SR Backgrounds for a 1 cm Radius Beam Pipe V2

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Outline

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- SR sources
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  - Direct hits
  - Forward scatter from upstream beam pipe
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Introduction

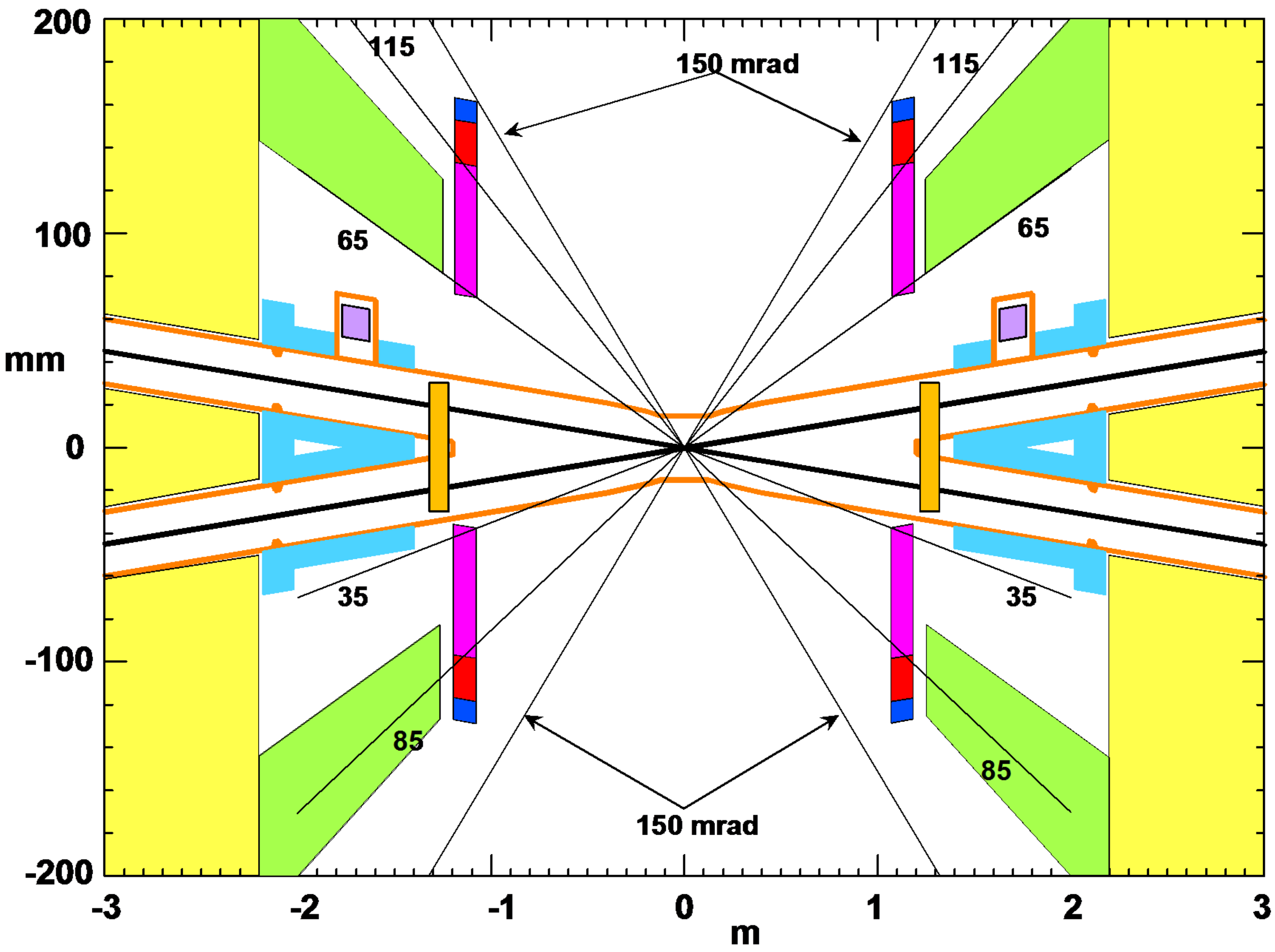
- **Preliminary calculations of SR backgrounds for a 1 cm radius central beam pipe**
- **The baseline central pipe is 1.5 cm radius ±12.5 cm in Z**
- **Try a new central beam pipe 1.0 cm radius ±9 cm in Z**
- **We taper the beam pipes down to the new central radius starting at ±40 cm from the IP**
- **Z – case**
- **ZH – case**

Beam Parameters Used

	Z	ZH
– Beam Energy	45.6	120
– Beam current (A)	1.39	0.29
– Number of bunches	16640	328
– Electrons per bunch	1.73×10^{11}	1.84×10^{11}
– Emittance x (nm-rad)	0.277	0.63
– Emittance y (pm-rad)	1.0	1.3
– Beta x* (m)	0.15	0.30
– Beta y* (mm)	0.8	1.0

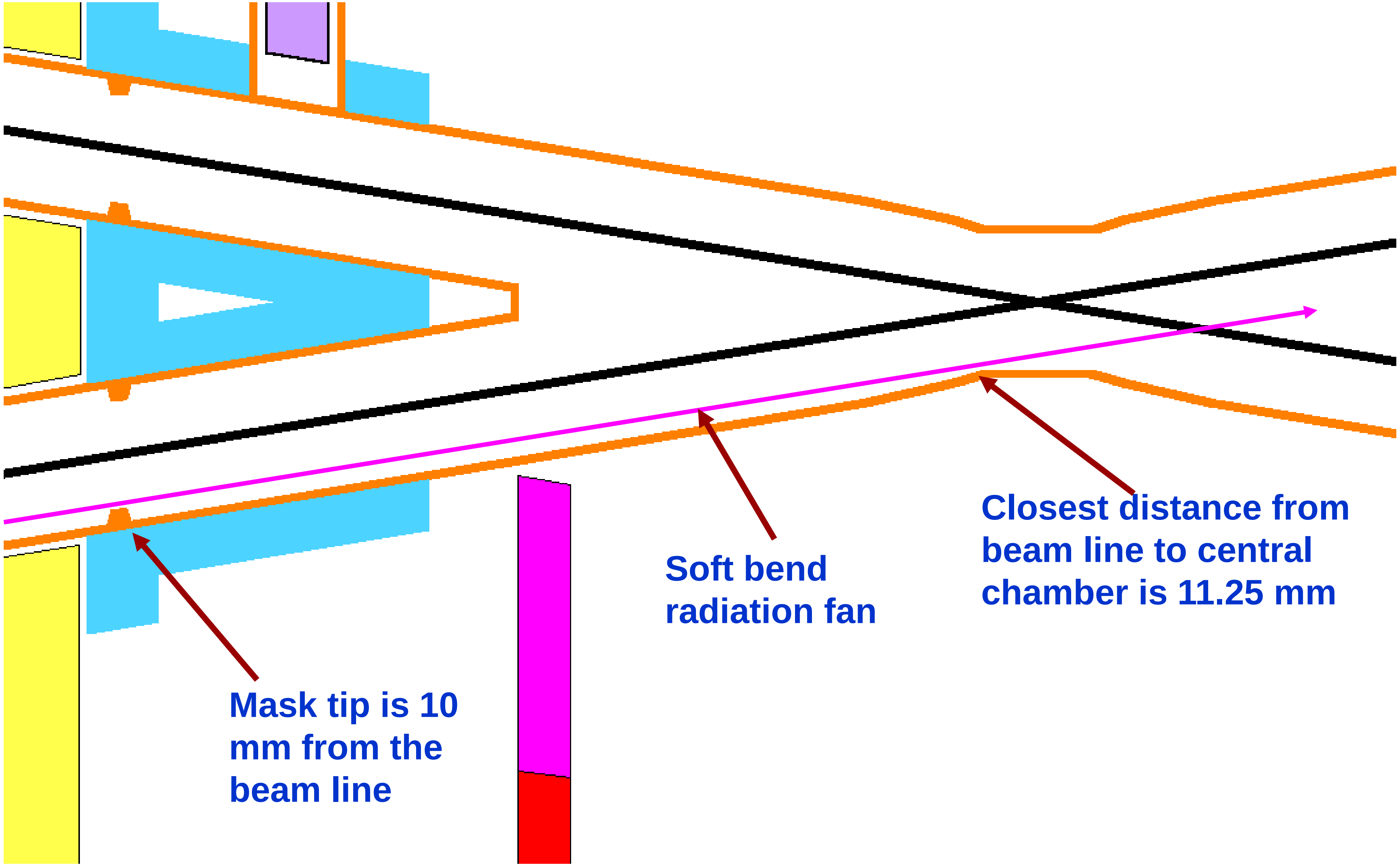
IR Layout

- IR with a 1.5 cm beam pipe
- Present baseline
- Reference slide for changes to a 1 cm radius central beam pipe



