Update of the SR studies for the FCCee Interaction Region

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for the FCCee MDI team

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Outline

- Introduction and MDI machine parameters
- Current beam pipe design
  - Features
- SR background calculations
  - Method
  - Results
    - Top
    - Higgs, WW and Z
- Secondary sources
- Summary and conclusions

MDI machine parameters used

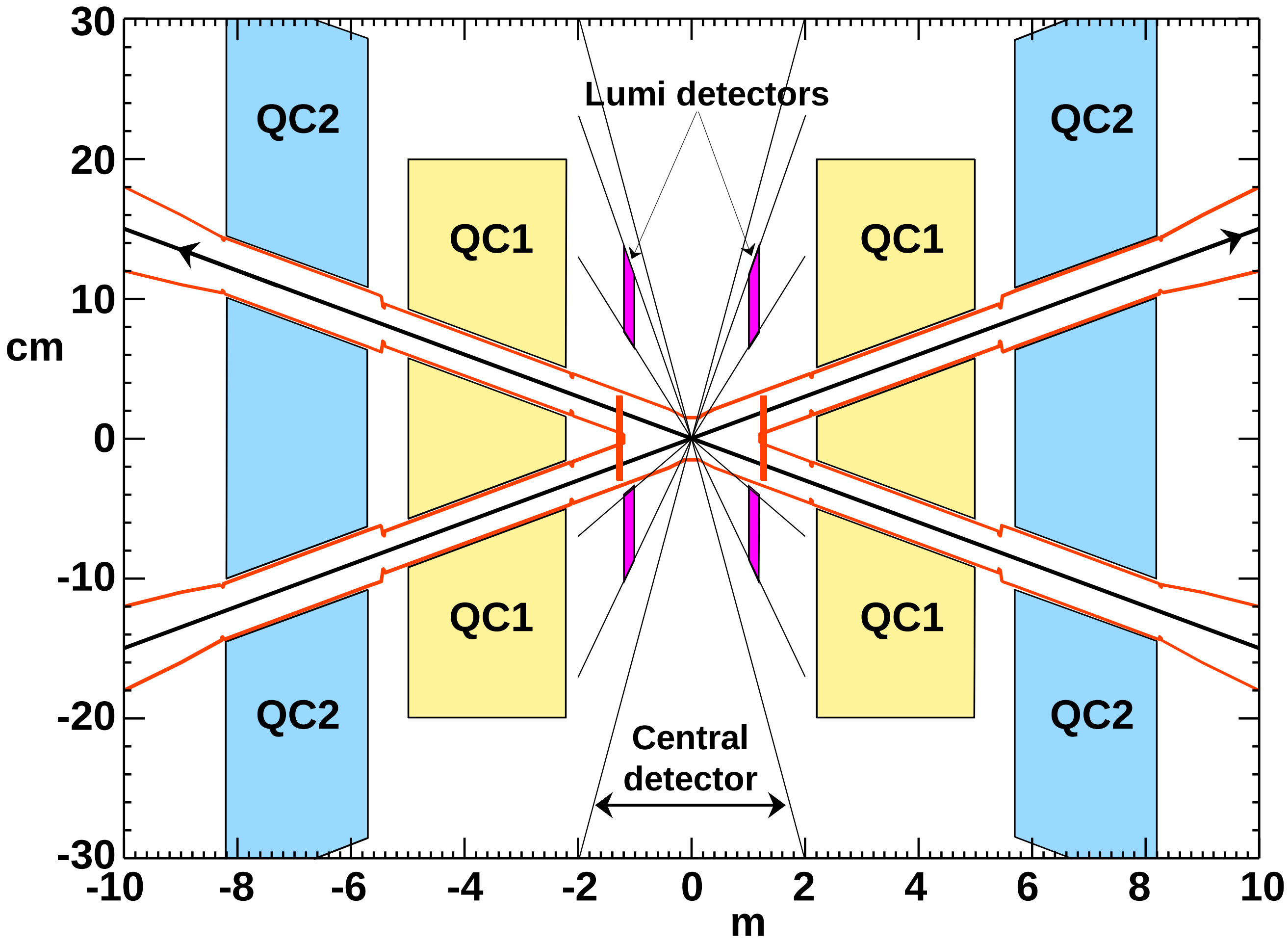
	Z	WW	Higgs	tt
Energy (GeV)	45.6	80	120	175
Current (mA)	1450 (1400)	152 (147)	30 (29)	6.6 (6.4)
#bunches	30180 (71000)	5260 (7500)	780 (740)	81 (61)
Particles/bunch (10^{10})	10 (4)	6 (4)	8	17 (21)
Emittance Hor. (nm)	0.28	0.26	0.61	1.26
Emittance Vert. (pm)	1	1	1.2	2.52
Beta* X (m)	0.15	1	1	1
Beta*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

(Michael Benedikt's presentation on Monday)

