Preliminary Look at a FCC-ee IR Layout

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for the FCC-ee week meeting

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Outline

- Introduction
- tt machine parameters
- Initial IR layout
- Initial SR study
- Z machine
- Discussion points
- Summary
- Conclusion

Introduction

- **The interaction Region is always one of the more challenging parts of a new accelerator**
  - Detector requirements
  - Accelerator requirements
- **Conflicting requirements mean compromises**
- **Everyone has to succeed**
- **This study concentrates on the SR issues**
- **Start with the tt accelerator design**

Machine parameters used in following very Initial IR tt design

- **Beam Energy** — **175 GeV**
- **β_x^*/β_y^*** — **1000/2 mm**
- **$\varepsilon_x/\varepsilon_y$** — **$1.3\times10^{-9}/2.5\times10^{-12}$ m-rad**
- **σ_x/σ_y** — **36 μm /71 nm**
- **L*** — **2.2 m**
- **Crossing angle** — **±15 mrad**
- **Beam current** — **6.632 mA**
- **e/bunch** — **1.71×10^{11}**
- **# bunches** — **81**

Final Focus parameters for tt

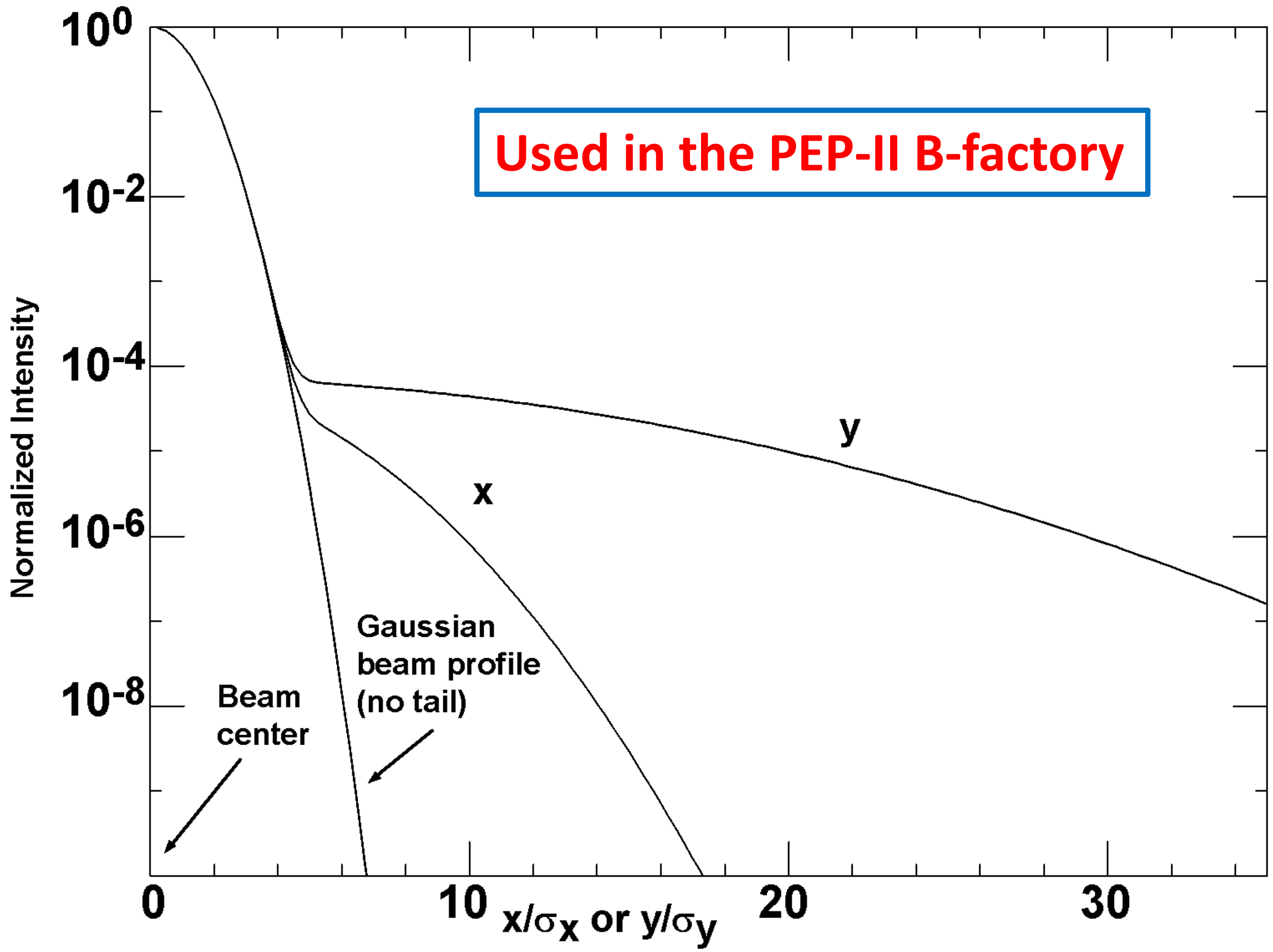
Magnet	L (m)	Z face (m)	G (T/m)
Q1C1	1.6	2.2	97
Q1C2	1.6	3.8	97
Q2C1	1.25	5.7	61.5
Q2C2	1.25	6.95	61.5

