs	tt
Energy (GeV)	45.6	80	120	175
Current (mA)	1450 (1400)	152 (147)	30 (29)	6.6 (6.4)
#bunches	30180 (71000)	5260 (7500)	780 (740)	81 (61)
Particles/bunch (10^{10})	10 (4)	6 (4)	8	17 (21)
Emittance Hor. (nm)	0.28	0.26	0.61	1.26
Emittance Vert. (pm)	1	1	1.2	2.52
Beta* X (m)	0.15	1	1	1
Beta* Y (mm)	1	2	2	2

(Michael Benedikt's presentation on Monday)

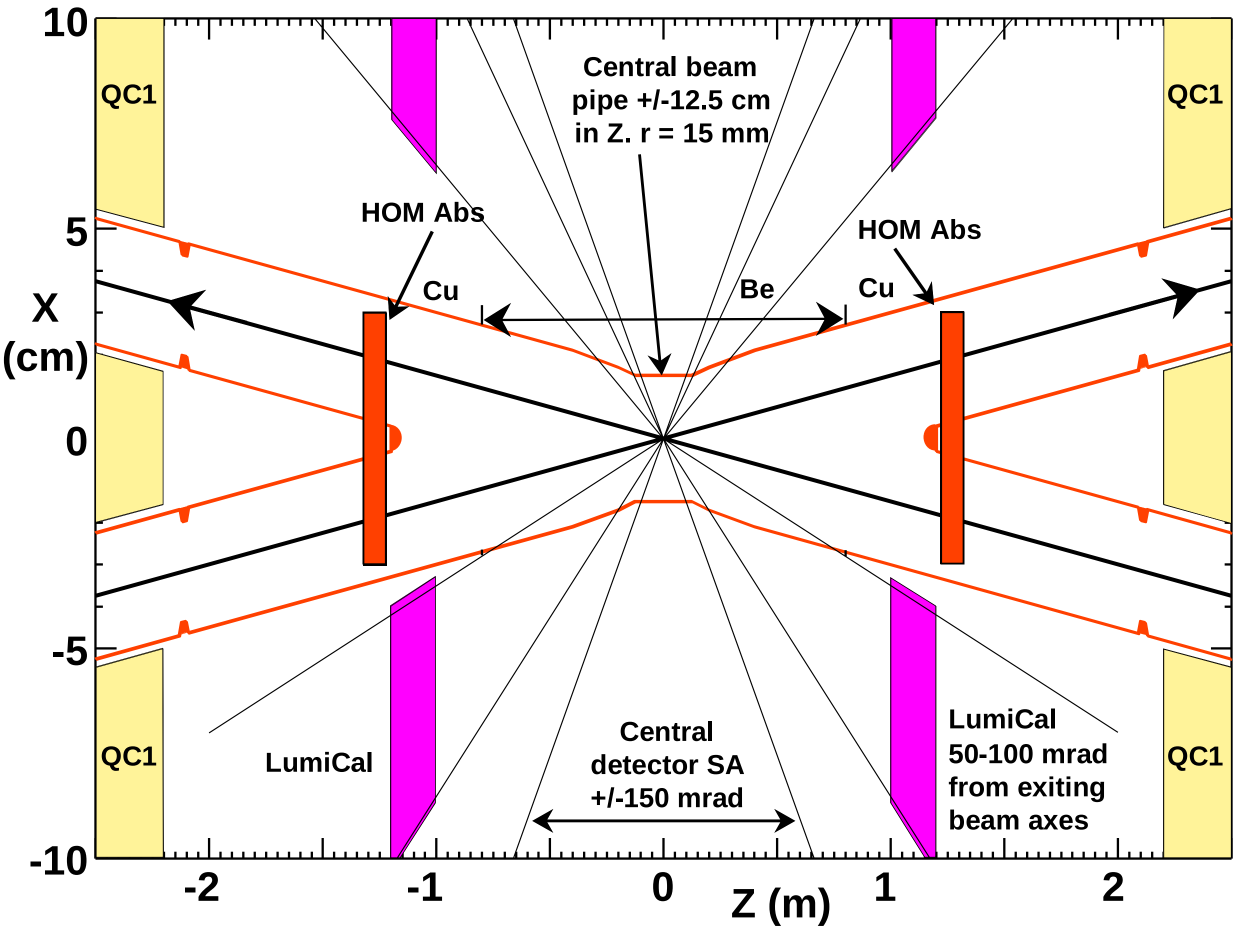
Several numbers have changed

The first upstream soft bend magnet has 100 keV critical energy at the Top

Interaction Region Beam Pipe



Interaction Region Beam Pipe



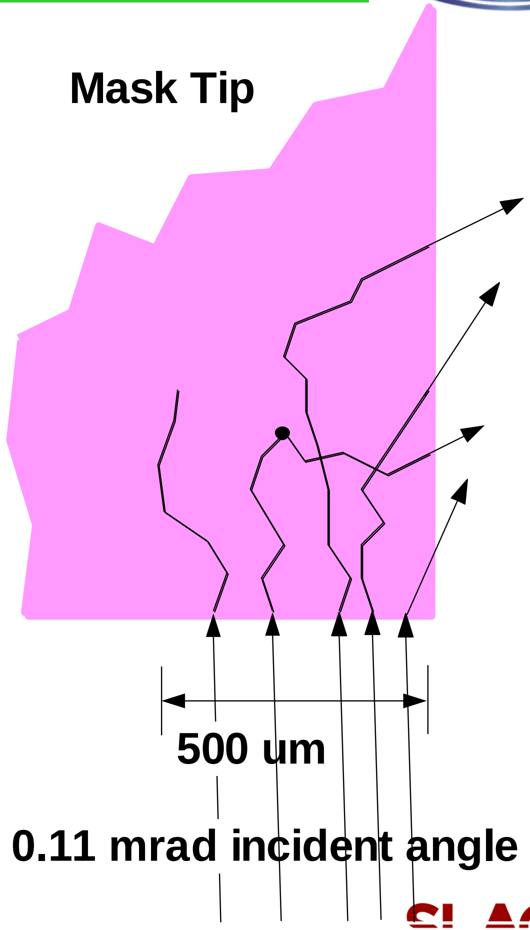
Features

- Central beam pipe has 3 cm dia.
- Entering and exiting beam pipe through Q1 (3cm dia.)
- Be from about +/-80 cm to accommodate LumiCal
- Pipe size increases to 4cm dia. in Q2
- Size outside Q2 is currently 6 cm dia.
- Mask tips +/-12 mm radius at +/-2.1 m and +/-5.44 m
- Mask tips +/-18 mm radius at +/- 8.27 m
  - Allows for possibility of cold bore magnets (shields quad beam pipes)
  - Need to remove 43 W of SR power between Q1 and Q2 on upstream side
  - Current IR design is for warm bores