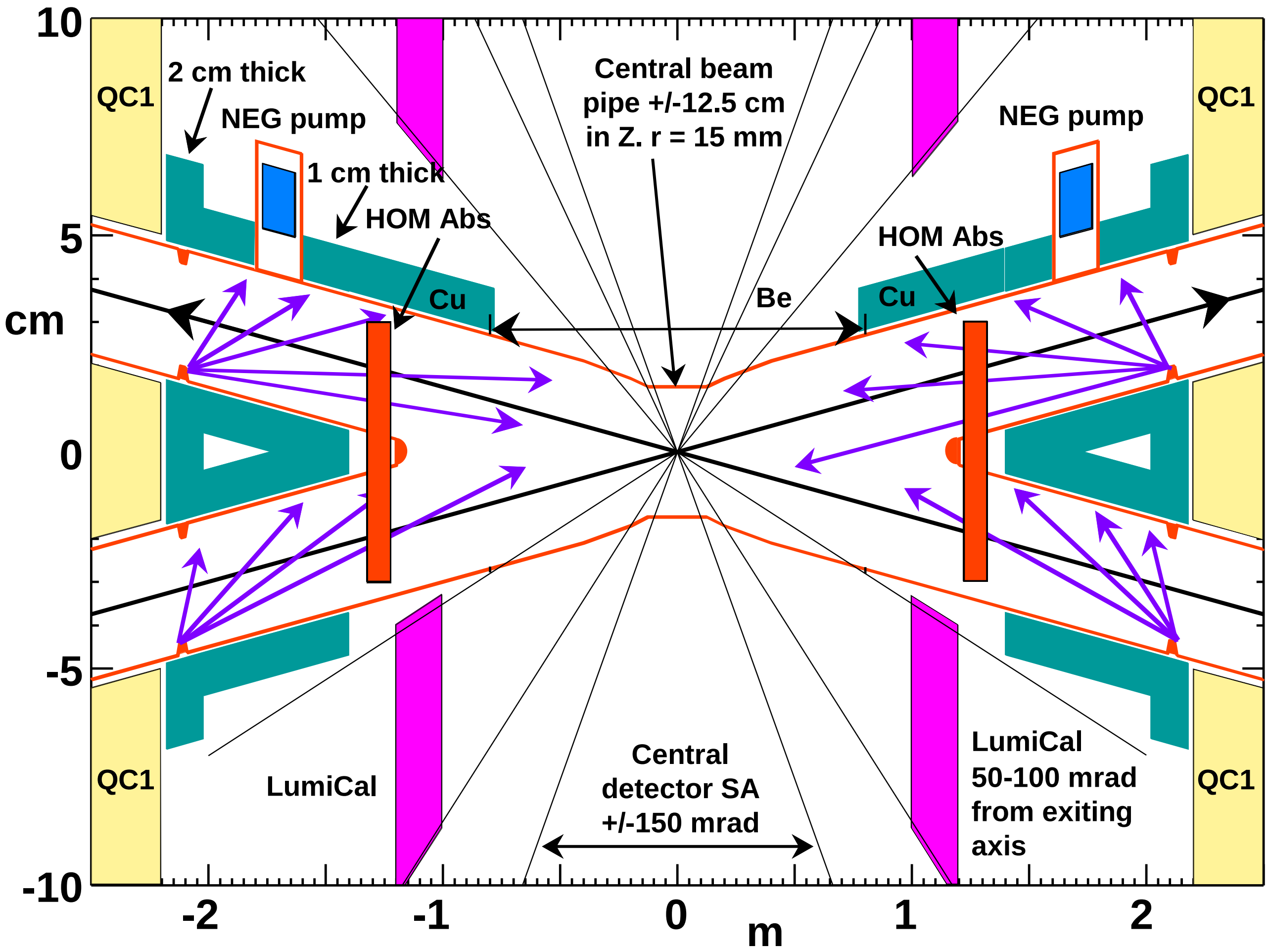
Several numbers have changed

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

Interaction Region Beam Pipe



Interaction Region Beam Pipe



Features

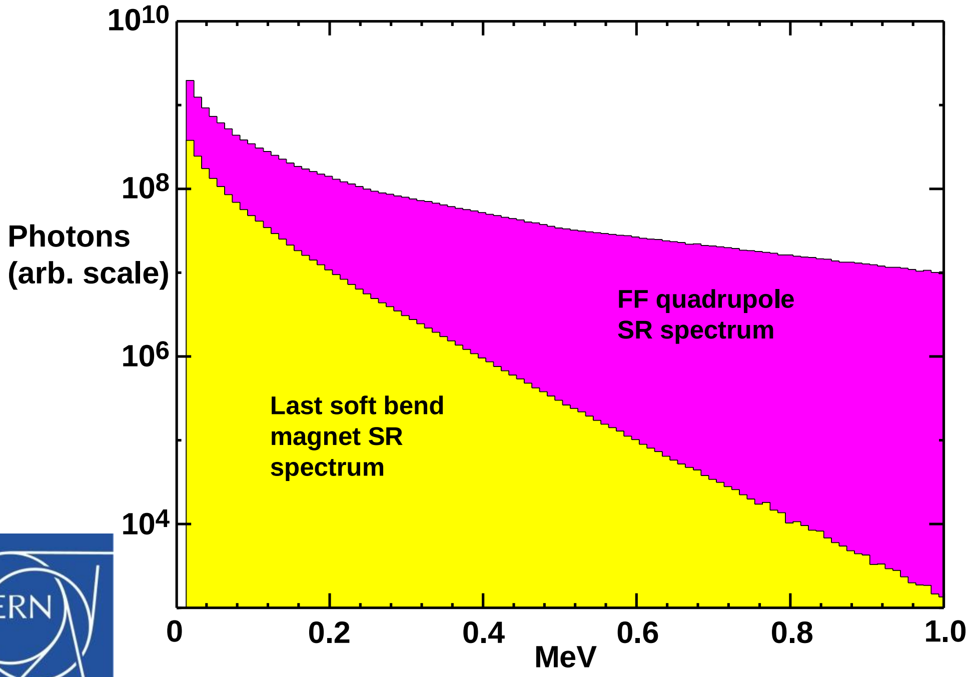
- Central beam pipe has 3 cm dia.
- Entering and exiting beam pipe through Q1 (3cm dia.)
- Be from about +/-80 cm
- Pipe size increases to 4cm dia. in Q2
- Size outside Q2 is currently 6 cm dia.
- Mask tips +/-12 mm and +/- 18 mm (show locations)
  - Allows for cold bore magnets (shields quad beam pipes)
  - Current IR design is for warm bores
  - Alternate plan instead of mask tips is to put a saw-tooth pattern on the water-cooled warm beam pipe – but we still need a tip at about 2m
    - suggested by R. Kersevan and also used in superKEKB

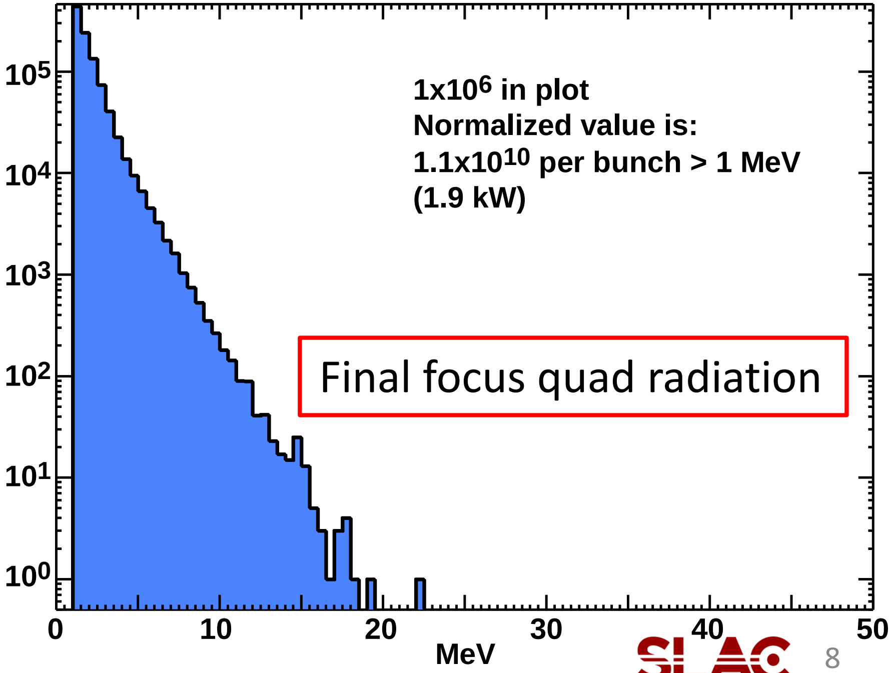
Brief summary of the method used for calculating the SR background rate

- The transverse size of the beam is divided into a grid (~20 x 60 sigmas) x (4x4) of weighted macro-particles
- Each macro-particle is traced through the optics and for each optical slice (4 to 8 slices per magnet) an arc is formed from the incoming and outgoing trajectories
- The magnetic field strength is calculated for the trajectory and a SR bend critical energy is calculated
- Then a geometric calculation is made for each beam pipe aperture downstream as to how much of the given produced SR fan intercepts each aperture
- A weighted histogram of critical energies for each aperture is kept and this is used to calculate the final photon energy distribution, photon number and power for each aperture
- The energy distribution is used to generate the incident photons onto a mask tip where the photons are traced through the mask material and a tally is kept of the photons which either travel through the mask or that reflect back out of the mask