- Beam pipe aperture under magnets = 24 mm dia.
- SR masks near the magnets = 20 mm dia.

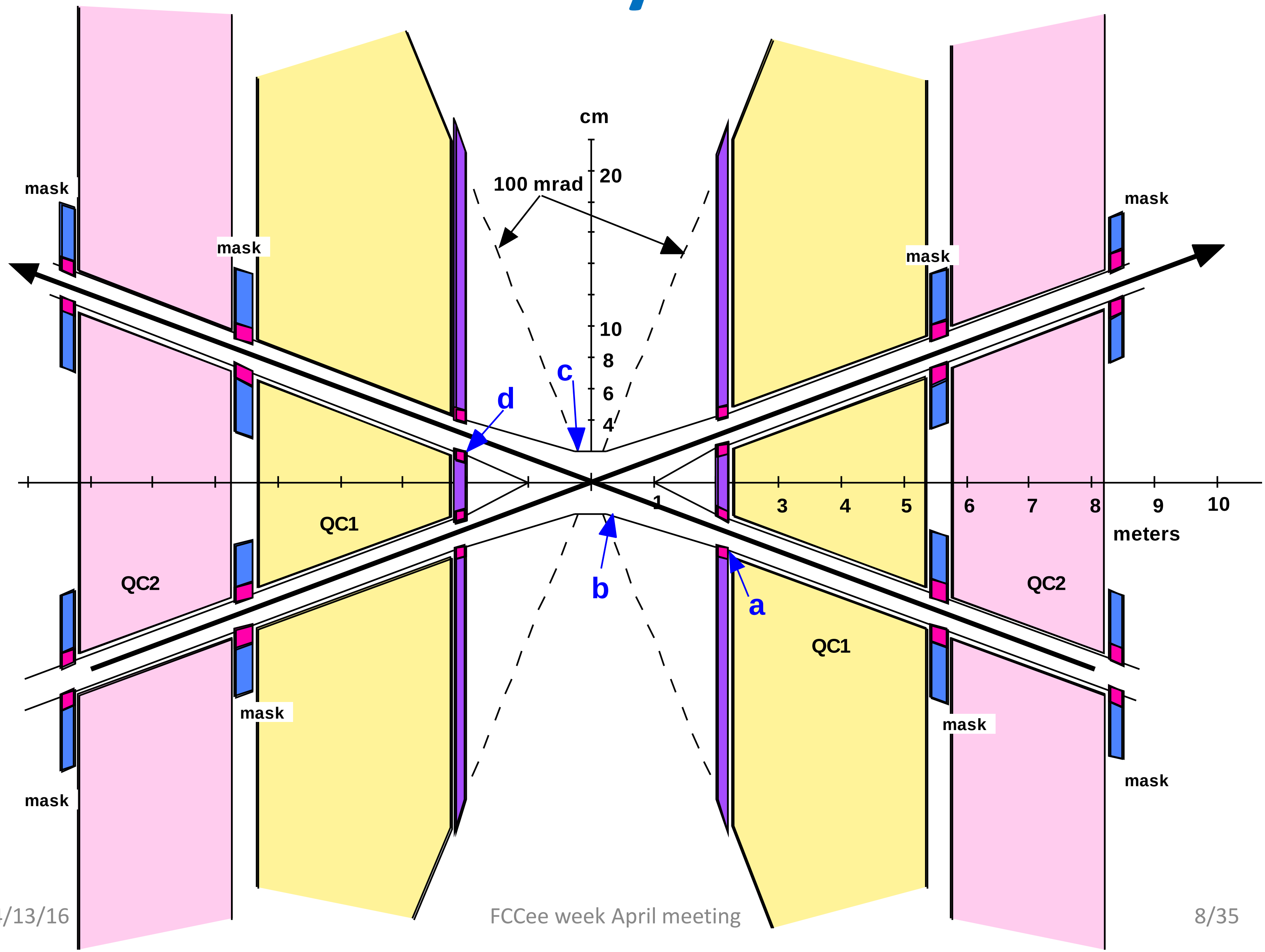
Final Focus SR study

- **BSC used in FF (half aperture)**
  - 20 σ_x (about 11 mm at back end of QC2)
  - 60 σ_y (about 5 mm in middle of QC1)
    - B factories had ½ $\varepsilon_{tot} \times \beta_y \times 10$ (>20 mm for tt case)
- **Beam tail distribution (halo)**
- **Ray tracing out to:**
  - ±15 σ_x
  - ±50 σ_y