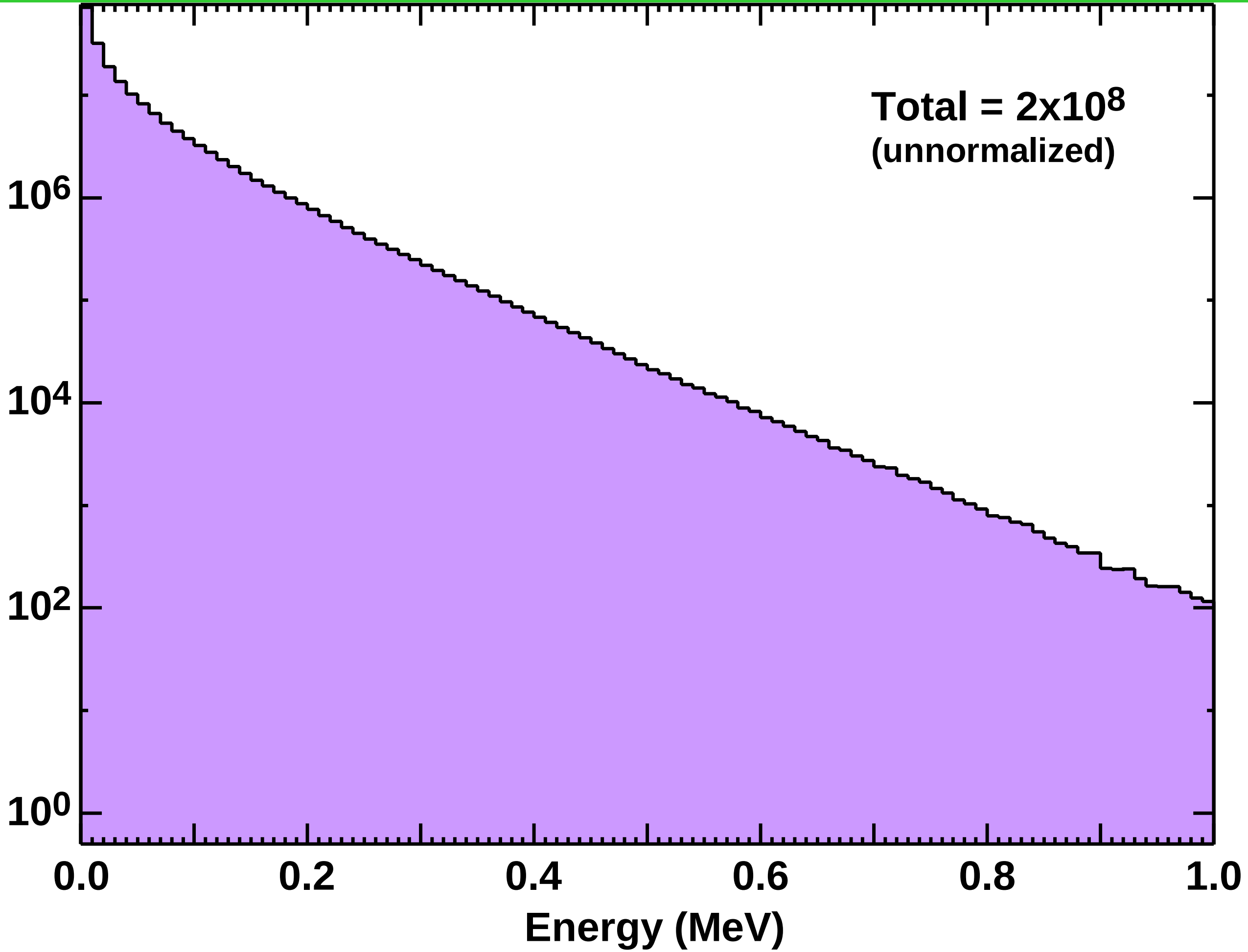
SR quad radiation

- The IR design prevents FF quad radiation from striking nearby beam pipe elements

- The SR backgrounds then come only from the last soft bend radiation striking the mask tips