Close up of baseline central beam pipe

- The SR fan from the last bend magnet misses the central chamber
- The mask at -2.1 m shadows the central chamber
- No SR direct hits in the central region



Bend magnet radiation

- The SR fan from the last bend magnet always goes through the IP
- This model has the magnet split into 8 pieces
- For the Z, the magnetic field of this magnet is 11 gauss
- The SR power of each magnet piece is 32 W
- Each magnet piece generates a 51 μrad fan
  - At the IP, this is a fan that is 5.1 mm wide
- The critical energy of the SR fan is 1.56 keV
- For the ZH case the critical energy is 28.46 keV

Going to a 1 cm Beam pipe

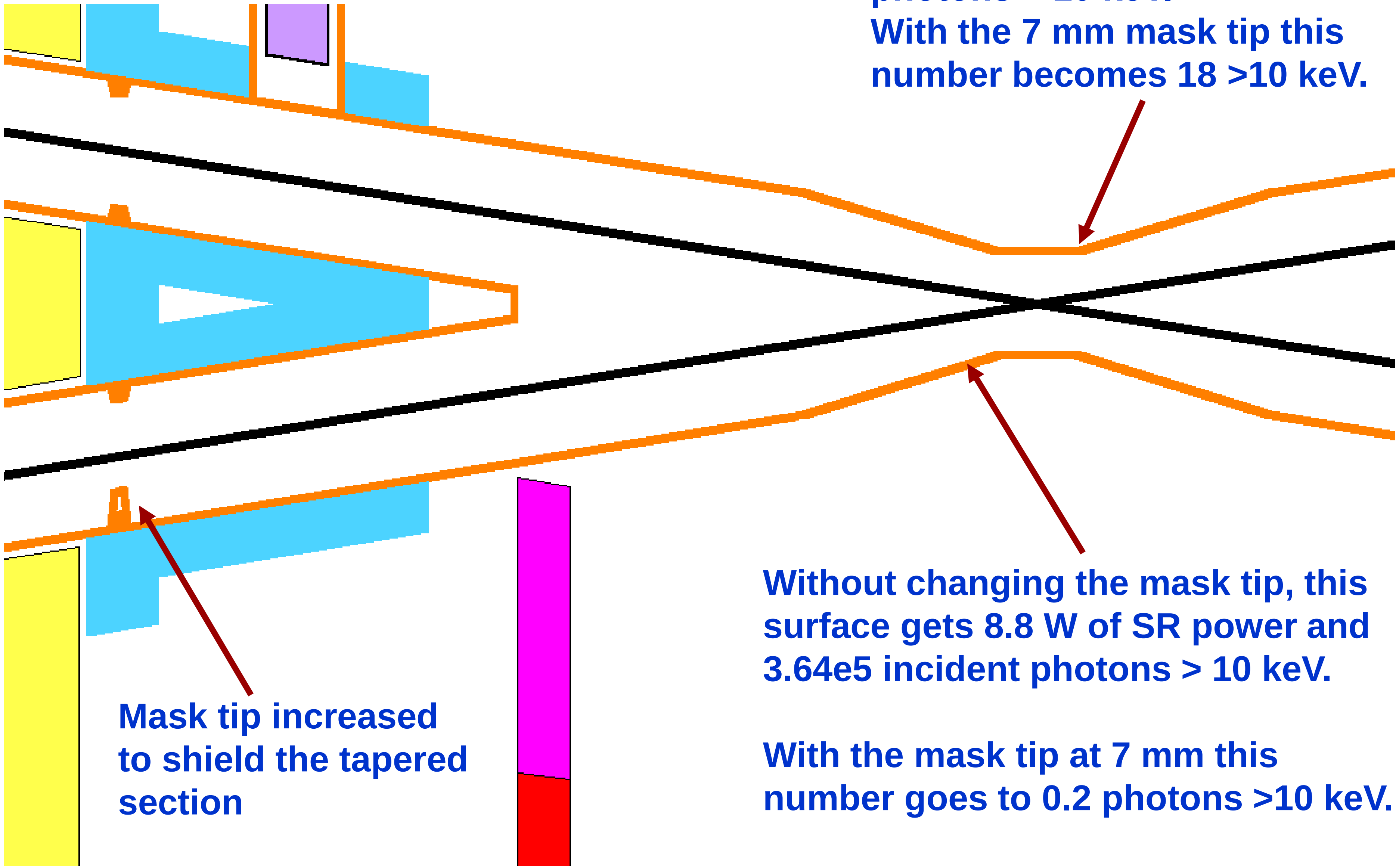
- We have changed the central beam pipe from ±12.5 cm with a 1.5 cm radius to ±9 cm and a 1.0 cm radius
  - The closest point of the central chamber to the beam line is now 8.65 mm
- The tapered upstream part of the pipe (-40 cm to -9 cm) is hit by the SR fan from the bend magnet at -100 m
  - About 9 W of SR power strikes this surface
  - This surface has a view to the central chamber and some of the incident photons will forward scatter to the central Be chamber
- We also see that a small amount of the FF quad SR is striking the downstream part of the central Be chamber

Going to a 1 cm Beam pipe (2)

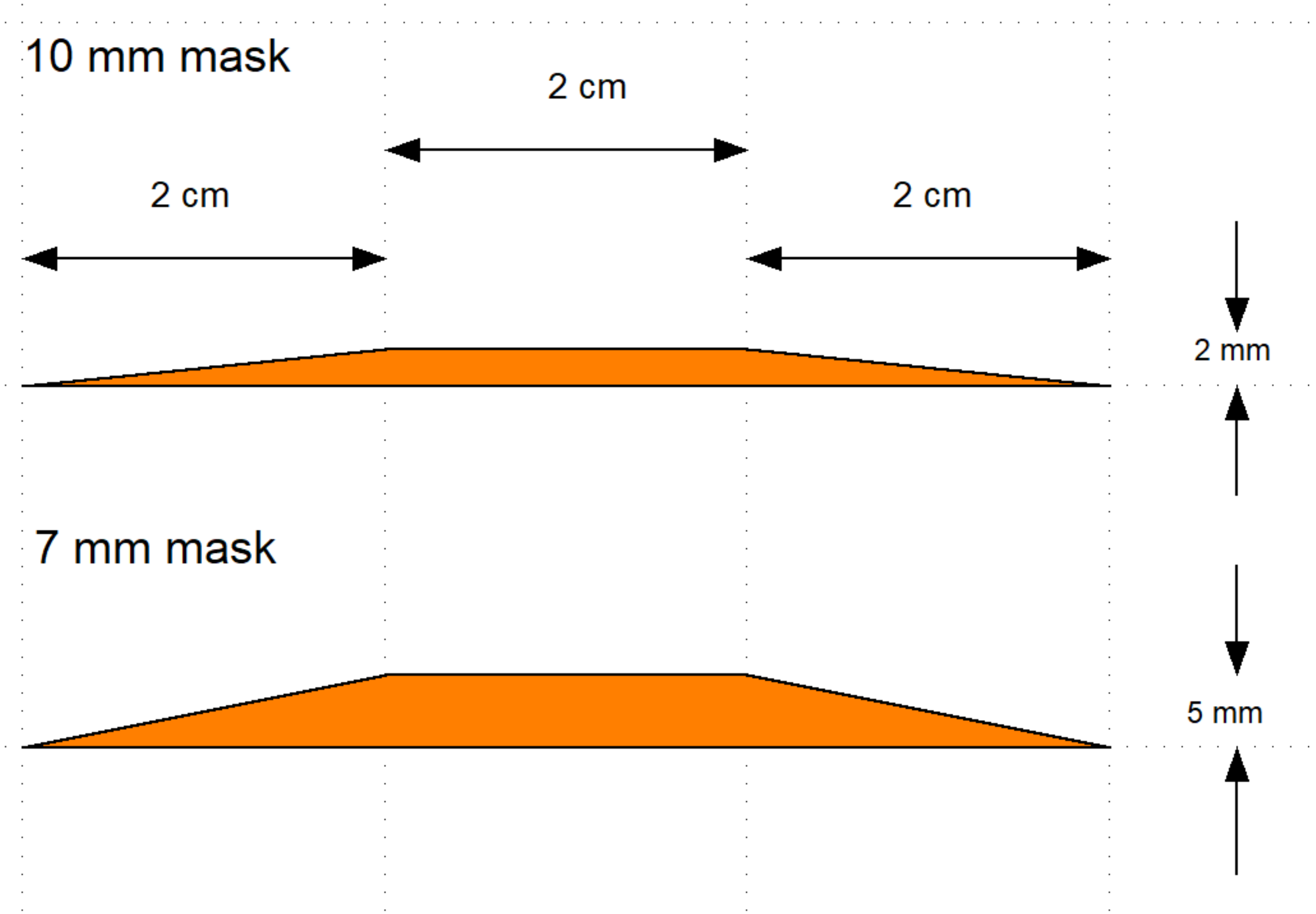
- The direct hit rate count may be OK for the Z (the photon energy is low)
- If we increase the size of the mask tip at -2.1 m from 10 mm from the beam line to 7 mm from the beam line the central chamber is once again shadowed by this mask tip from the bend radiation as in the 1.5 cm case
- The FF quadrupole radiation that strikes the downstream part of the central chamber is also reduced by a factor of 50 for the Z case
  - The FF radiation has a higher photon energy spectrum than the bend radiation