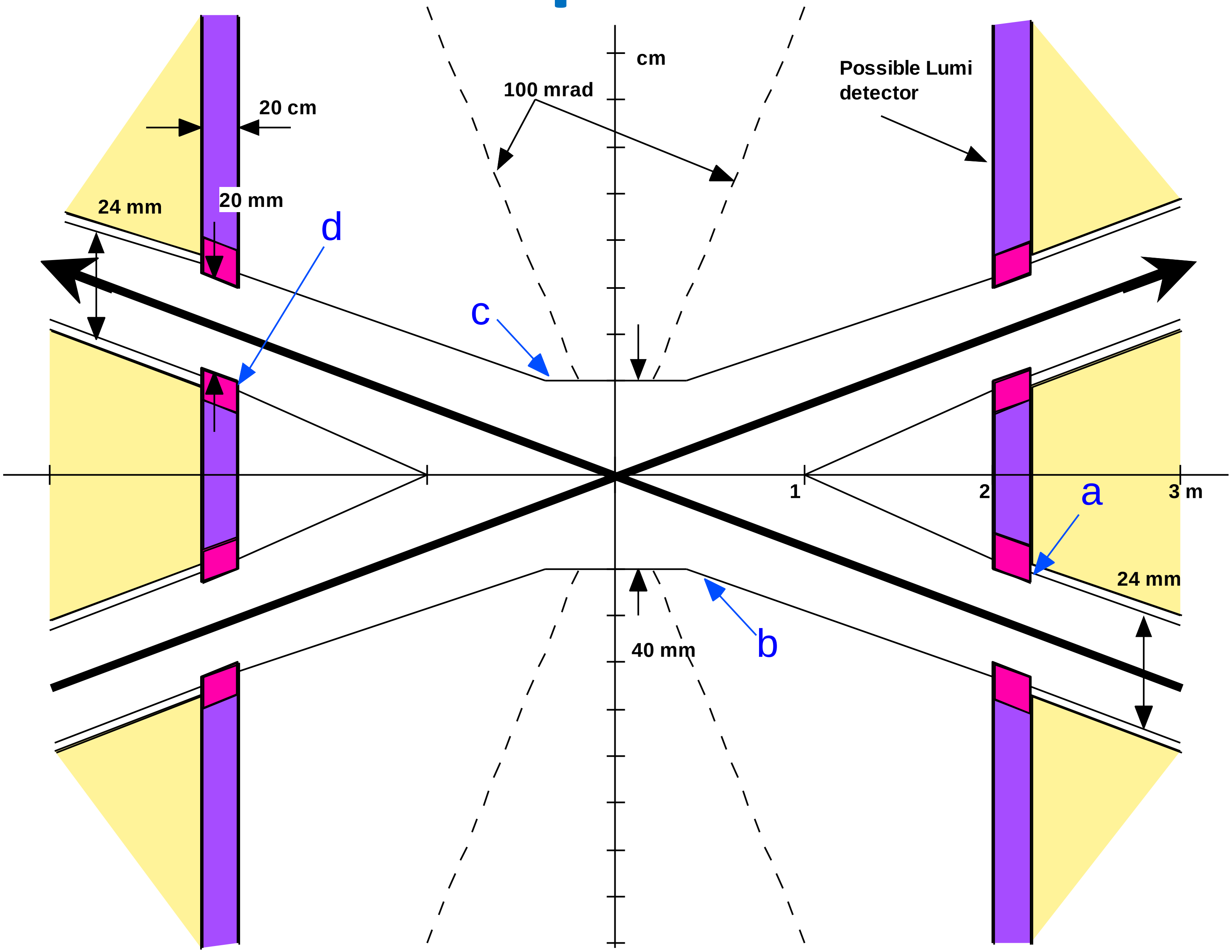
Beam tail distributions used



IR Layout


cm
100 mrad
20
10
8
6
4
c
d
b
a
mask
mask
mask
mask
mask
mask
mask
mask
QC1
QC1
QC2
QC2
1
3
4
5
6
7
8
9
10
meters

Close up of IP Area



Hits/crossing FF quads only

- Location Photons that hit each location

Location	Tot	>1 MeV	>4	>10	>50
a	3132	1462	728	293	5
b	4.03e5	1.78e5	8.32e4	7.99e4	320
c	3.74e5	1.62e5	7.35e4	2.56e4	209
d	1.82e6	7.59e5	3.29e5	1.07e5	609

- Notes:
  - All γs are from beam particles that are 40-50σ in the vertical
    - Very high energy γs. These numbers are **MeV** photons.
  - **Hits at points b and c are with a 10 mm radius beam pipe**
  - **No hits at b and c if the beam pipe radius goes to 15 mm**
  - **Drawing shows a 20 mm radius beam pipe**