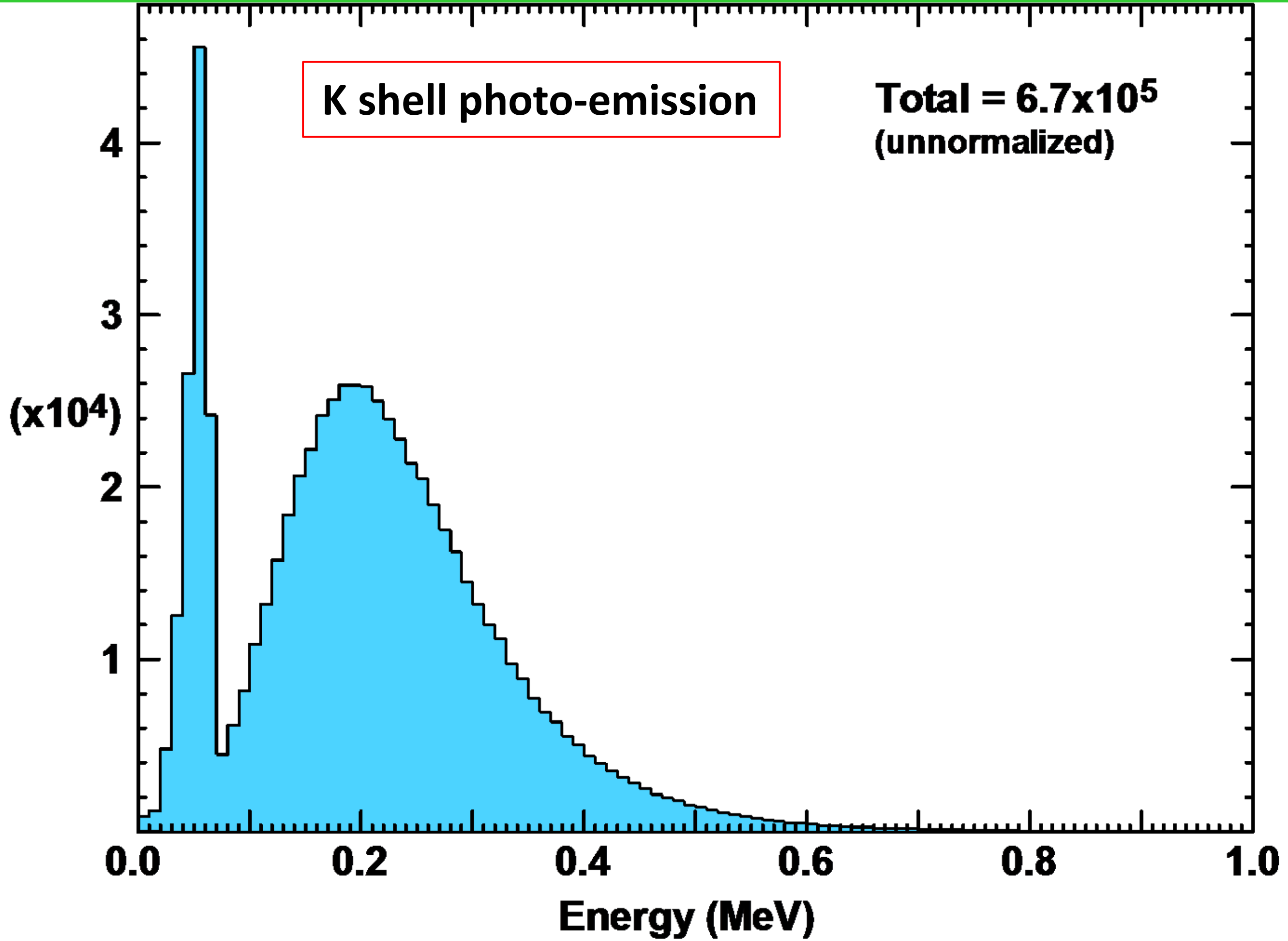


Top Incident photon energy spectrum

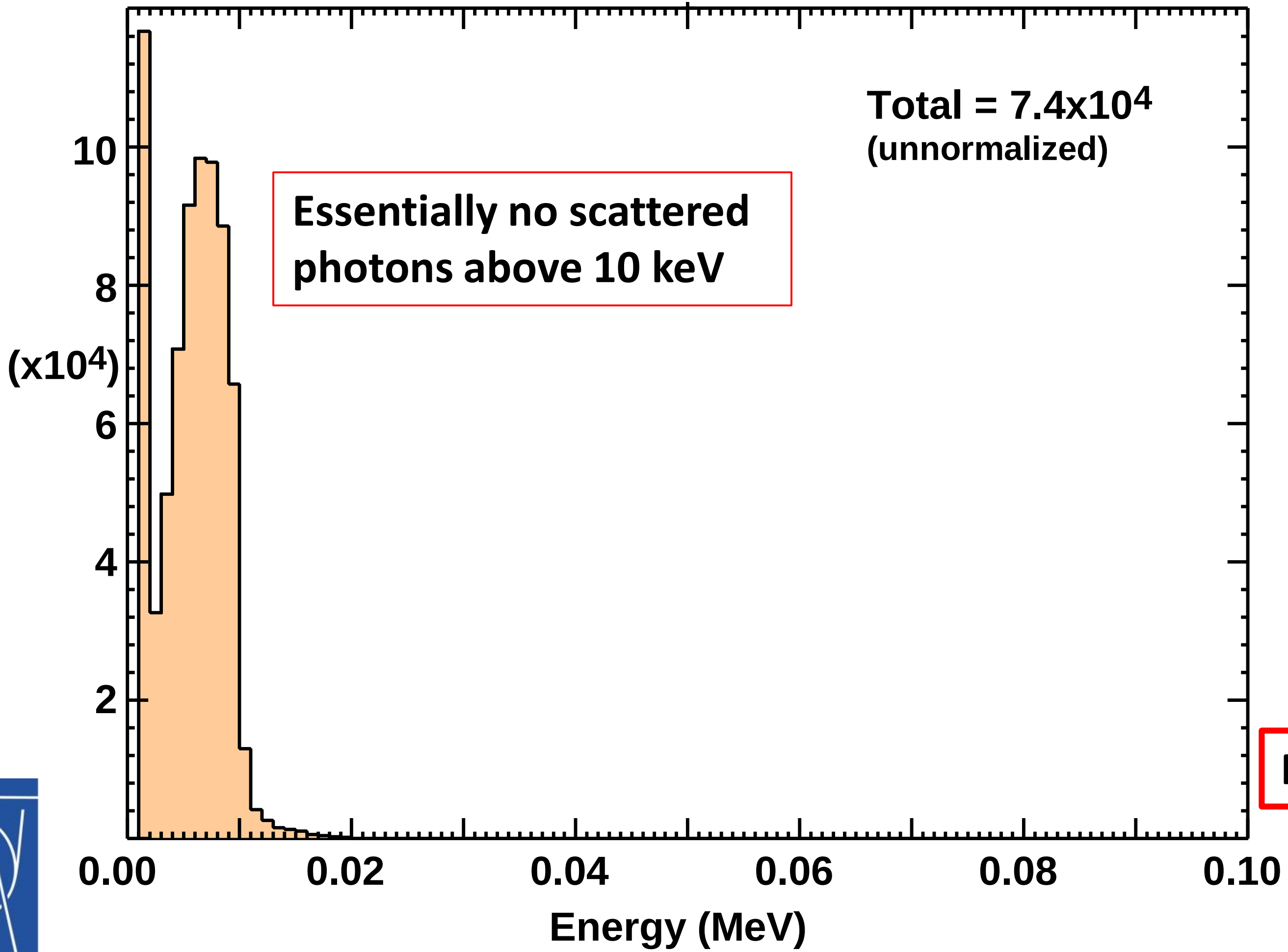


Photon energy spectrum incident on the mask tip at 2.1 m

Top scattered photon energy spectrum



Z scattered photon energy spectrum



Note change of scale

Scatter rate normalization table

Beam energy (GeV)	Soft bend critical energy (keV)	Incident photon rate/xing (>1 keV)	Generated photons	Ratio Inc/Gen	Generated scattered photons	Actual tip scatter rate/xing
175	100	1.57×10^{9}	2×10^{8}	7.95	670120	5.3×10^{6}
125	35.0	1.87×10^{8}	2×10^{9}	0.094	868218	8.1×10^{4}
80	9.56	2.79×10^{7}	2×10^{10}	1.4×10^{-3}	799455	1119
45.6	1.77	2.26×10^{7}	5×10^{10}	4.5×10^{-4}	73685	33.3

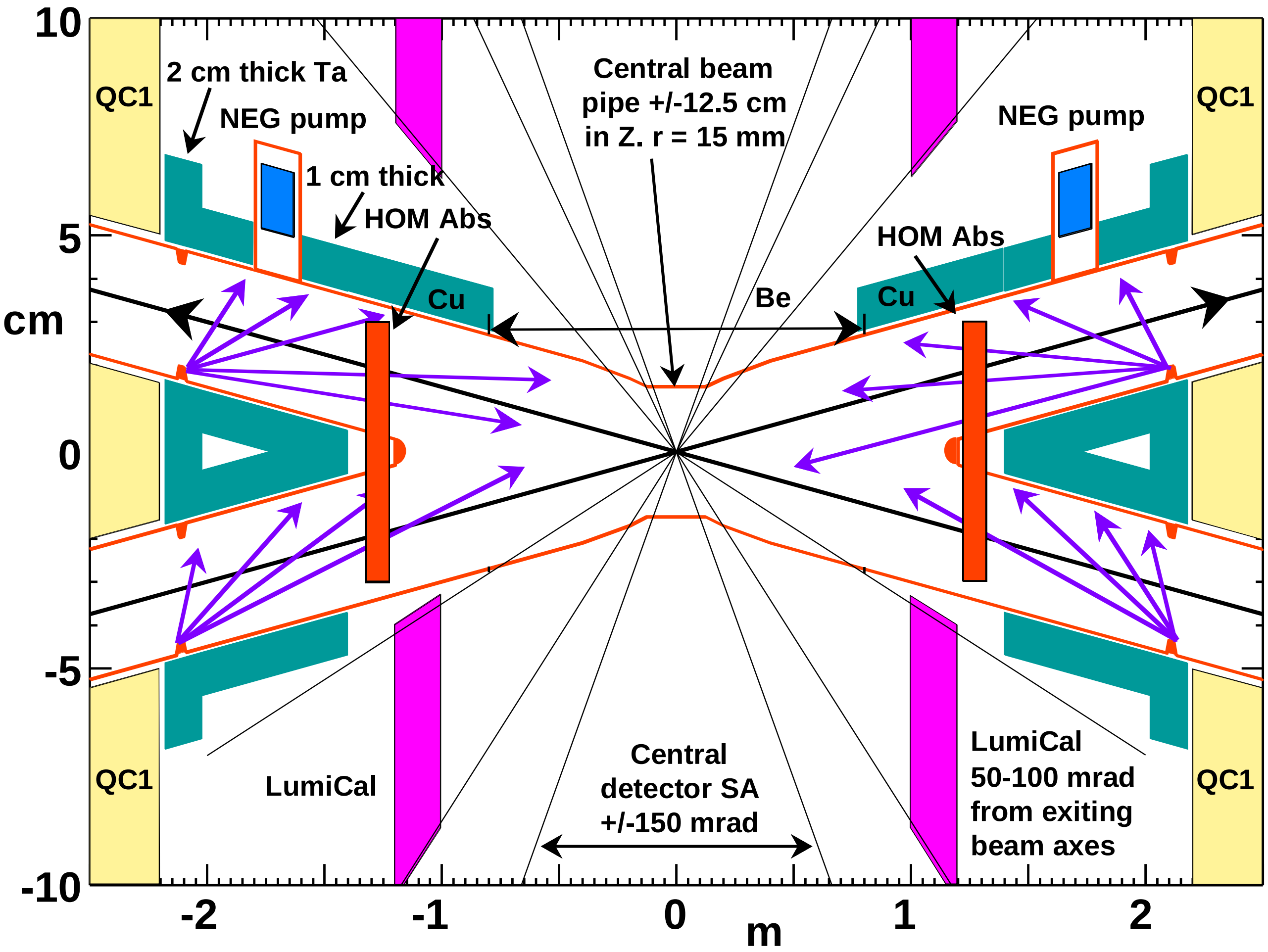
Table again with preliminary detector hits

Beam energy (GeV)	Soft bend critical energy (keV)	Incident photon rate/xing (>1 keV)	Generated photons	Ratio Inc/Gen	Generated scattered photons	Actual scatter rate/xing	Hits in the detector rate/xing
175	100	1.57×10^{9}	2×10^{8}	7.95	670120	5.3×10^{6}	$4.5\times10^{4*}$
125	35.0	1.87×10^{8}	2×10^{9}	0.094	868218	8.1×10^{4}	33
80	9.56	2.79×10^{7}	2×10^{10}	1.4×10^{-3}	799455	1119	$0^{\dagger}$
45.6	1.77	2.26×10^{7}	5×10^{10}	4.5×10^{-4}	73685	33.3	$0^{\ddagger}$

* No shielding. With some shielding ~600
† Over 1400 xings
‡ Over 45000 xings

From A. Kolano

Local primary SR scatter points



The pumping and shielding designs must be combined

Possible detector interests

- Zero degree Luminosity detector?
  - At the Z, W and Higgs – perhaps OK?
  - Crucial for luminosity feedback orbit control?
  - At the top beam energy SR background from FF magnets may be too much
- Smaller radius beam pipe?
  - At the Z and W perhaps possible
    - SR photon energies are very low
    - Requires a careful engineering study
    - Physics driver needed