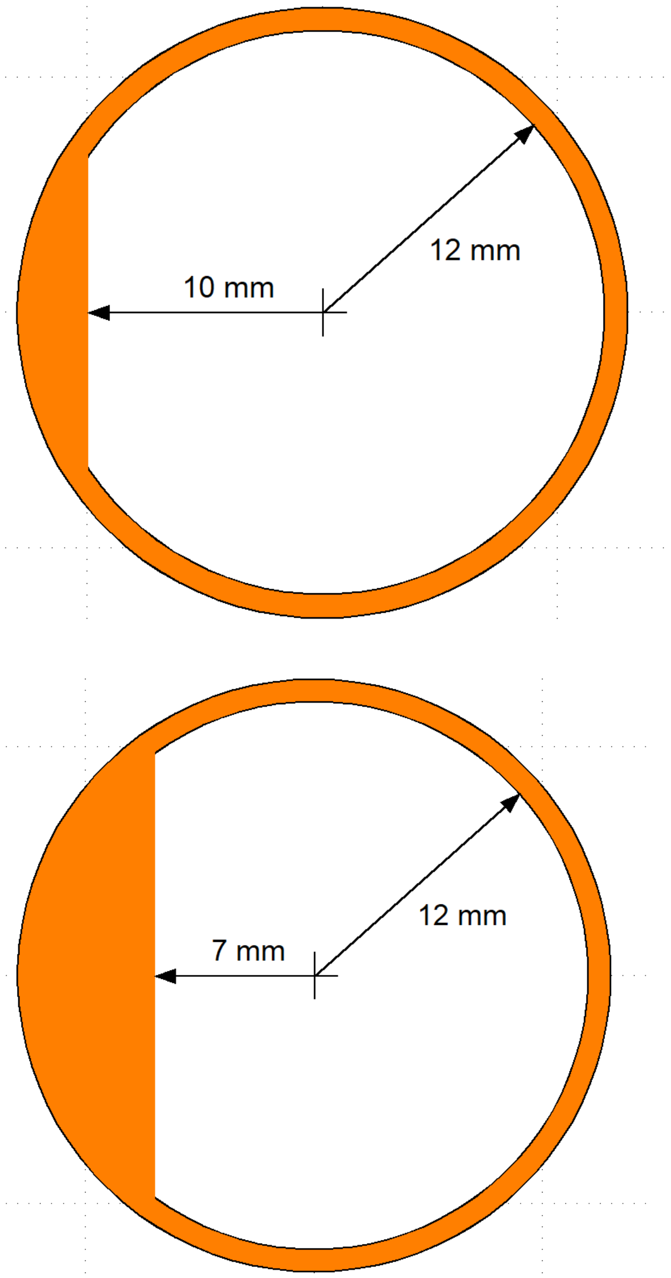
New beam pipe – Z case

- The SR fan from the last bend magnet misses the central chamber only if we increase the mask tip from 10 mm to 7 mm from the beam line
- The central chamber is then shadowed by the larger mask tip
- There is some quadrupole radiation from the FF quads now striking the downstream part of the central chamber