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**

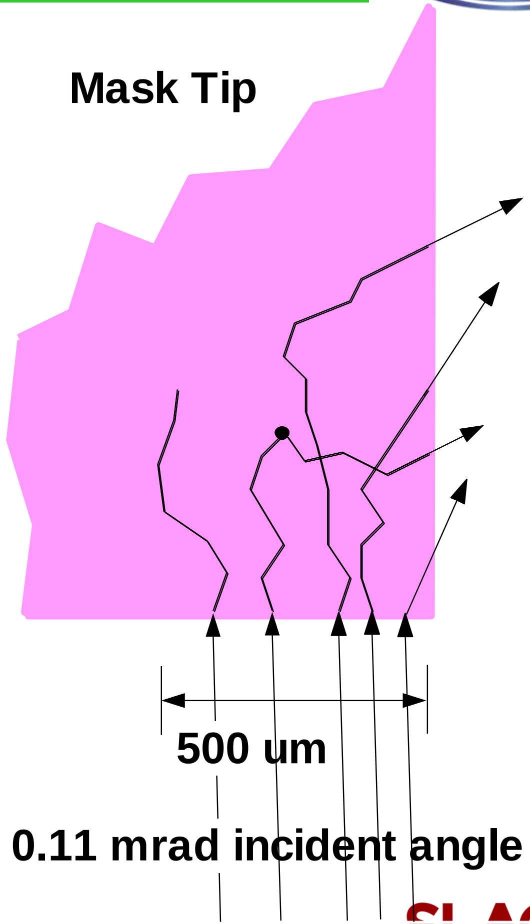




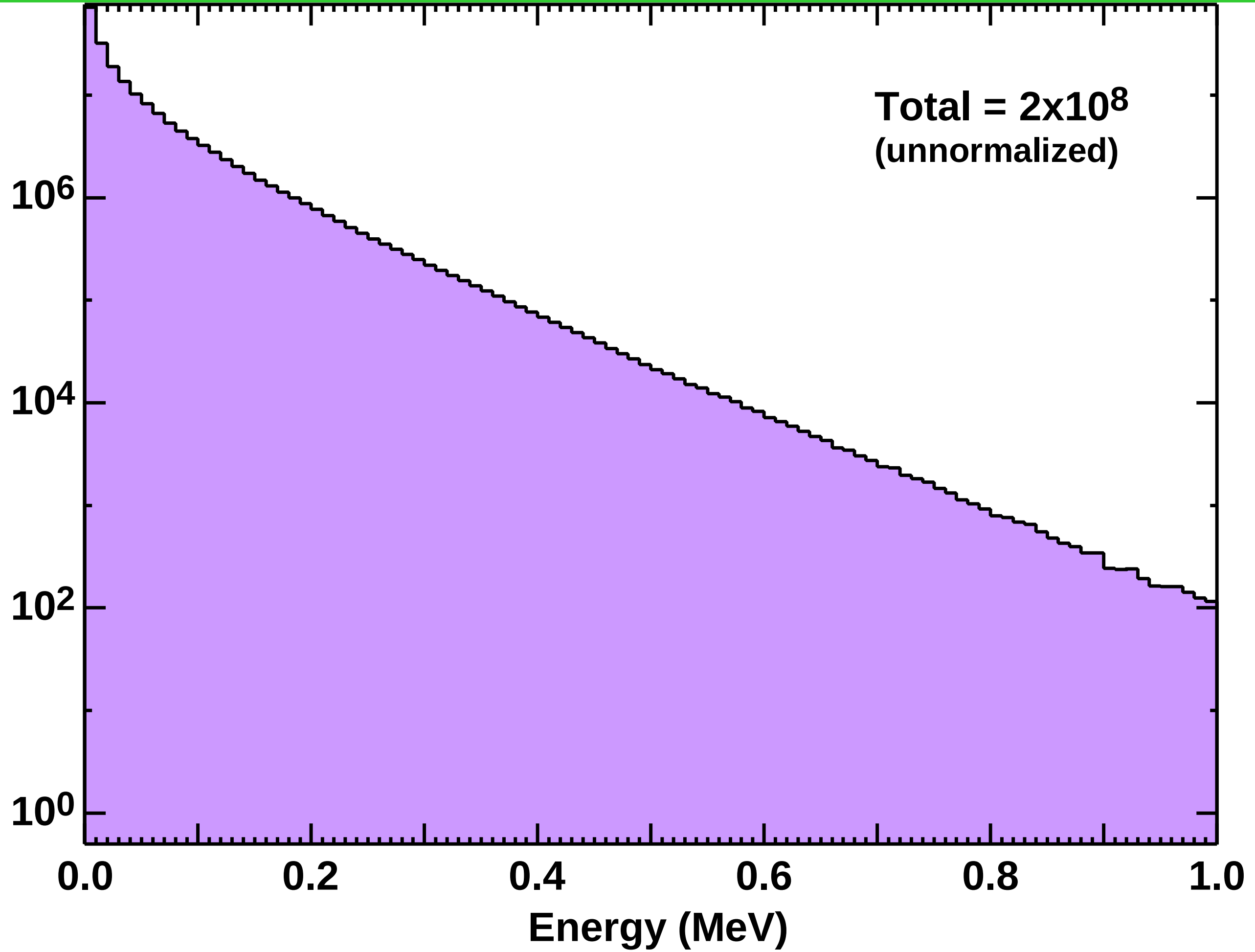
SR quad radiation

- 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

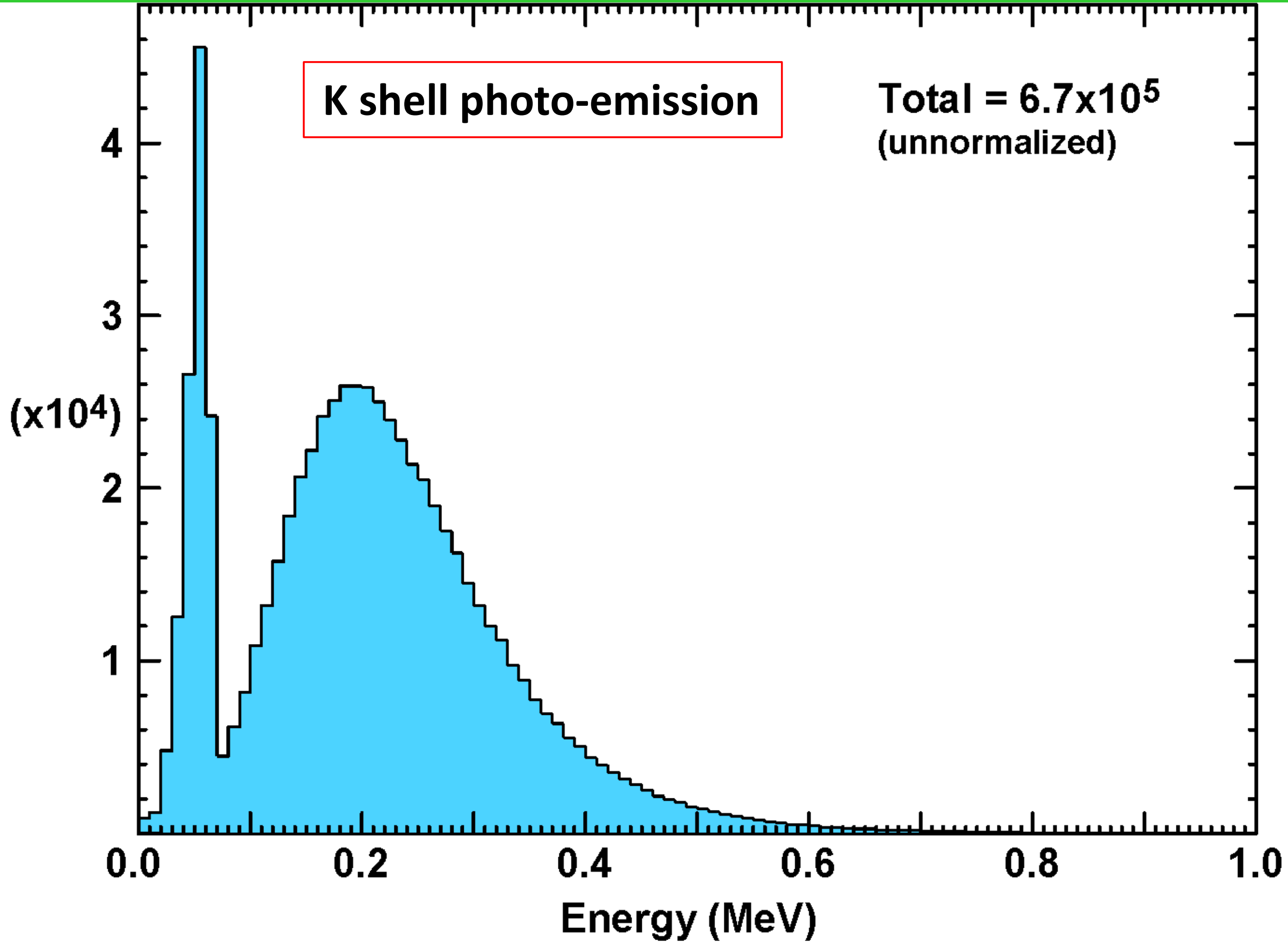


Top Incident photon energy spectrum

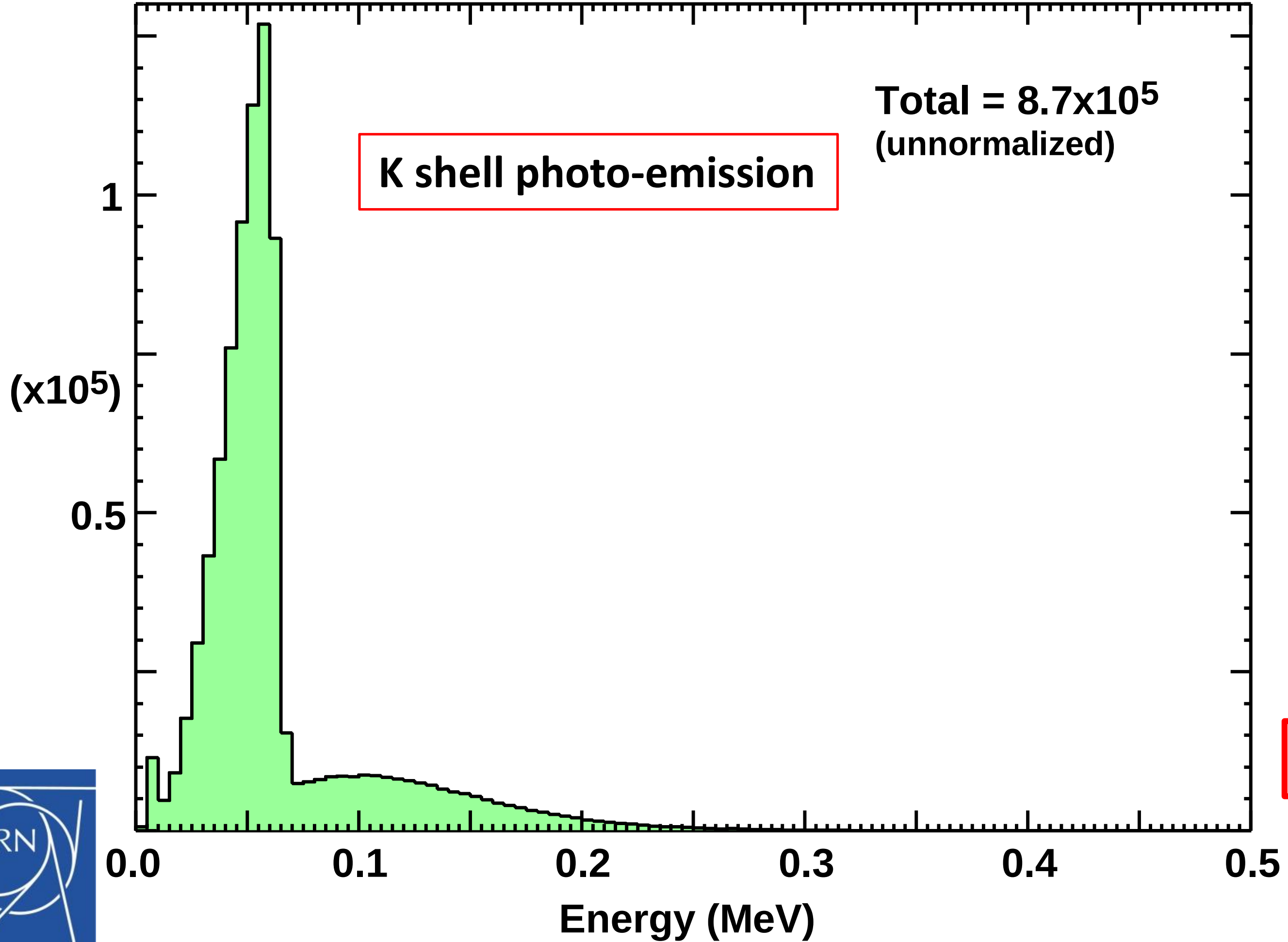