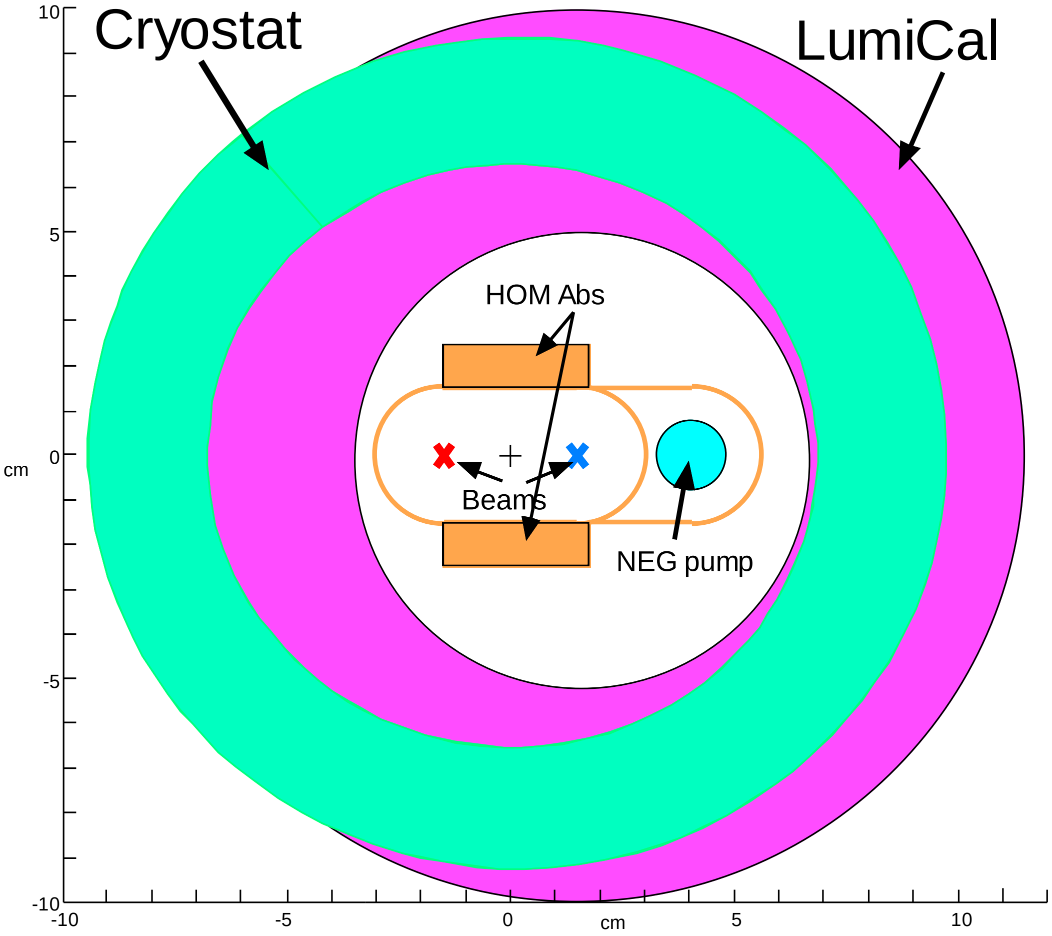
Other concerns

- **Assembly**
  - Remote vacuum connection (ala Belle II)?
  - Bellows between Central chamber and cryostat chambers (at least 1-2 convolutions)
  - Central chamber support
  - Cable and cooling pipe space for central detectors

More concerns

- Vibration control
- Cryostat support
- Magnetic forces
  - Anti-solenoids have strong expulsion forces?
  - Compensating solenoids have strong expulsion force near detector field edge

End view behind LumiCal



Shielding is not shown but we should be able to fit in at least 1 cm of a high Z material (Pb, W, Ta)

Still More Concerns

- Overlapping Z space
  - LumiCal
  - Cryostat
  - Remote vacuum assembly
  - NEG pump
  - HOM absorbers
  - Shielding

Summary

- The IR design has been relatively stable
- But now engineering concerns are coming into play
- These may force a reevaluation of the IR design
- We need space for bellows and vacuum connections and possibly supports
  - Move the FF quads back?
  - Shorten the anti-solenoid?
  - Move the Lumi-Cal forward?

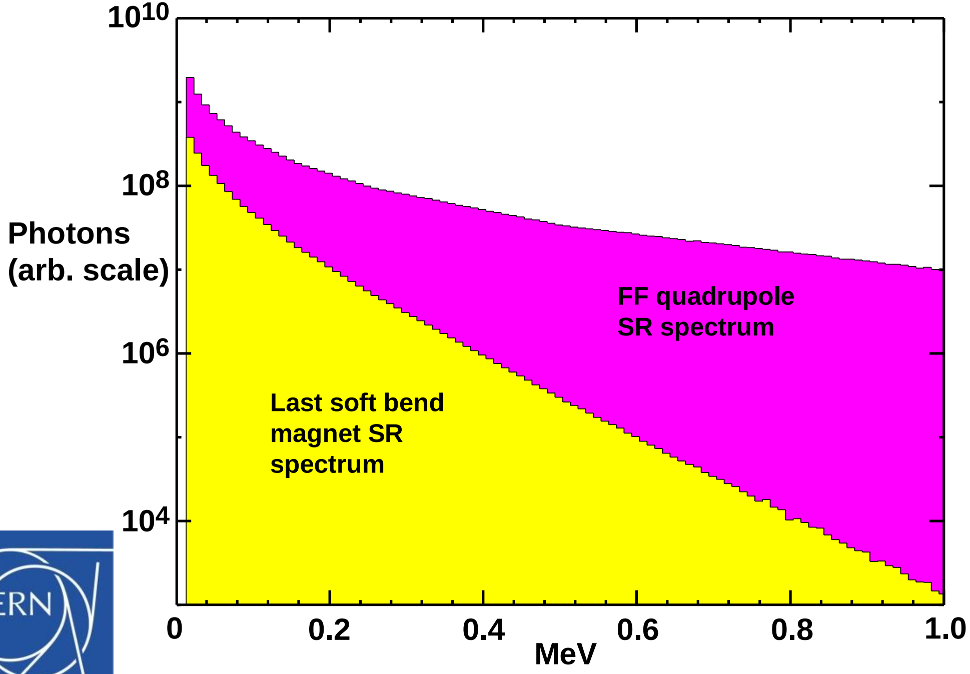
Conclusion

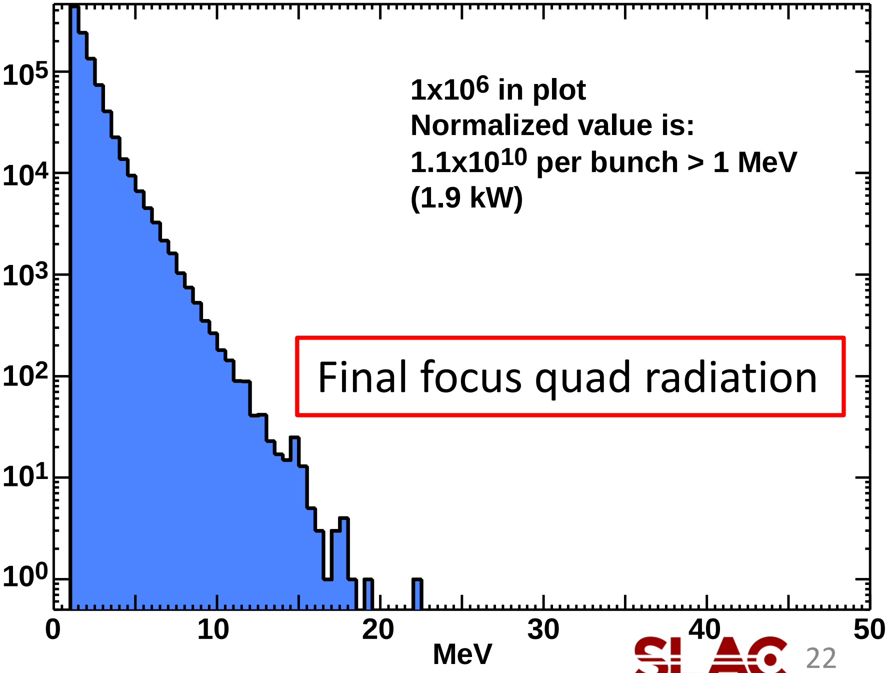
- **A good time for a workshop like this to take a first look at some of these issues in an integrated way**