2.1 m mask dimensions

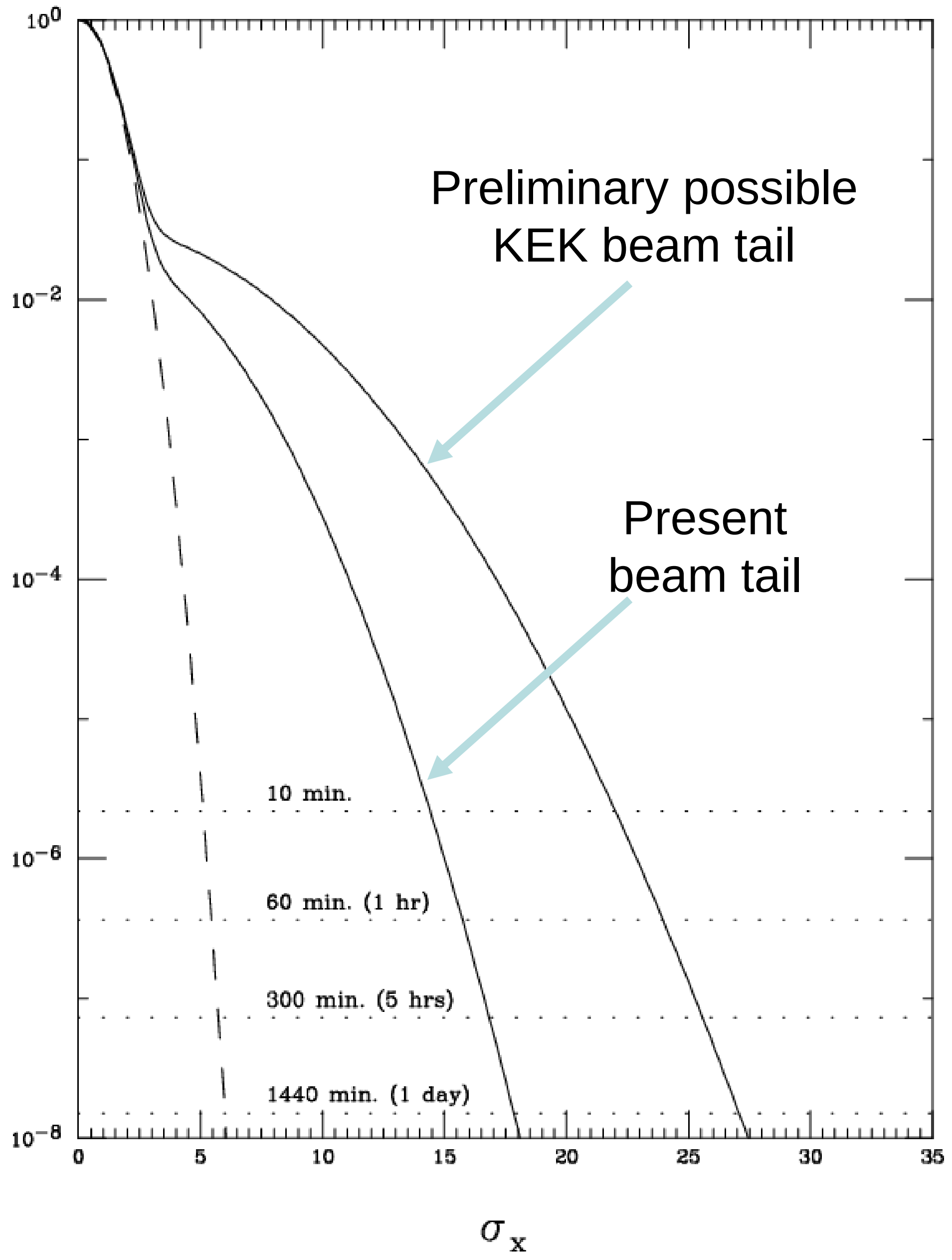


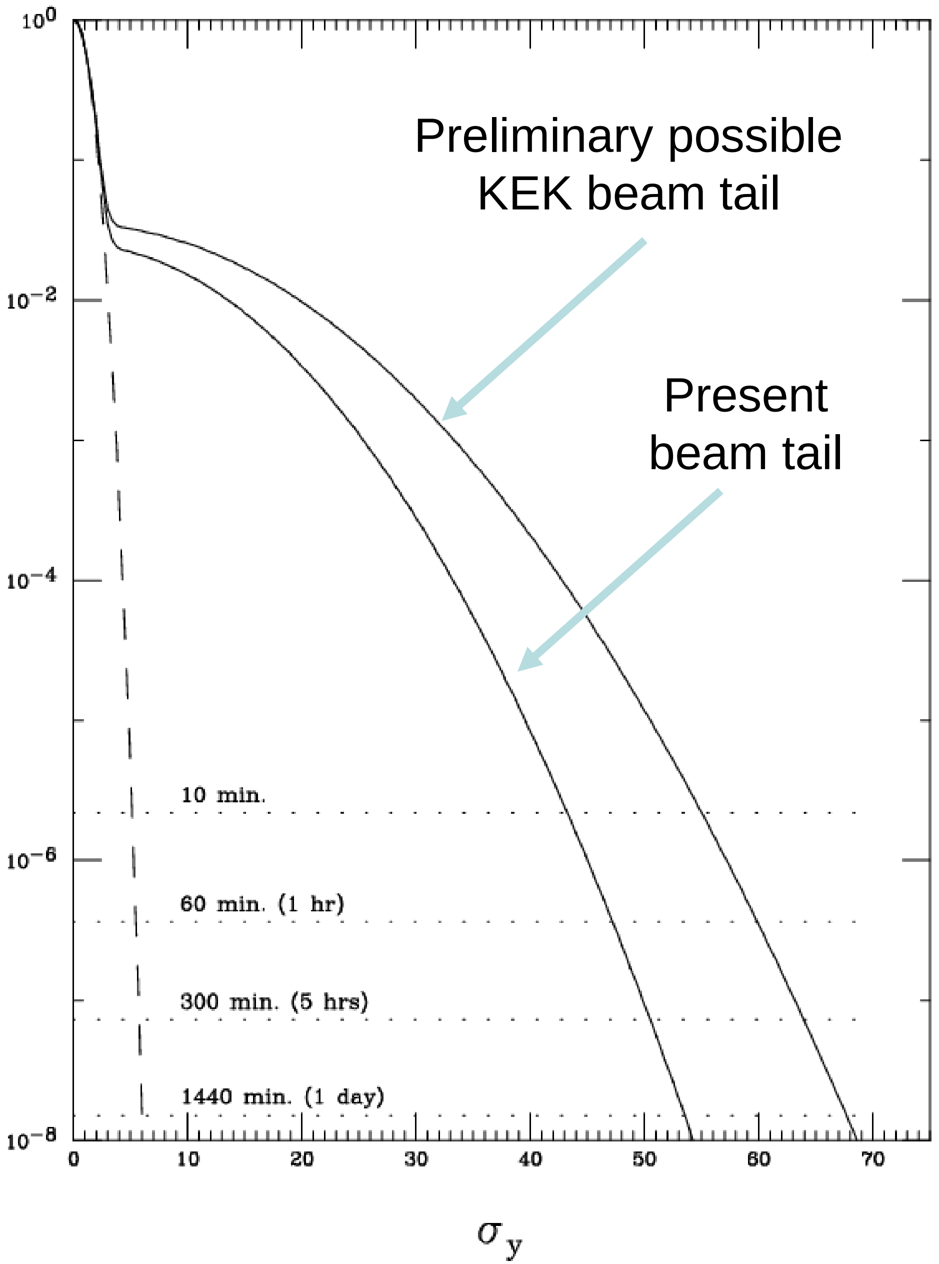


Z case summary

- Looks OK
  - The photon energies are low
  - Some worry about the direct hits on the central chamber from the FF SR but the rate is low
- However, now the main background (FF SR) depends on the particle distribution in the beam tails
  - This is not a well known distribution
  - The beam tail distribution used in this study is the "present tail" in the beam tail plots in the following slide

Beam Tails





The number of beam particles in the tail can differ by more than a factor of 10 depending on the stored beam conditions

ZHiggs – case

- **The ZH case has very similar results**
- **Unfortunately, the photon rates are higher because the photon energies are higher**
- **With the same 7 mm mask tip used in the Z case we see:**
  - **That the photon rate on the upstream chamber is higher**
  - **The photon rate on the central chamber from FF SR is higher**
  - **The numbers are summarized in the following table**

Summary table for 1 cm central beam pipe

Mask at -2.1 m	Z case (>10 keV/bun)		ZH case (>10 keV/bun)	
	Upstream of CC	Central Chamber	Upstream of CC	Central chamber
Std 10 mm radius mask	3.64e5	903	1.59e9	8.72e4
7 mm radius mask*	0.2	17.9	3753	1.24e4
6 mm radius mask*	0.2	16.7	485	2310
5 mm radius mask*	0.2	8.5	88.5	570

- **The 1 cm radius beam pipe (even though shorter) intercepts FF quadrupole radiation even with a 5 mm radius mask**
- **For the Z case a 7mm mask is fine (even 10 mm mask is OK?)**
- **For the ZH case a 5 mm mask is necessary?**
- ***FF quadrupole radiation only**

Transmission numbers through CC

- We simulate a central chamber to estimate the number of direct hit photons on the CC that go through
- Beam pipe materials
  - 5 µm Au
  - 1.5 mm Be
  - 1 mm H_2O
- Angle of incidence is 15 mrad
- 10^8 incident photons (45s CPU time for Z, 110s for ZH)
- Ave inc. photon energy is 16 keV for Z and 108 keV for ZH
- Through rate for Z is 0.8% and for ZH we get 12.9%

Forward scattered numbers

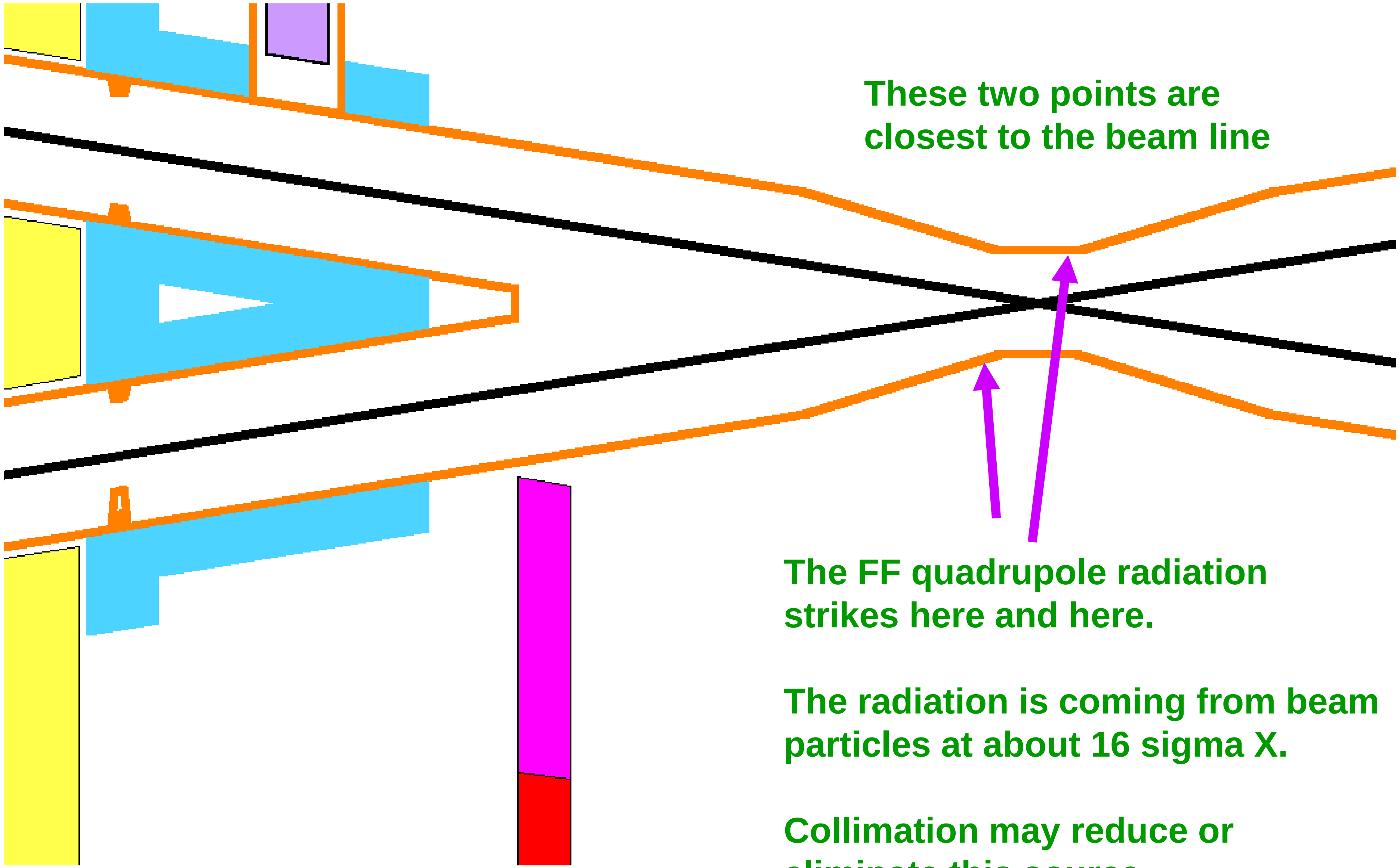
- Back in June I picked Ta as the surface for the upbeam beam pipe
- Here I use Ti to see how much the results change
- Au coated Ti is a better choice (ala SuperKEKB)
  - Result should be between these numbers
- I also have a more accurate scattering model
- I have not yet studied transmission through this part of the beam pipe