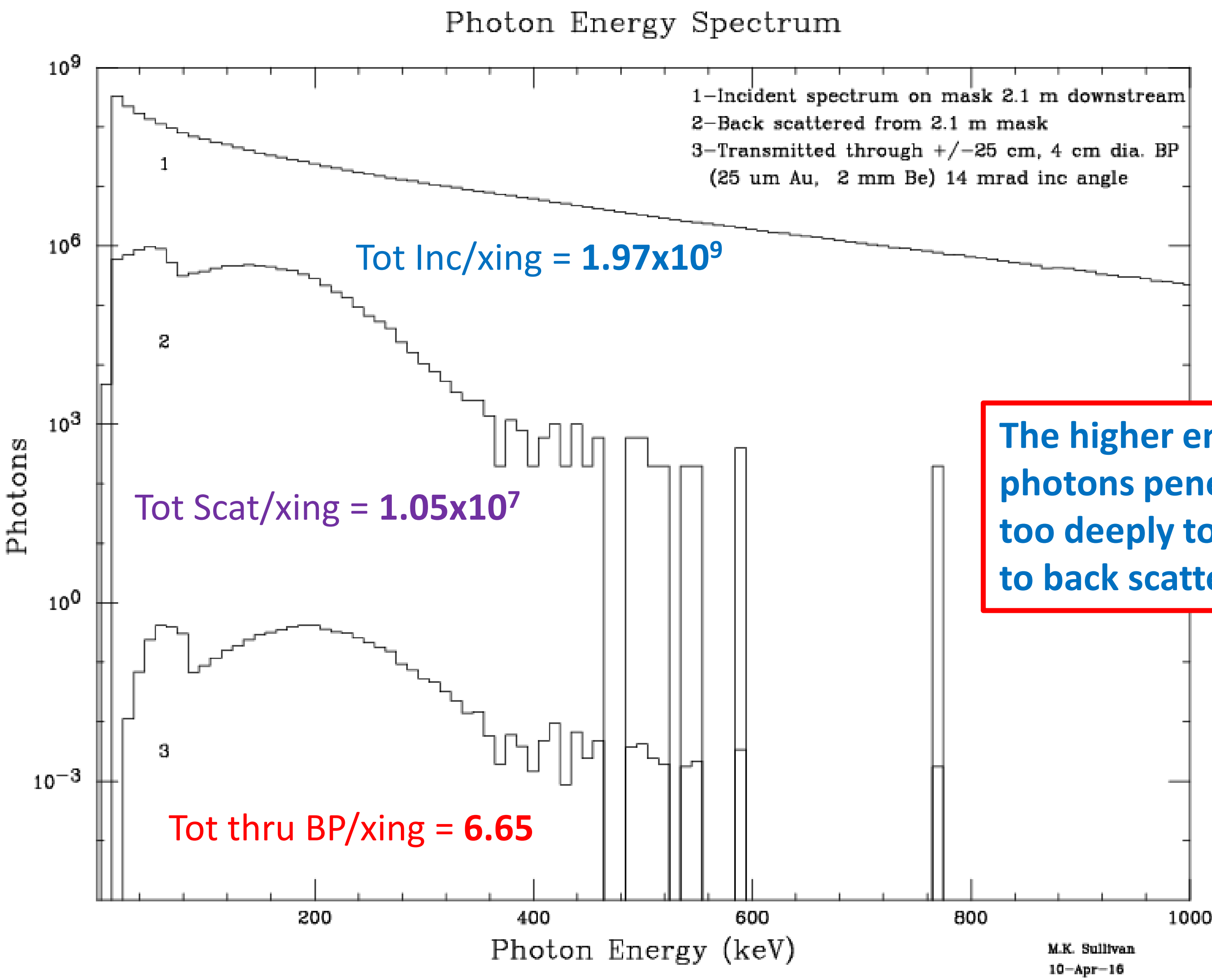
Hits/crossing FF + last bend

- Location Photons that hit each location
- Tot >1 keV >10 >50 >250 >1000
- a 5.63e9 1.98e9 1.44e9 8.22e8 1.78e5 1.78e5
- b 2.32e10 8.13e9 5.91e9 3.38e9 7.73e8 1.50e7
- c 4.82e9 1.69e9 1.23e9 7.03e8 1.61e8 3.08e6
- d 1.74e6 1.63e6 1.51e6 1.34e6 1.07e6 7.23e5
  - Numbers are again for a 10 mm radius beam pipe
  - No hits if inner beam pipe radius goes to 15 mm but then
  - Downstream QC1 face gets ~1000x more photons
- d 5.93e9 2.08e9 1.51e9 8.67e9 1.89e8 4.44e6

Downstream Face of FF quad at 2.1 m

- **There are enough hits on the downstream quad face to cause a significant backscatter rate to the IP beam pipe**
  - About 0.5% backscatter
  - The SA fraction of the IP beam pipe from the quad face is about 2.22×10^{-5} for BP 2 cm rad ±25 cm long
  - The result is about 7 photons/crossing will go through a 25 um Au and 2 mm Be beam pipe with an average energy of 170 keV for each beam

Back Scattered (location d)