Photon energy spectrum incident on the mask tip

Top scattered photon energy spectrum

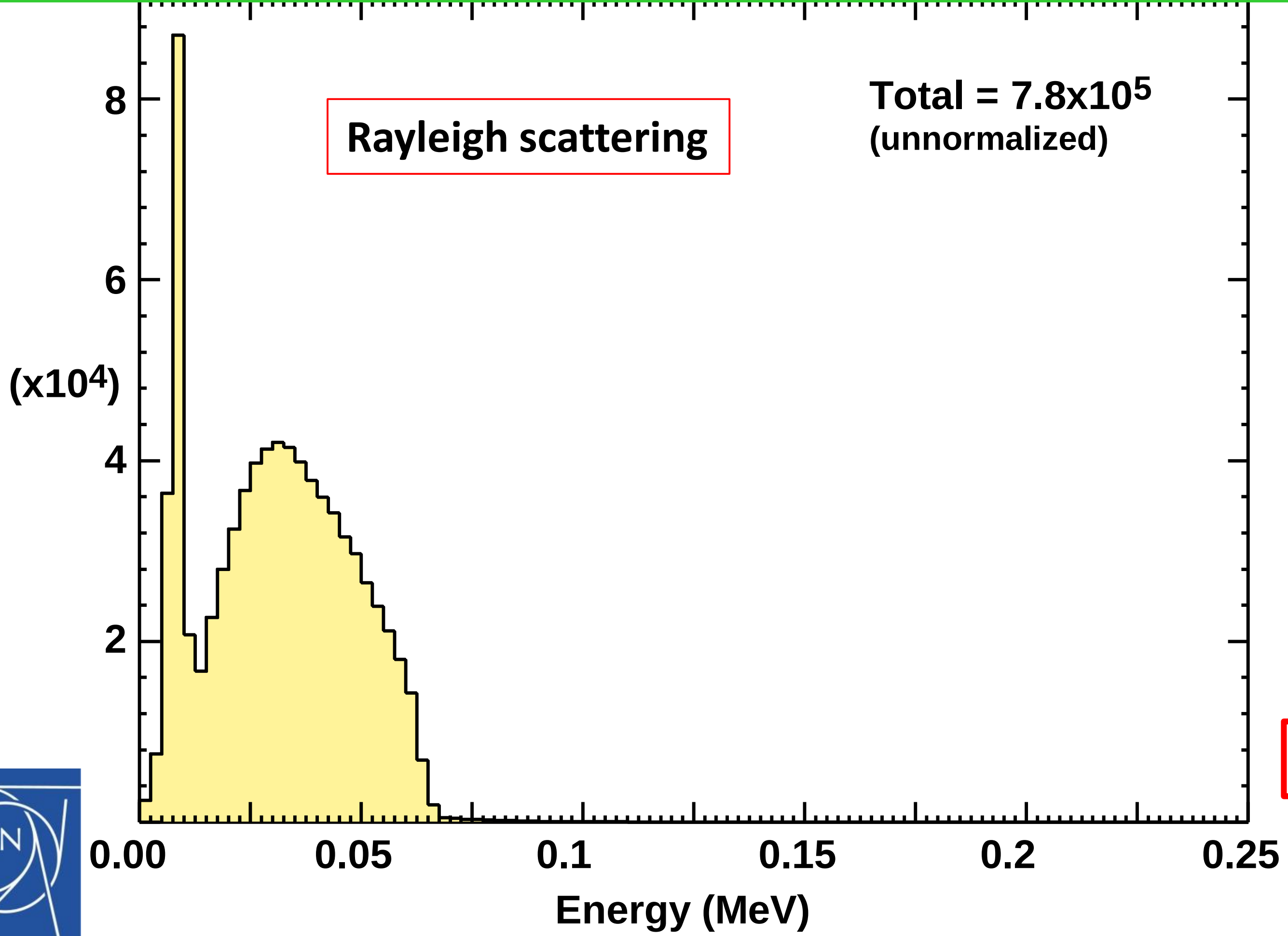


Higgs scattered photon spectrum



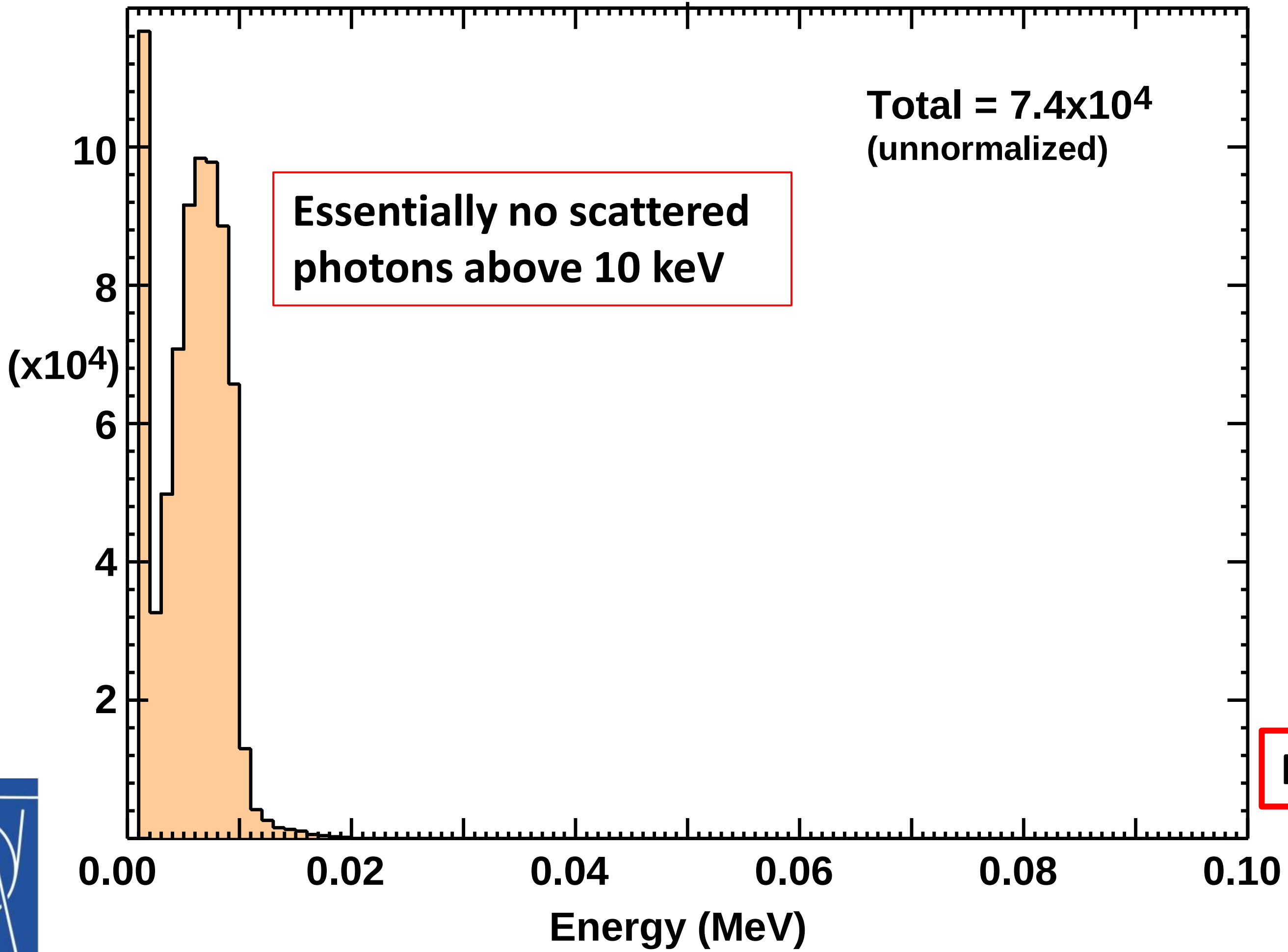
Note change of scale

WW photon energy spectrum



Note change of scale

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