Transmission numbers and forward scattered numbers to the CC

Mask at -2.1 m	Z case		ZH case	
	Upstream of CC scattered to CC (incident on CC)	Direct hits through Central Chamber beam pipe	Upstream of CC scattered to CC (incident on CC)	Direct hits through Central chamber beam pipe
Std 10 mm radius mask	126	7.3	1.32e6 (Ta) 2.25e6 (Ti)	1.13e4
7 mm radius mask	1.7e-3	0.14	7.67 (Ta) 37.4 (Ti)	1602
6 mm radius mask	1.7e-3	0.13	0.99	298
5 mm radius mask	1.7e-3	0.07	0.18	73.6

- **These numbers are for forward scattered and for direct hits that go through the beam pipe coming from the table in slide 14**
- **For the Z case a 7mm mask is fine (even 10 mm mask is OK?)**
- **For the ZH case at least a 6 mm mask is necessary?**

FF quadrupole radiation



These two points are closest to the beam line

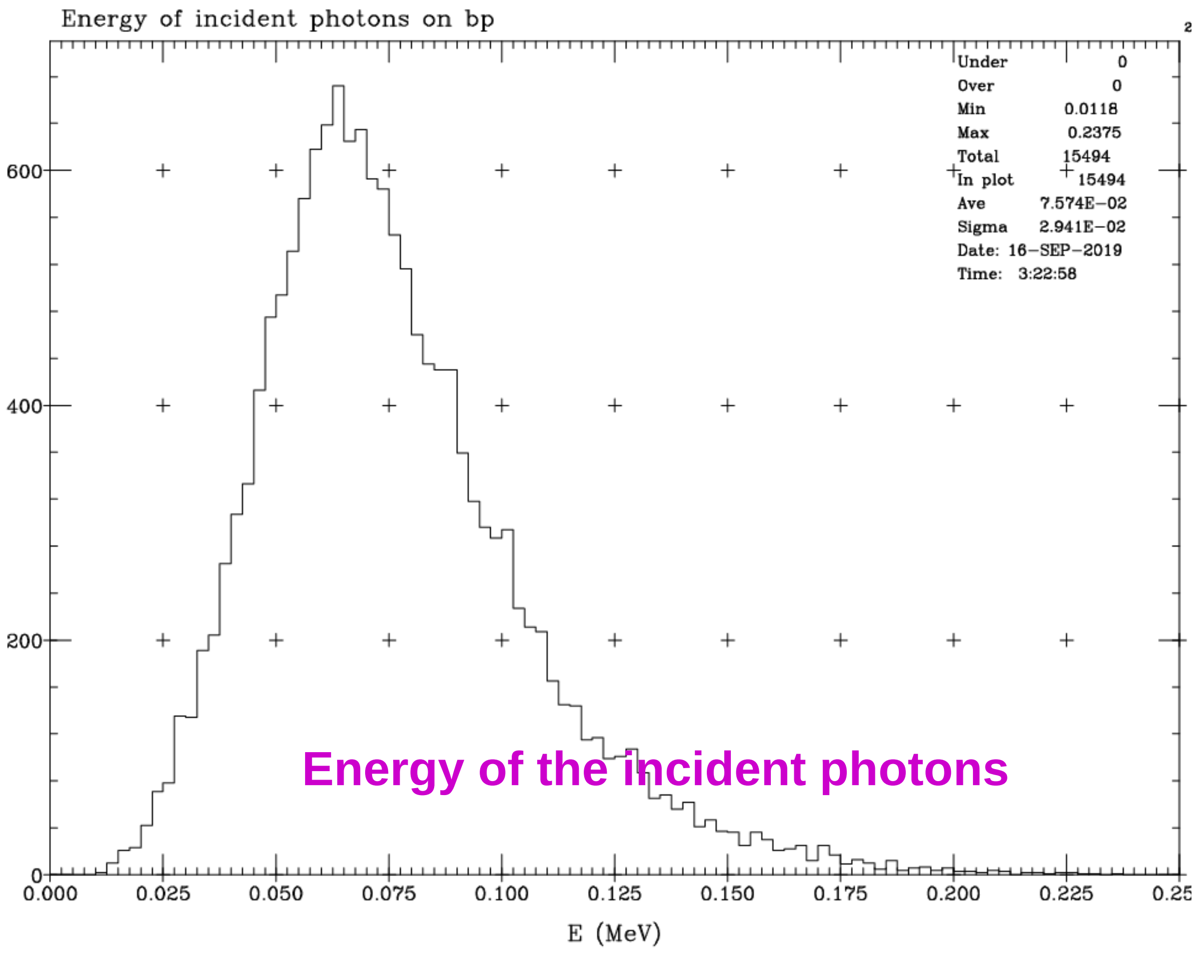
The FF quadrupole radiation strikes here and here.