Backup slides

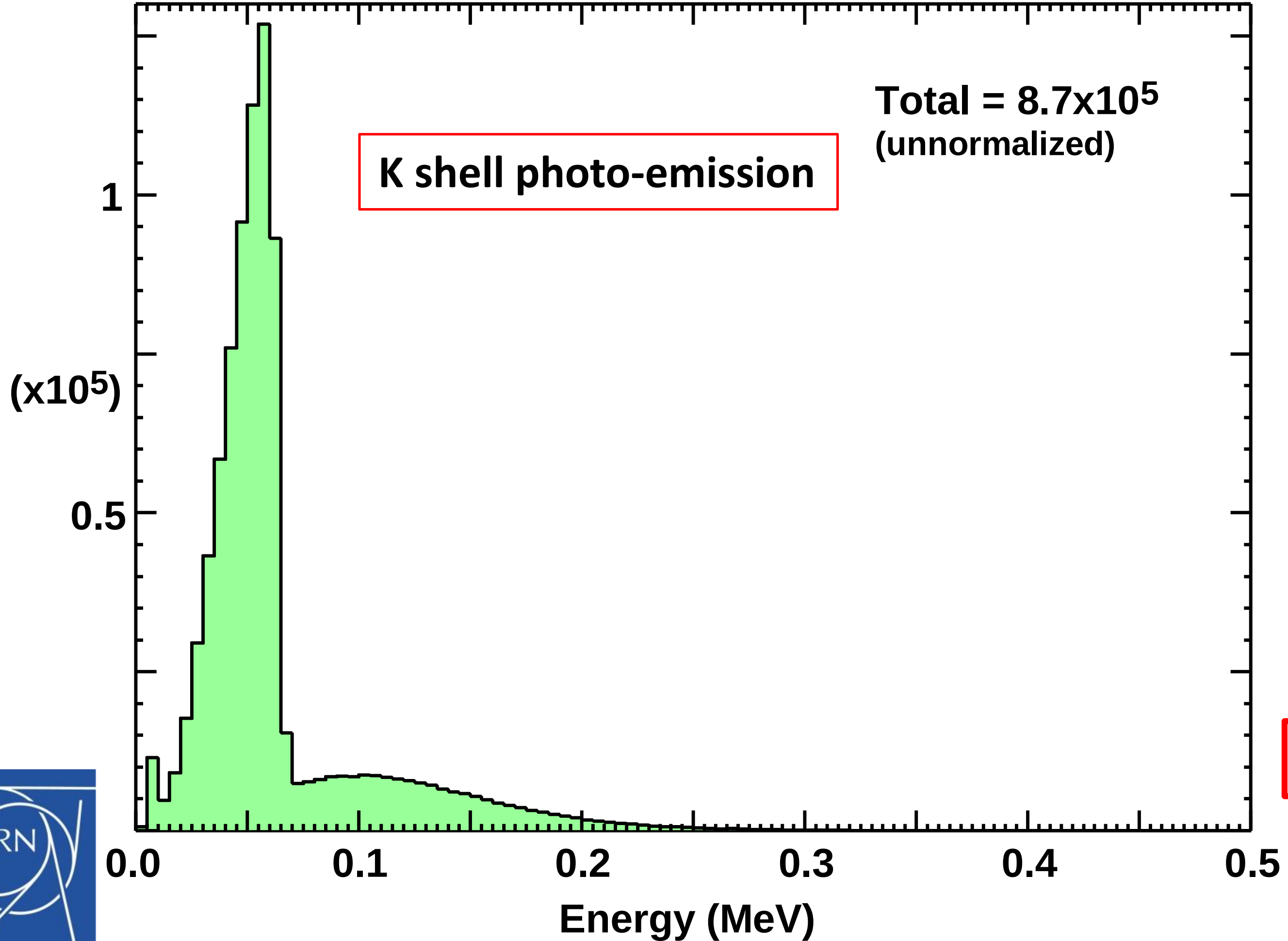
Final Focus quadrupole SR

- The energy spectrum of the SR from the final focus magnets is much higher than the spectrum from the last bend magnet