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)

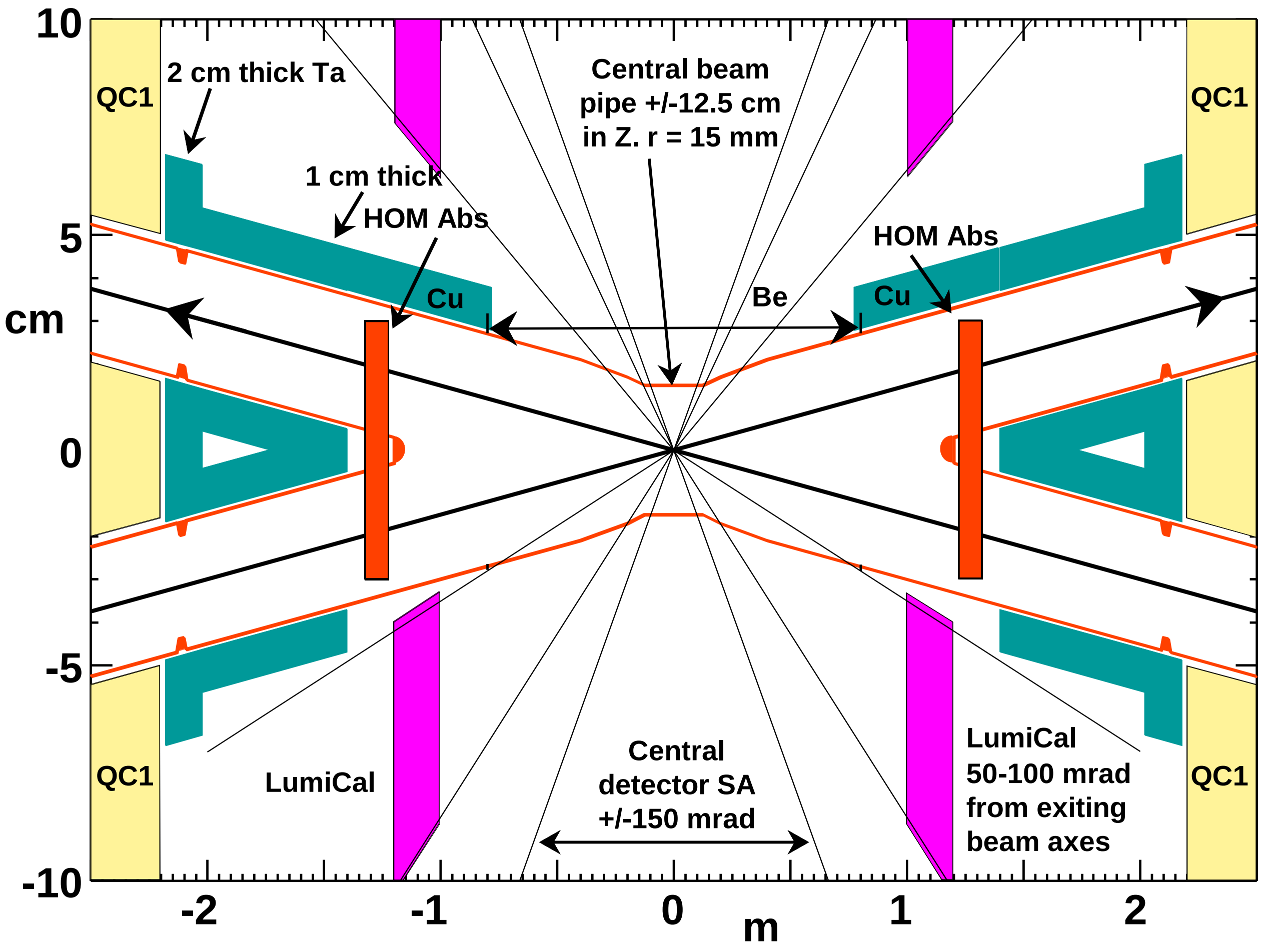
Table again with preliminary detector hits

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}	4.5×10^{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†
45.6	1.77	2.26×10^{7}	5×10^{10}	4.5×10^{-4}	73685	33.3	0‡