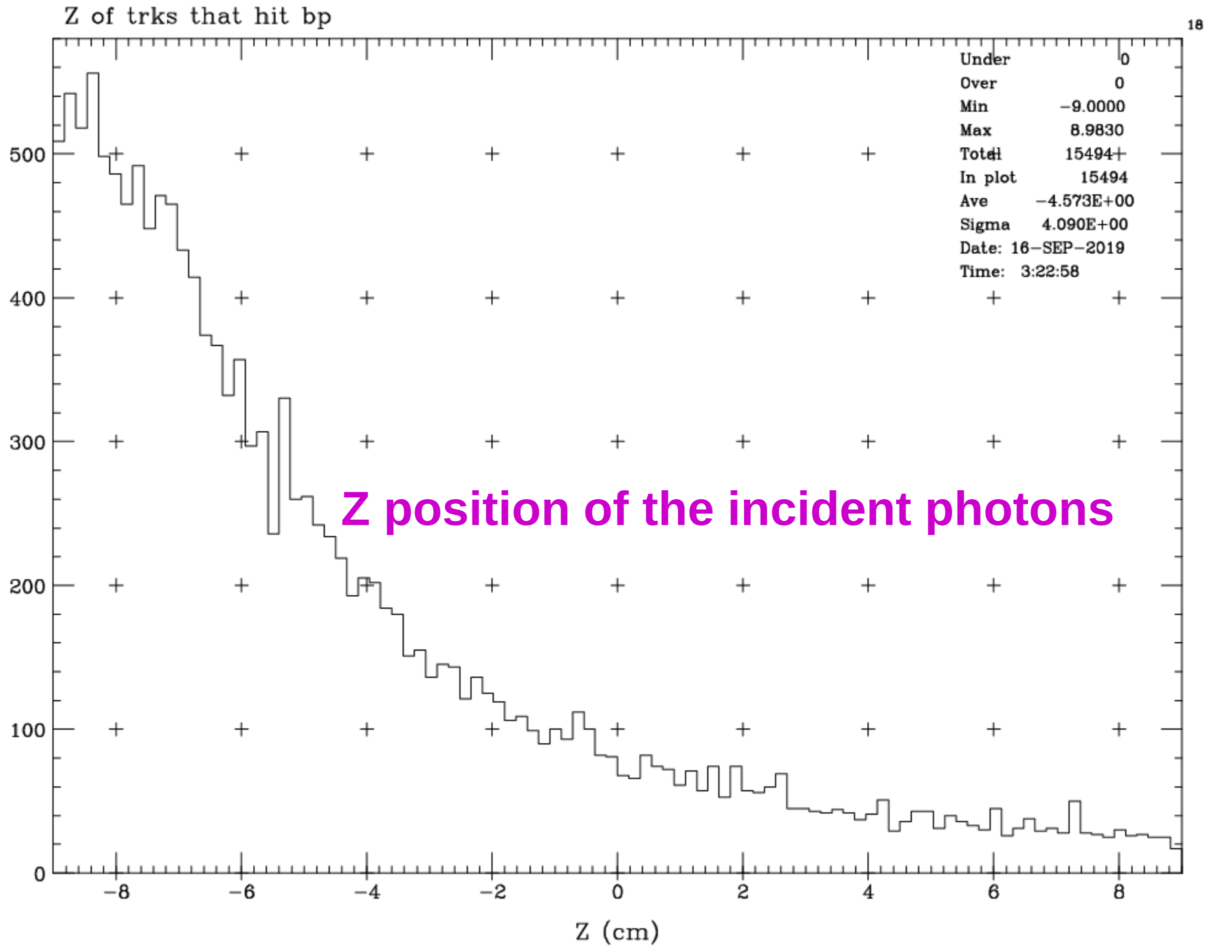
The radiation is coming from beam particles at about 16 sigma X.

Collimation may reduce or eliminate this source.

Some plots from the forward scattered photons

Photons primarily from the last bend radiation that get past the standard 10mm radius mask at -2.1 m





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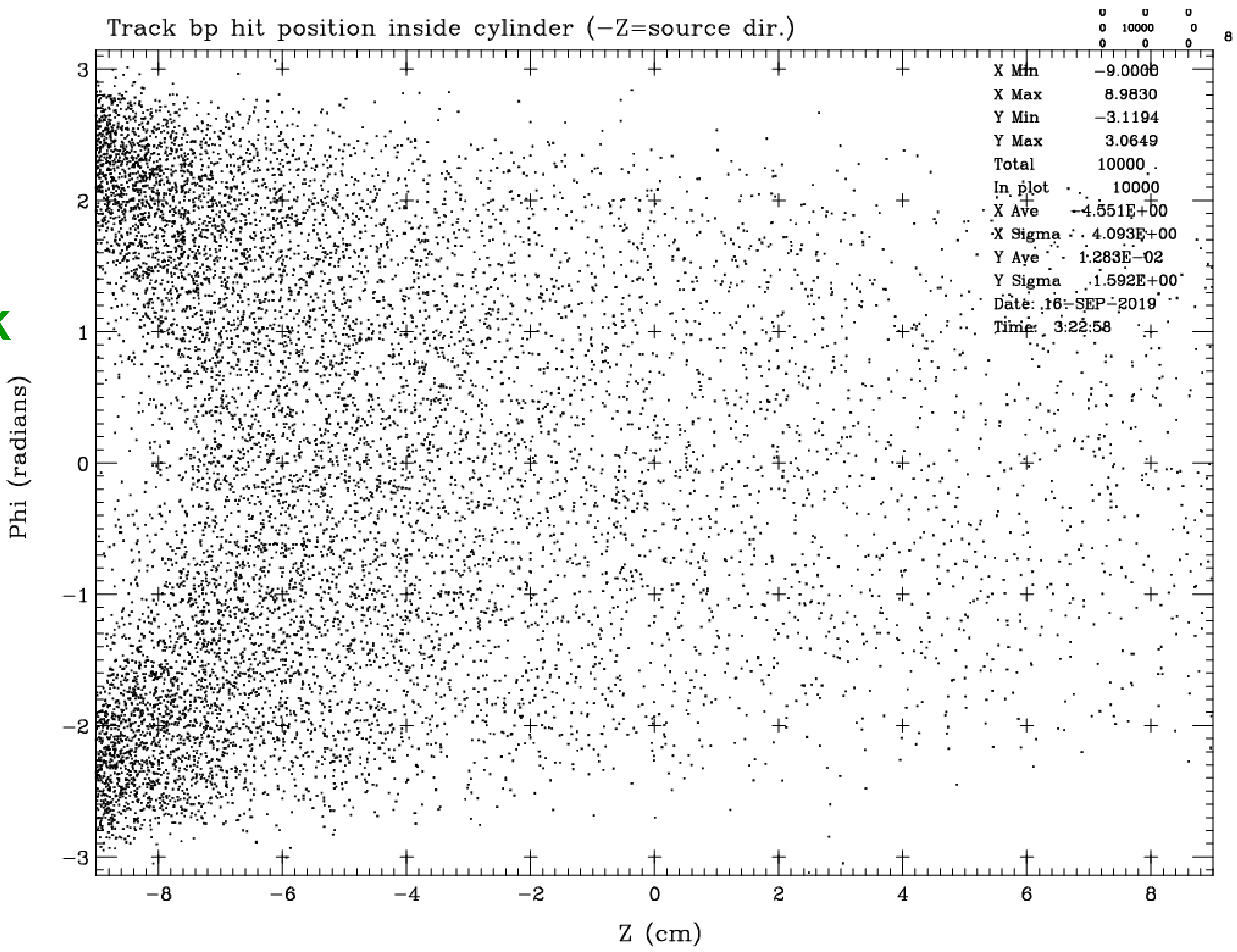
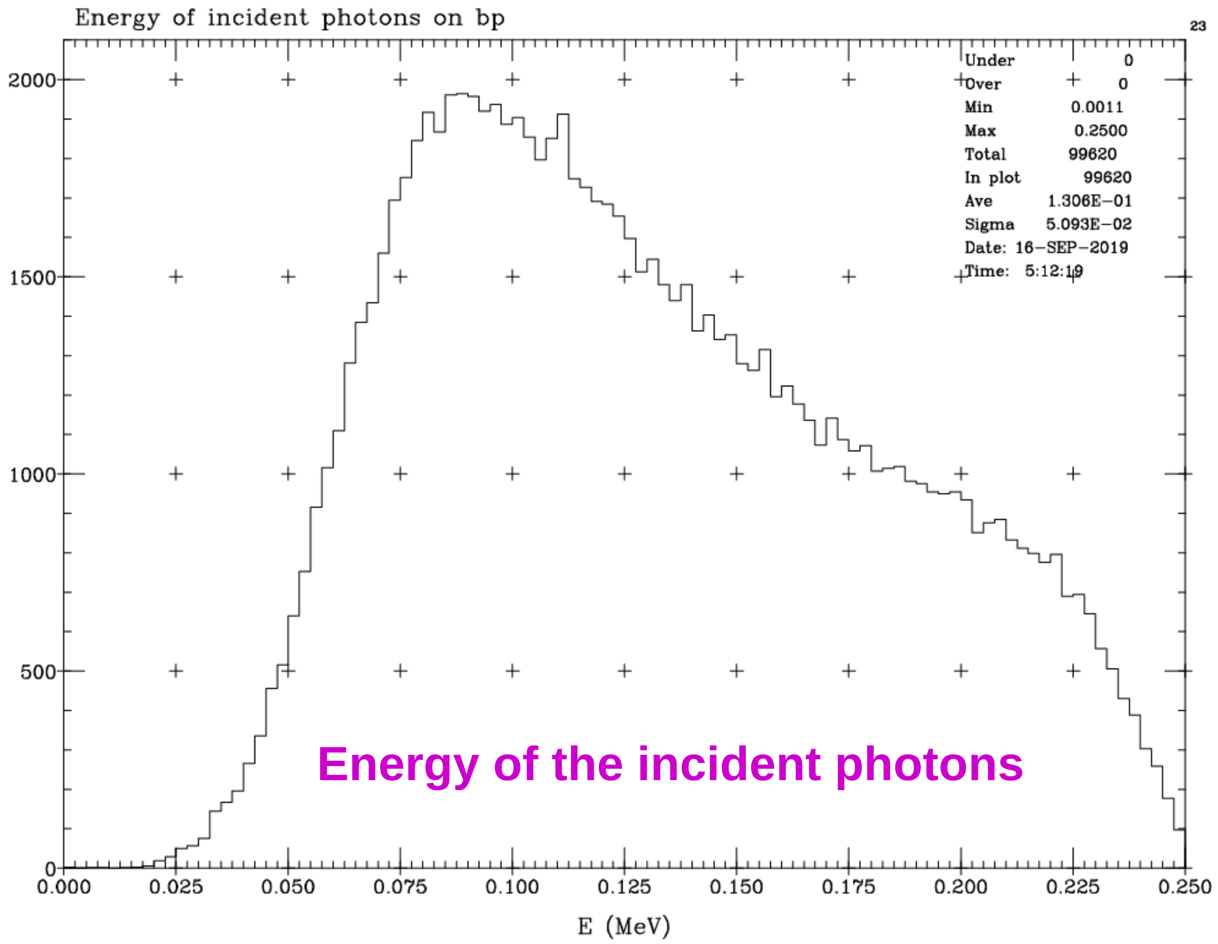
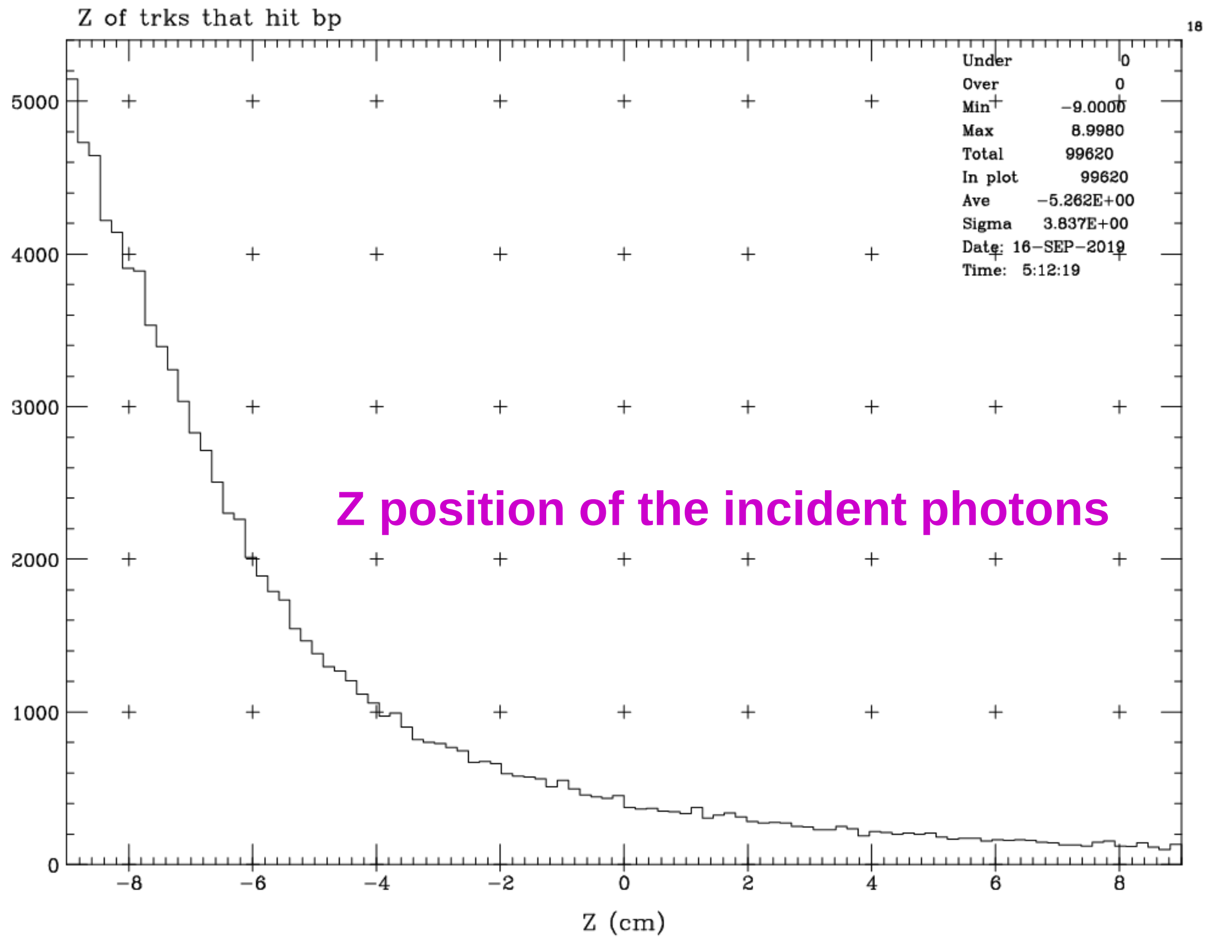