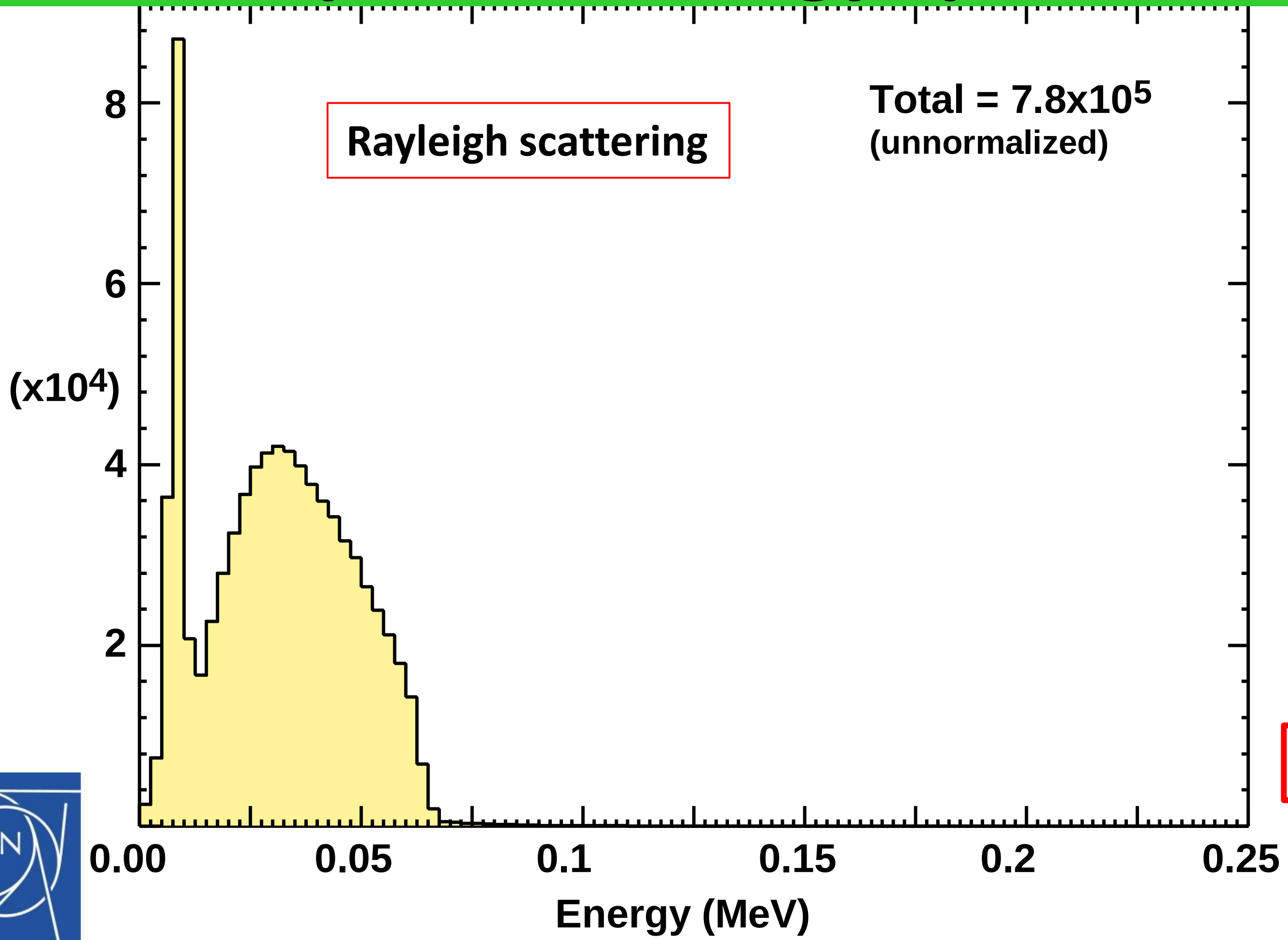


Higgs scattered photon spectrum



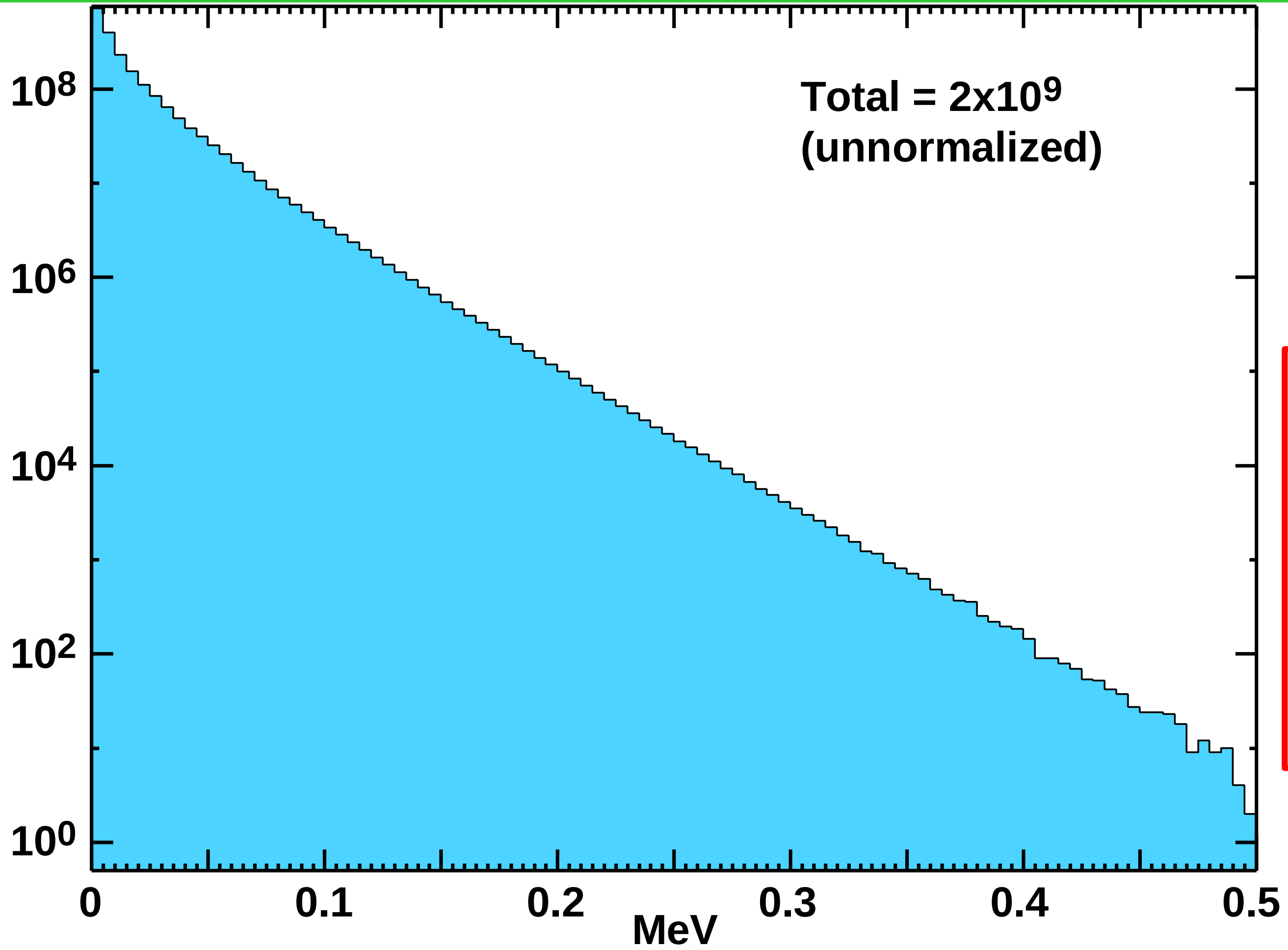
Note change of scale

WW photon energy spectrum



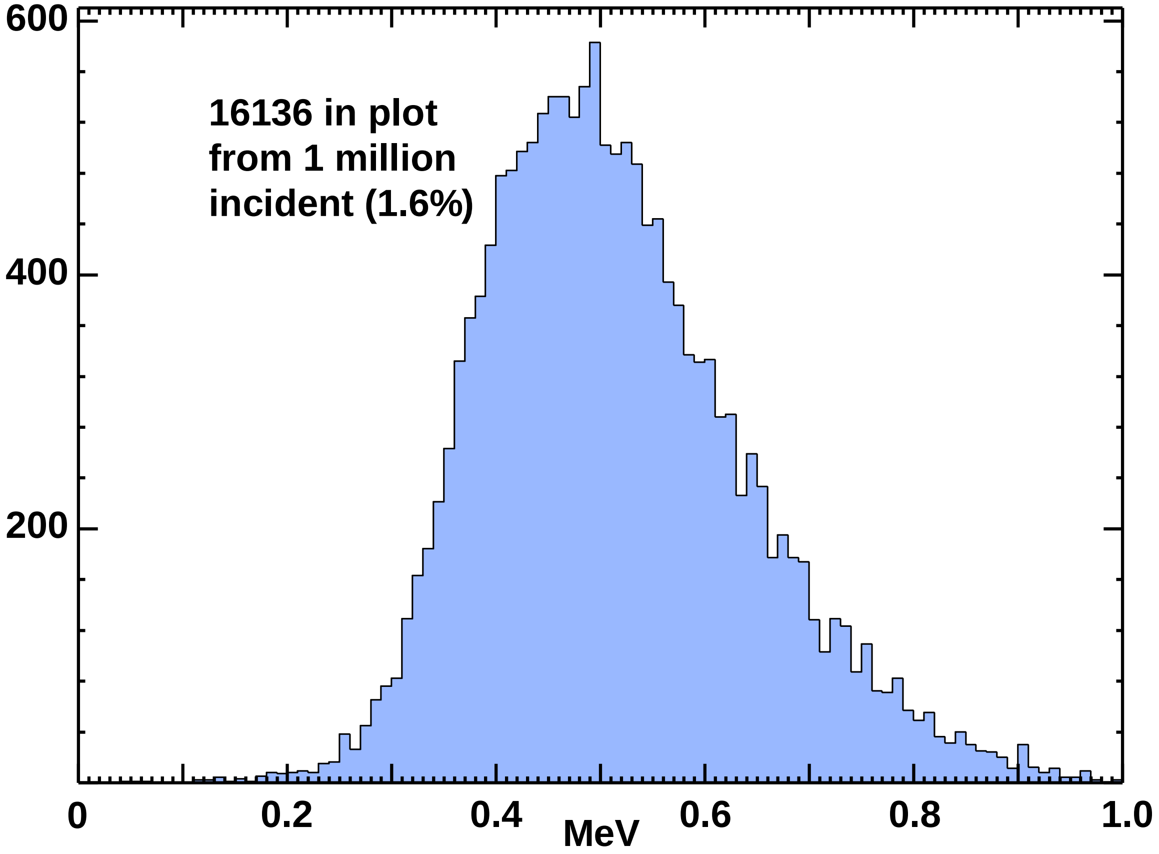
Note change of scale

Higgs Incident Photon Energy Spectrum



The spectrum is noticeably steeper than the top energy plot and is plotted out to only 0.5 MeV