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

From A. Kolano

Suggested Shielding



Initial Summary

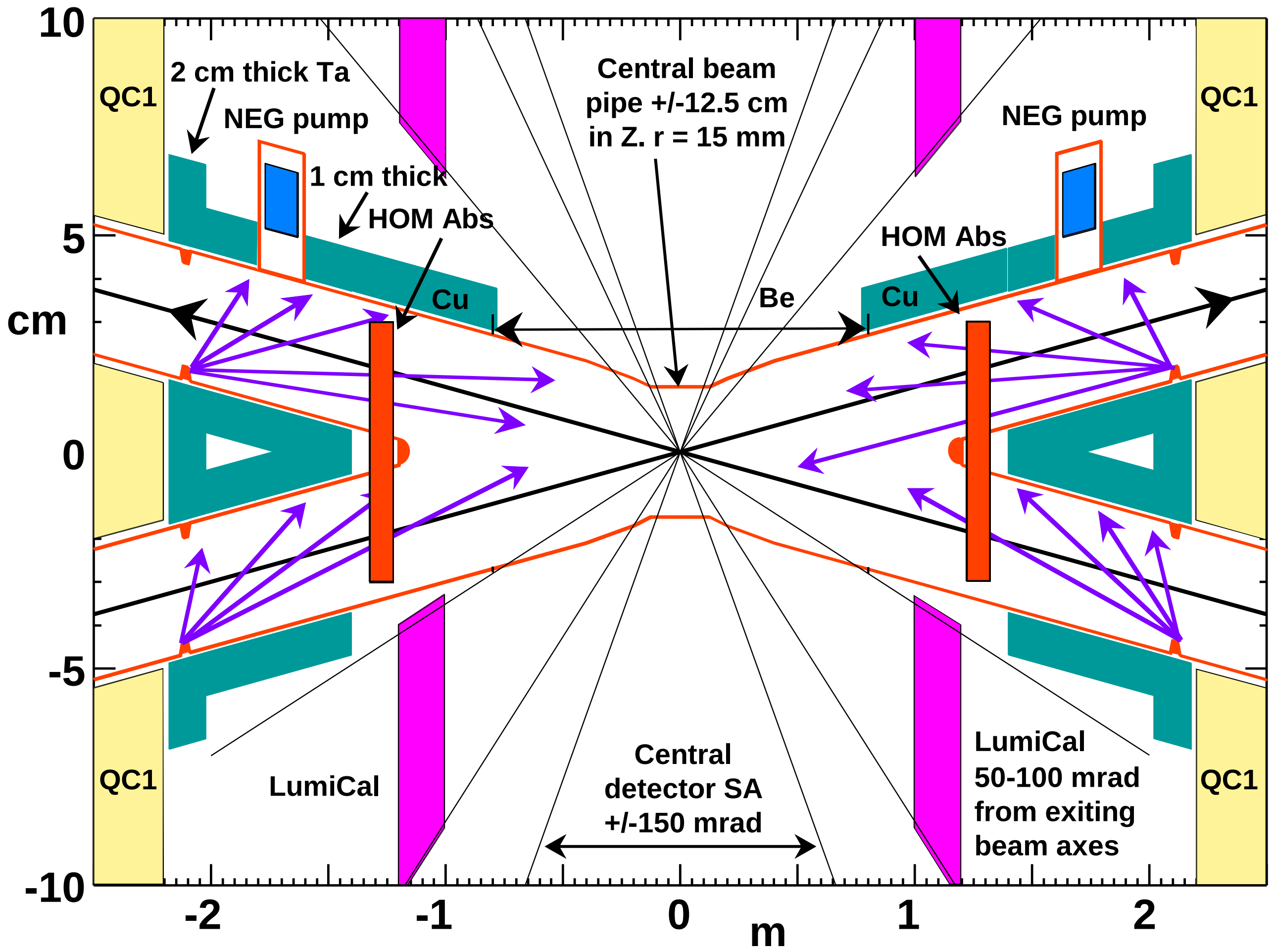
- The primary SR background source is the radiation from the last soft bend magnet
- This radiation appears under control and detector background rates look manageable at all beam energies
- Remember the numbers in the table are for a single beam and a single mask tip

- 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

Local primary SR scatter points

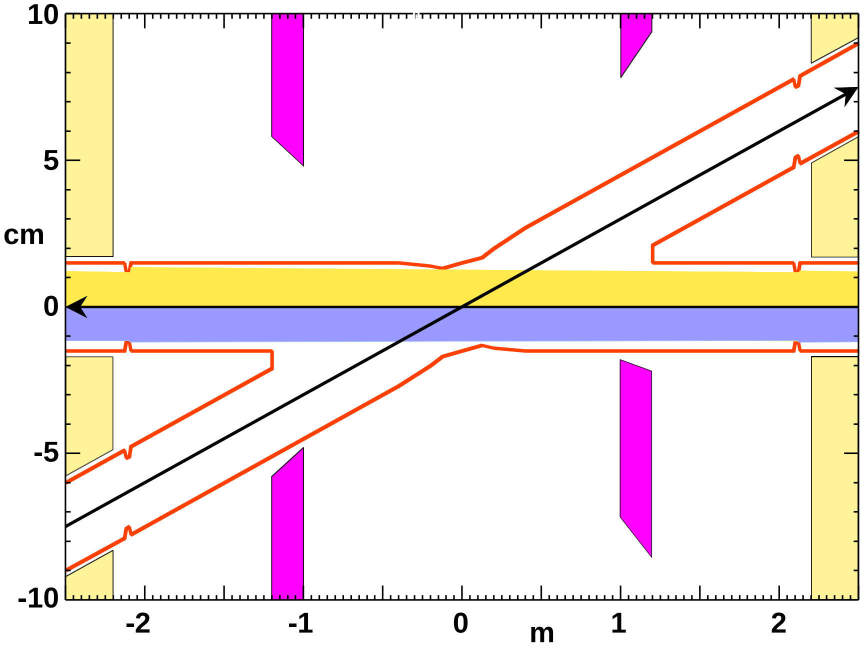


The pumping and shielding designs must be combined

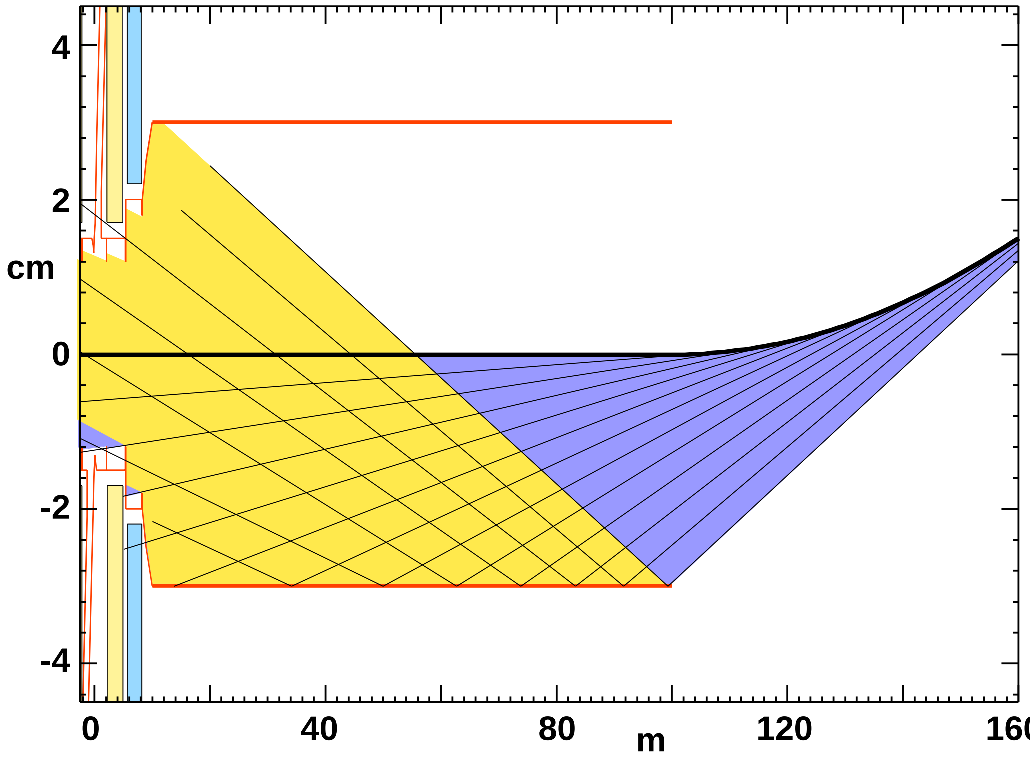
Additional sources (2)