Z vs Phi position of the forward scattered photons that scatter to the central beam pipe

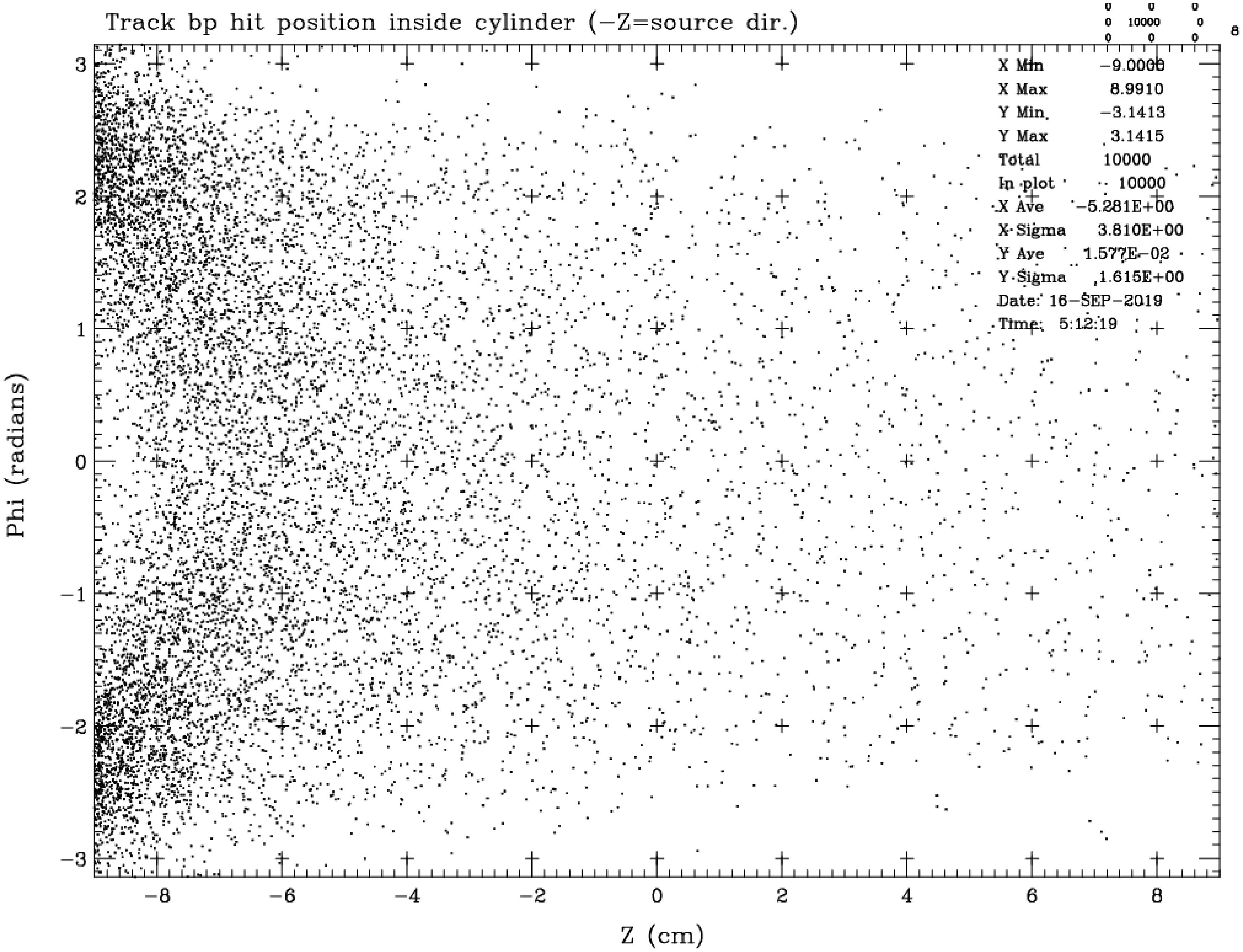
Some more plots from the forward scattered photons