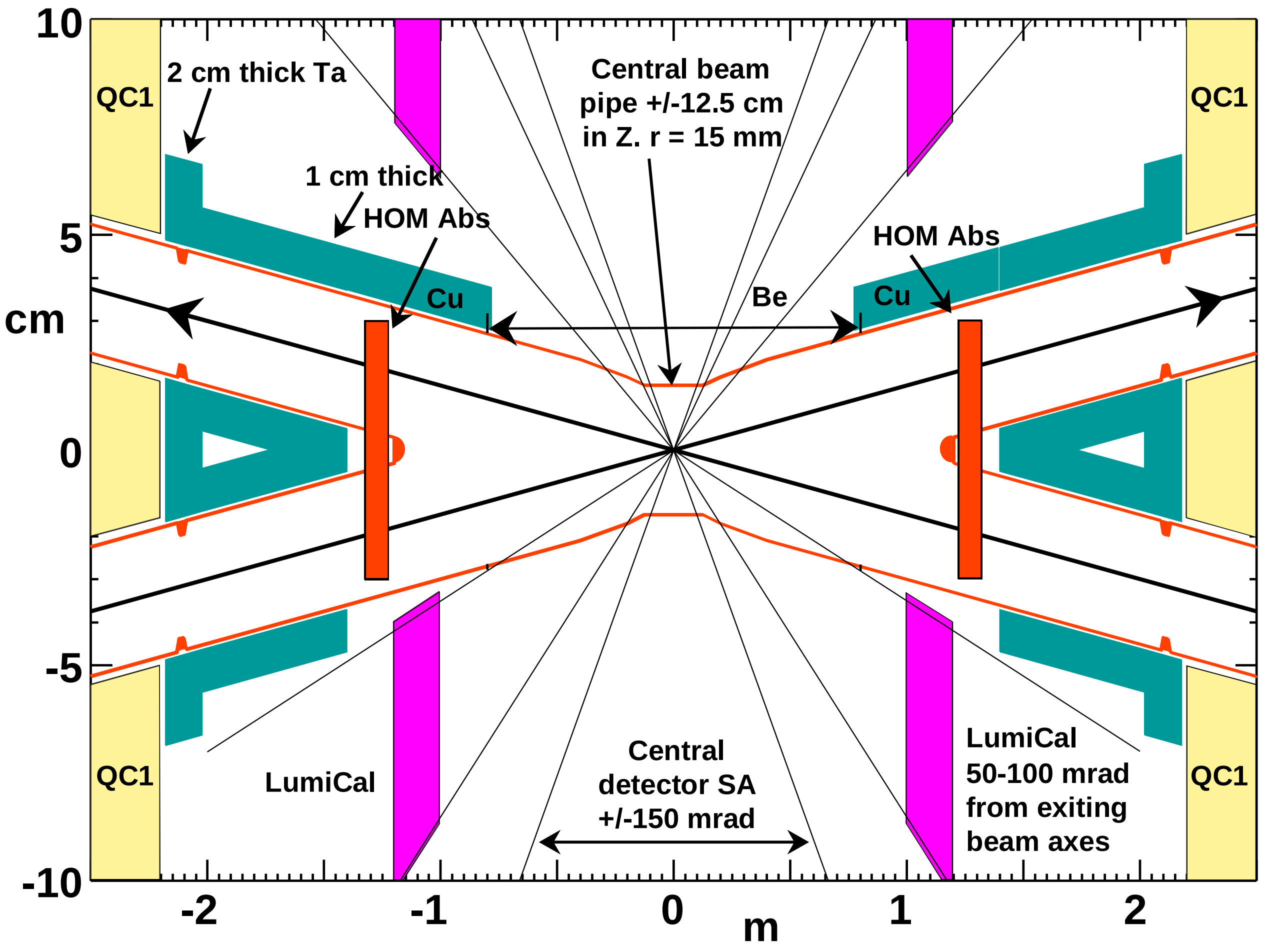
Energy spectrum of Top beam energy scattered photons through 2 cm Ta



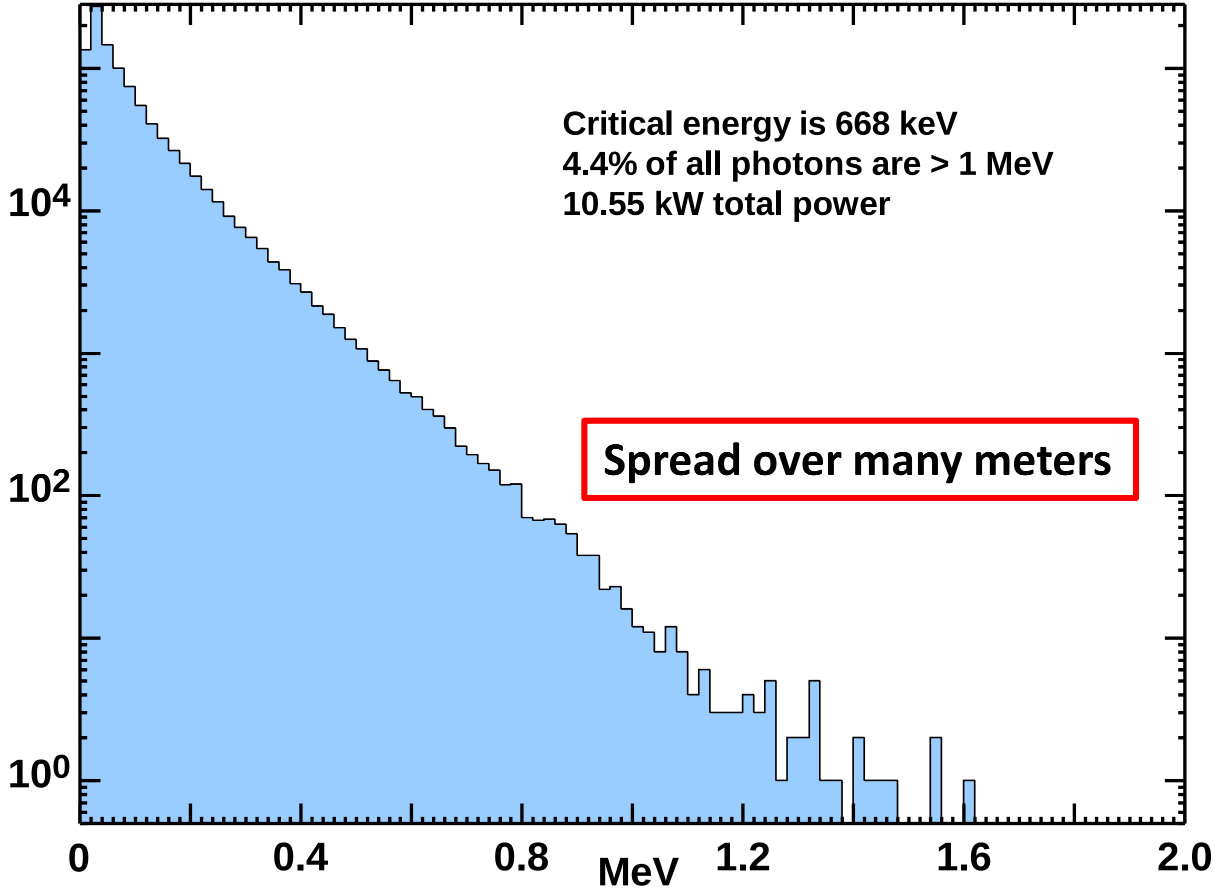
Detector shielding

- In order to get final background calculations for the detector we need a full simulation
- The photons scattered from the mask tips can then be propagated through the beam pipe and into the sensitive subsystems of the detector
- A GEANT4 simulation of a generic detector is being used to study the background rate in various tracking detectors
  - A. Kolano has produced some preliminary results using a GEANT4 model of a generic detector that look very good (next slide)