- 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

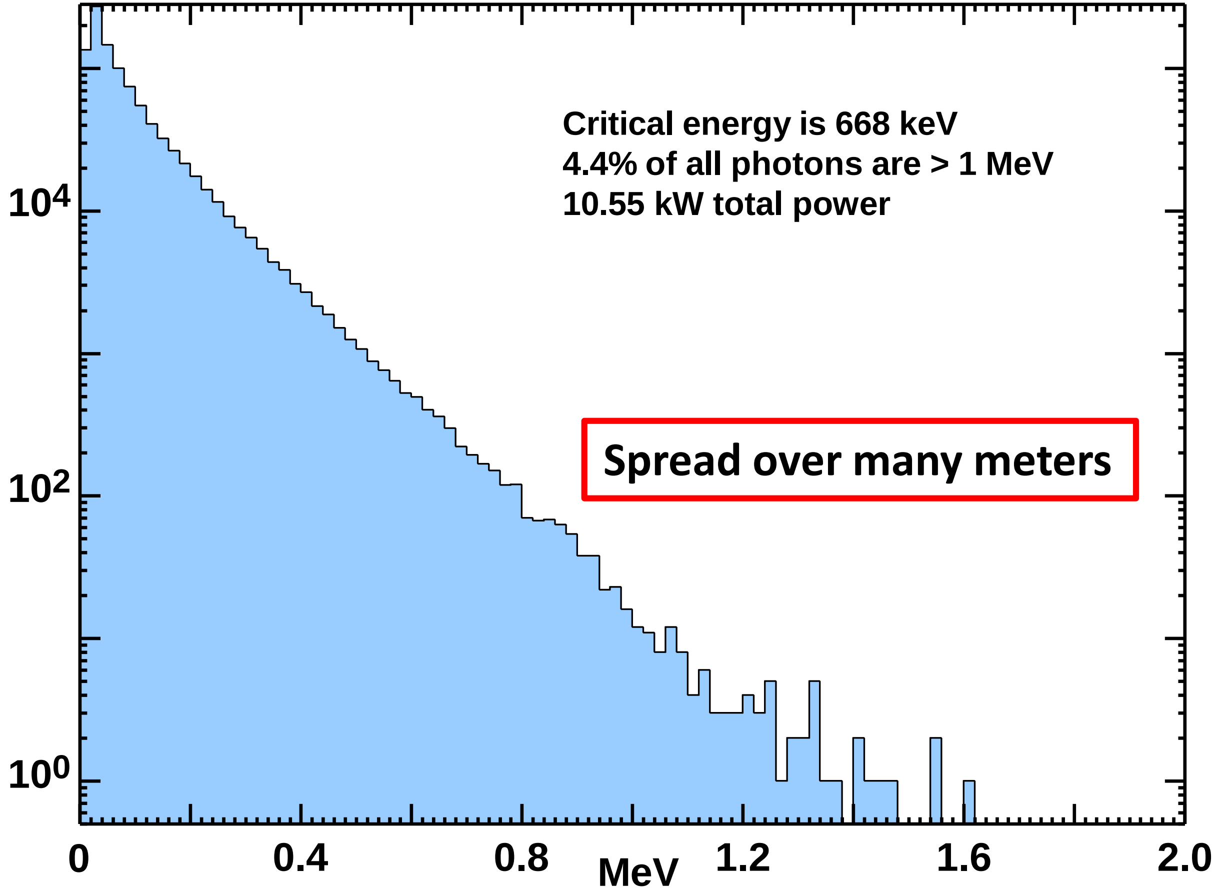


160 m upstream of IP

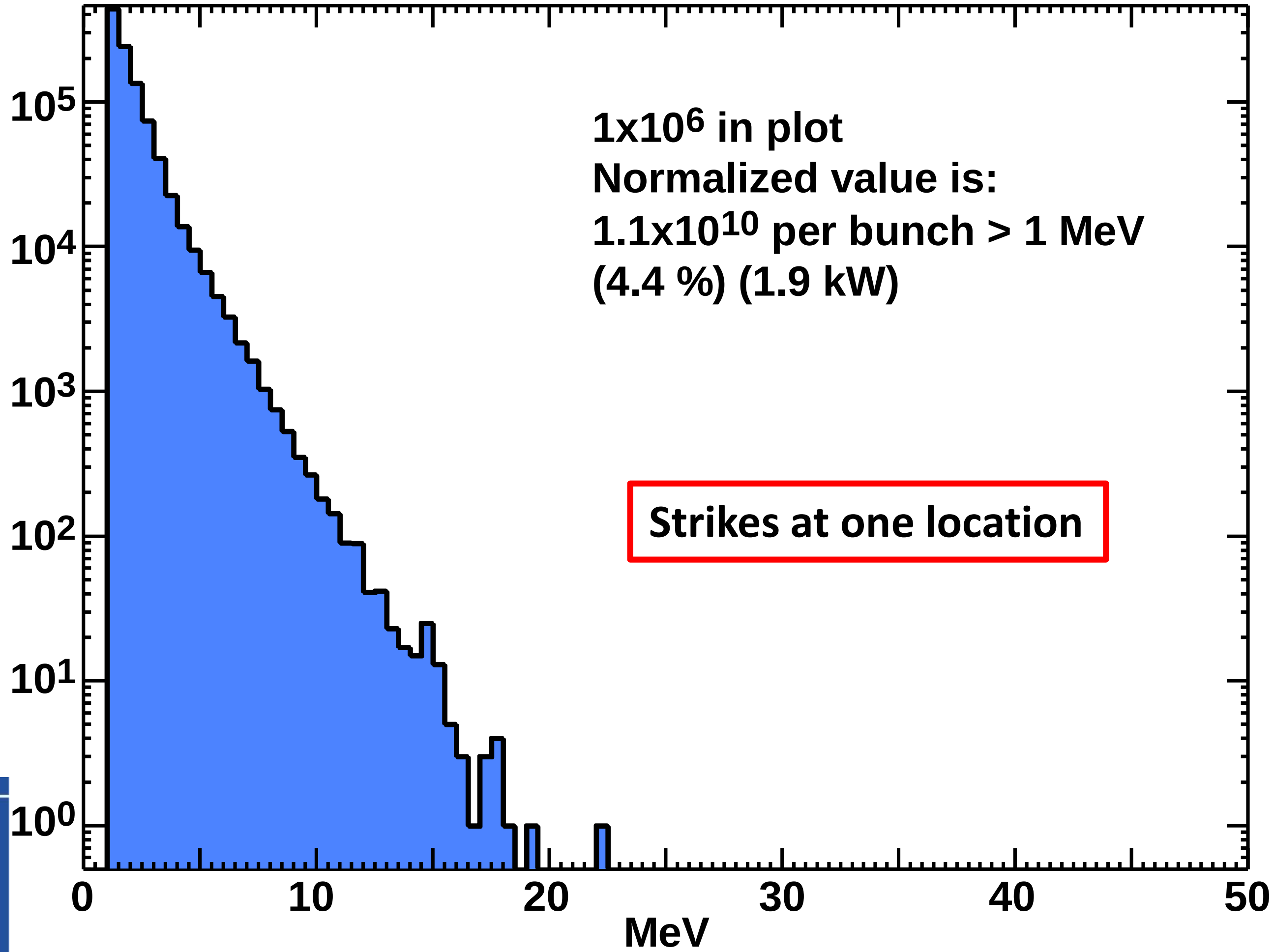
Downstream bend

- 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?