Photons from the FF quadrupole radiation left after the bend radiation has been masked away by a 7mm radius mask





Photons from the FF quadrupole radiation left after the bend radiation has been masked away by a 7mm radius mask



Z vs Phi position of the forward scattered photons incident on the central beampipe

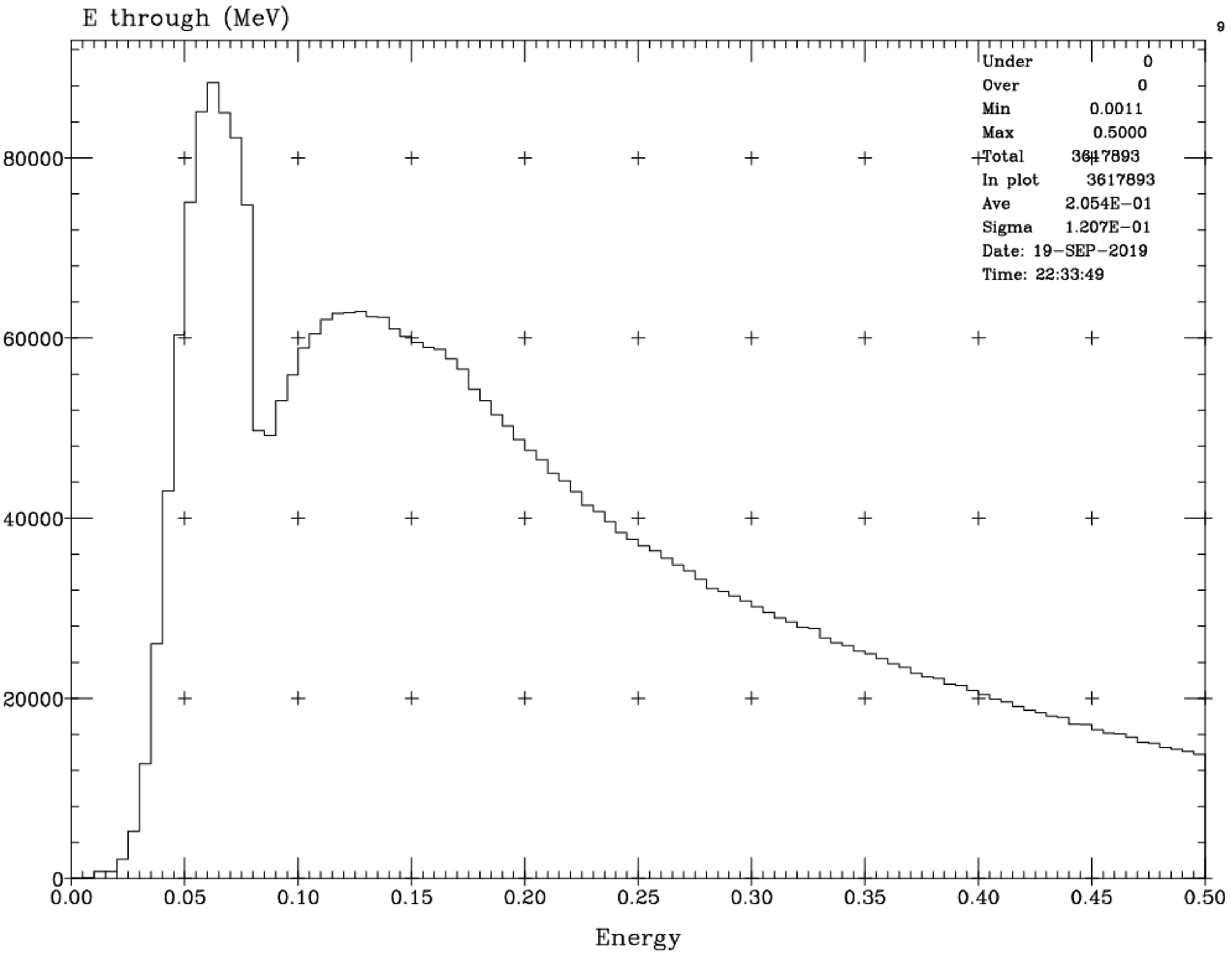
Transmission through the upstream beam pipe

- This is a first look at the transmission rate through this part of the beam pipe
- I had forgotten that the detector people want to use Be for this part of the pipe as well
- I have modeled 5 um Au, 1 mm Be and 1.5 mm of H_2O
- The angle if incidence is 55 mrad
- 36% of the incident photons go through the wall
- 64% of these (23% of total incident) do not scatter

Energy spectrum of the photons that penetrate the beam pipe

The spectrum is fairly hard

This is the radiation from the FF quads



Some thoughts on the transmission rate

- Since most of the photons that penetrate the beam pipe are not scattered these photons may also miss most of the detector
- They will be about 1 mm above the outside radius of the central beam pipe at the downstream end (+0.9 cm)
- I suspect the inner radius of the vertex tracker is larger (certainly no smaller) than this number
- This argues that only the scattered photons that penetrate have a chance of producing a background hit
- This is then 13% of the incident photons or 487/bunch/beam for the 7mm mask case
- Only a fraction of these photons will make a background hit

Summary

- We have looked at changing the central beam pipe radius from 15 mm to 10 mm and shortening the Z length from 25 cm to 18 cm
- The new beam pipe now intercepts SR from the FF quadrupoles and also intercepts bend radiation from the last soft bend before the IP
- The bend radiation can be masked away by reducing the mask radius at -2.1 m from 10 mm to 7 mm
- The quadrupole radiation cannot be totally masked away even with a 5 mm radius mask at -2.1 m

Summary (2)

- In addition, the upstream tapered chamber down to the central chamber radius also sees some SR
  - The design of this chamber will also take a careful study (initial study started)
  - We have assumed the incident radiation is either absorbed or forward scattered to the central chamber
  - This is most likely OK for the Z case but the higher energy photons of the ZH case will start to penetrate this chamber wall (initial study started)
- Please remember to multiply by two for both beams
- Also these numbers are per bunch crossing

Summary (3)

- **For the Z running (45.6 GeV) the quadrupole radiation has a low enough energy spectrum to not be a problem especially with a reduced mask radius of 7 mm**

- **However, the ZH running (120 GeV) has significantly harder photon energy spectra (i.e. see plot on slide 20) and this makes it difficult to prevent the direct hits from the FF quad radiation from penetrating the central beam pipe and entering the detector region**

Summary (4)

- SuperKEKB and Belle II also see the FF quad radiation strike the downstream part of the central beam pipe
  - This is even though there is a 5 mm radius mask at -0.4 m
  - The beam energy is much lower (8 GeV) and hence the photon energies are much lower
  - The beam tail particle distribution is important
- The FCCee design now becomes sensitive to the beam tail distribution
- This means a careful collimation scheme is needed

Some Conclusions

- A smaller beam pipe for the Z running looks possible
- A 1cm radius beam pipe for the ZH running is more problematical but with careful design work should be possible
  - The detector occupancy will be higher – may be still OK?
  - The IR design becomes more sensitive to the high sigma beam tail distributions
  - This also means that the IR design is more sensitive to β* changes in the machine lattice

Some thoughts

- There are a lot of design options ahead
  - Just how long in Z does the central chamber need to be?
  - How high a background rate can the detector take?
  - Perhaps more aggressive collimation outside the IR may help?
  - How tight can we make the SR mask at -2.1 m?
  - HOM and impedance issues with the tighter mask?
  - Even the top running may be possible if the detector backgrounds can be tolerated
  - …

Thank You!