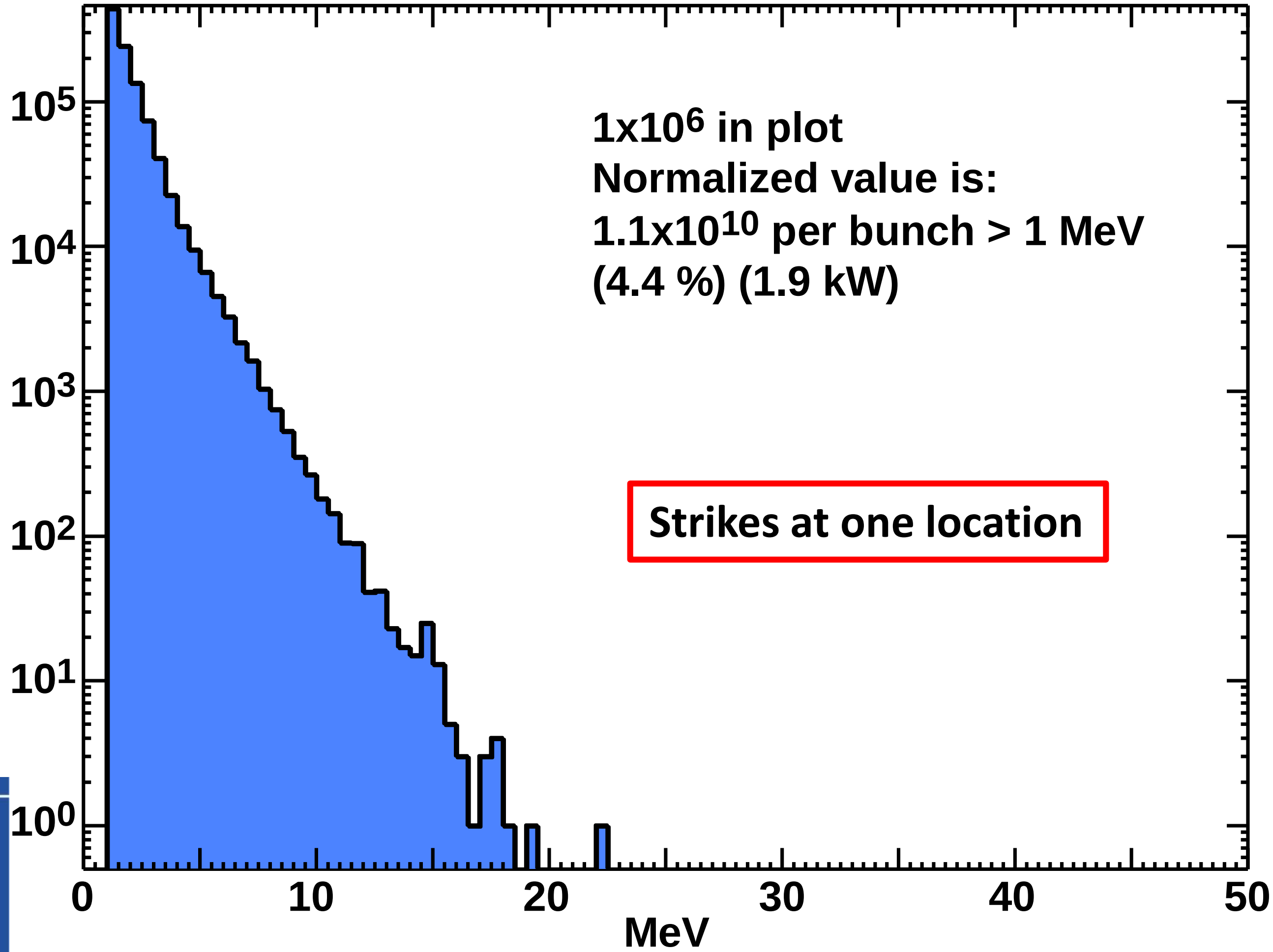
Suggested Shielding



Photon energy spectrum from the first downstream bend



Quadrupole radiation from Final Focus



Remember that these two high- energy gamma distributions only occur during Top running

Initial Summary

- The primary SR background source is the radiation from the last soft bend magnet
- This radiation appears under control and detector background rates look manageable at all beam energies
- Remember the numbers in the table are for a single beam and a single mask tip

- Now we need to look at other SR sources

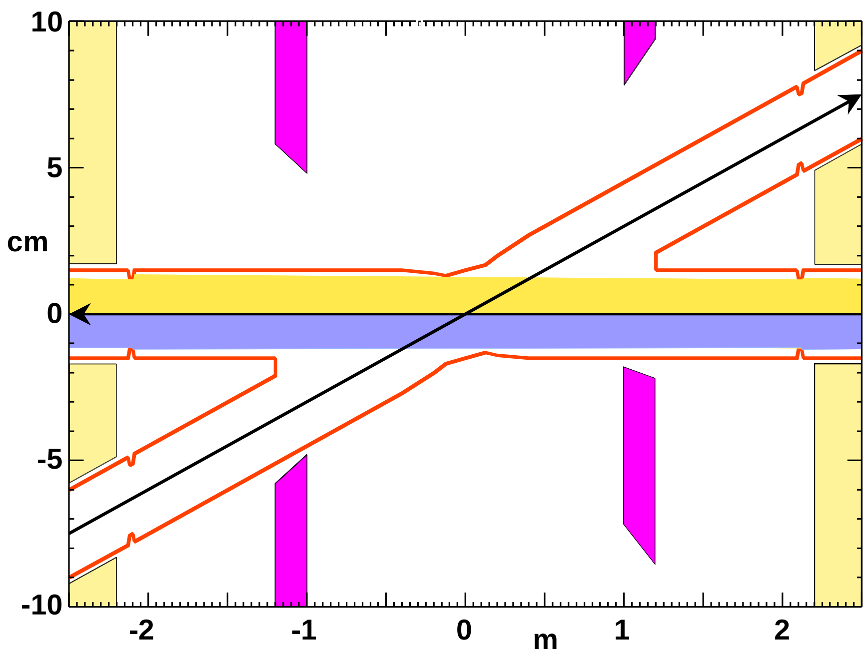
Other local scatter points

- Backscatter from upstream mask tip
  - The above calculations are for forward scattering from the upstream mask tip
  - Need to add backscattering from the upstream mask tip
    - Not much background increase expected from this
- Backscatter from downstream mask tip
  - Comparable to calculated value from upstream mask
- Forward scatter from downstream tip
    - Again do not expect much additional background from this source

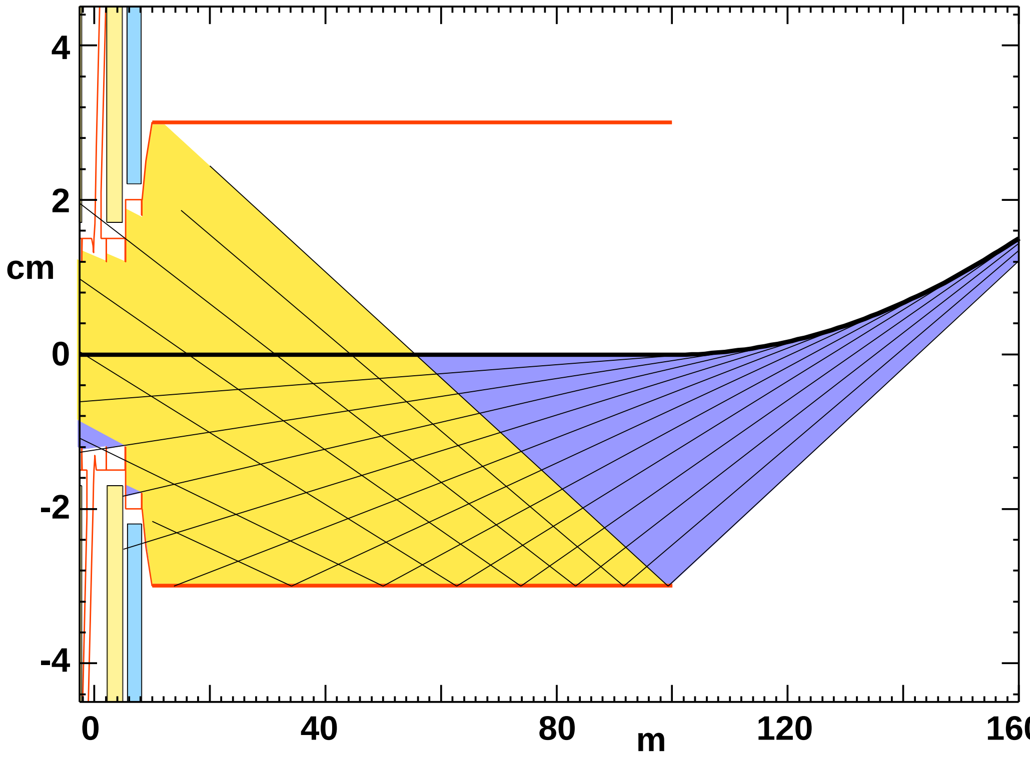
Additional sources (2)

- Present estimate from all local sources
  - X2 for both beams
  - X2 for backscatter from the downstream mask tip
  - So about 4 times the numbers in the table
- Further upstream sources
  - Scattering from the SR hitting the beam pipe between the FF and the last soft bend magnet
  - With a 3 cm radius beam pipe from 8-90 m we do not see any background increase even with perfect reflection
    - Should be able to roughen the inner beam pipe wall enough so that this is not an issue

Upstream beam pipe



Fans miss the IP Be chamber



160 m upstream of IP

Downstream bend

- Distance from IP is 29 m (38 m long)
- Bend strength is 328 Gauss
  – Critical energy is higher (668 keV)
  – Luminosity window?
- Radiation from the Final Focus magnets
  – Final Focus Quad radiation is about 2 kW
  – Quad radiation has high critical energies (~few MeV)
    - Possible source of neutrons in the detector?