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

Possible detector interests

- Zero degree Luminosity detector?
  - At the Z, W and Higgs – perhaps OK?
  - 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

Summary

- A great deal of progress has been made
- The primary SR sources are under control
  - Even at the Top
- Closer inspection of secondary sources underway
  - At first glance they look OK
- Other issues (i.e. injection, off-axis beam…) need to be checked
- Neutron production from SR photon high-energy tails
- Beam energy spread at the Top

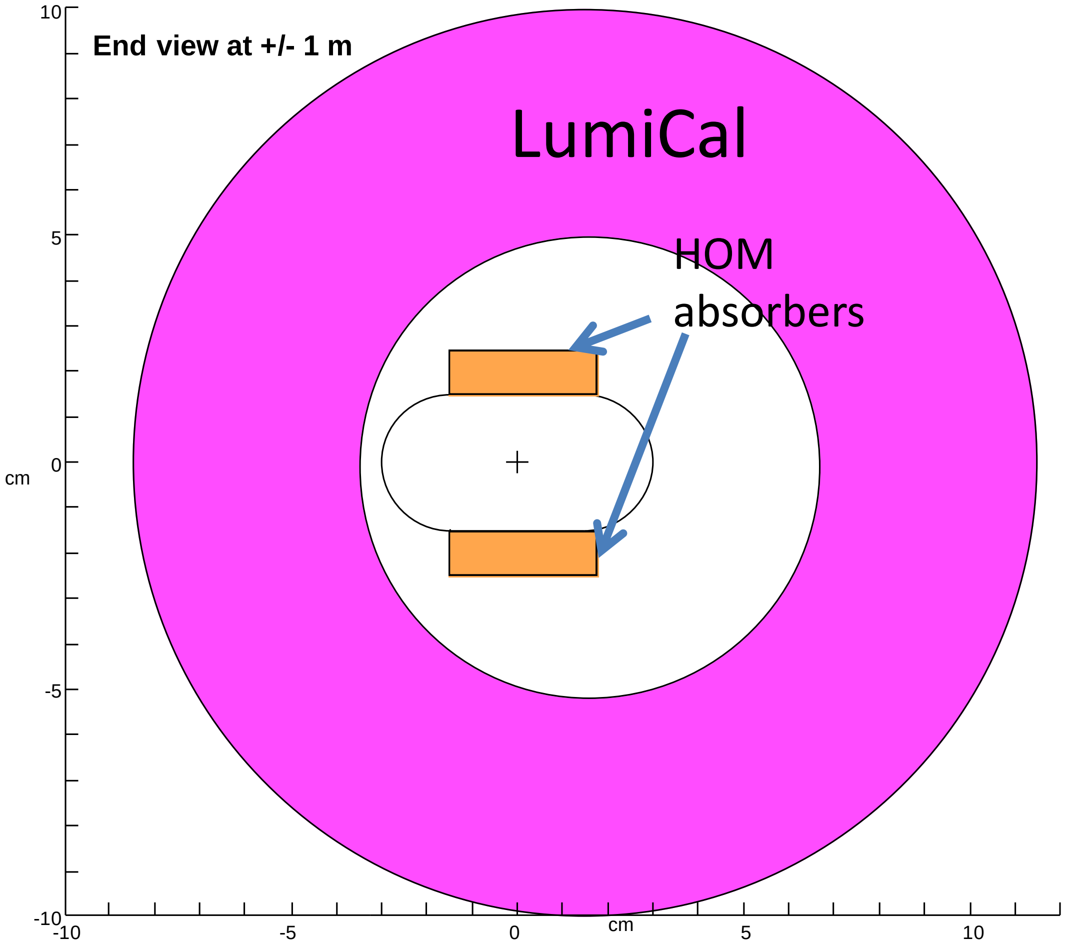
Conclusion

- Always more to do but so far so good…

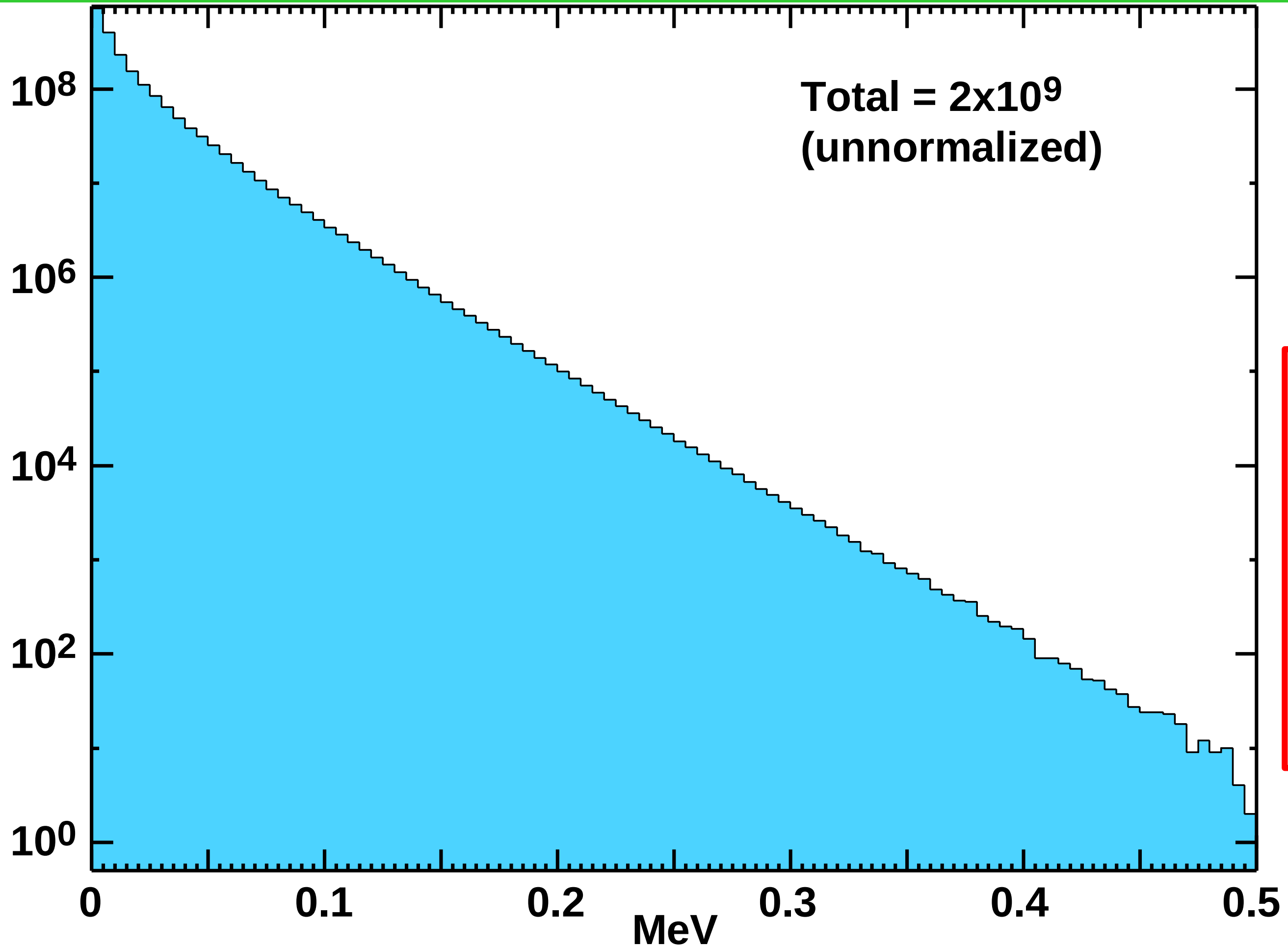
- Many thanks to everyone in the MDI group for contributing to discussions and helping to improve the IR design

Backup slides

End view at +/-1 m



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