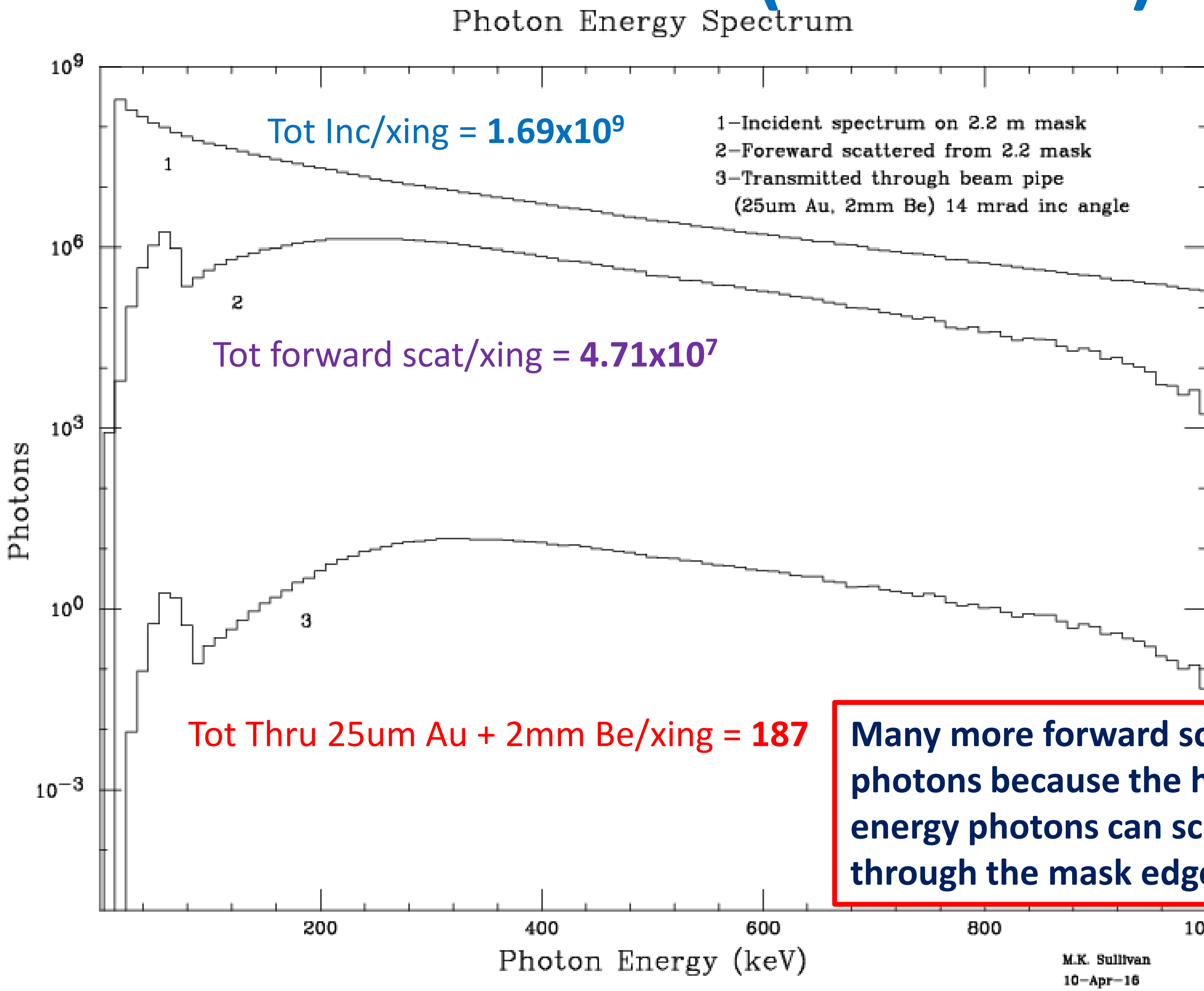


The higher energy photons penetrate too deeply to be able to back scatter out

Upstream Mask of FF quad at 2.2 m

- **There are also enough hits on the upstream mask to cause a significant forward scatter rate to the IP beam pipe**
  - About 2.5% forward scatter
  - The SA fraction of the IP beam pipe from the quad face is about 1.93×10^{-5} for BP 2 cm rad ±25 cm long
  - The result is about 187 photons/crossing go through a 25um Au and 2 mm Be beam pipe with an average energy of 410 keV for each beam

Forward Scattered (location a)



Many more forward scattered photons because the high energy photons can scatter through the mask edge

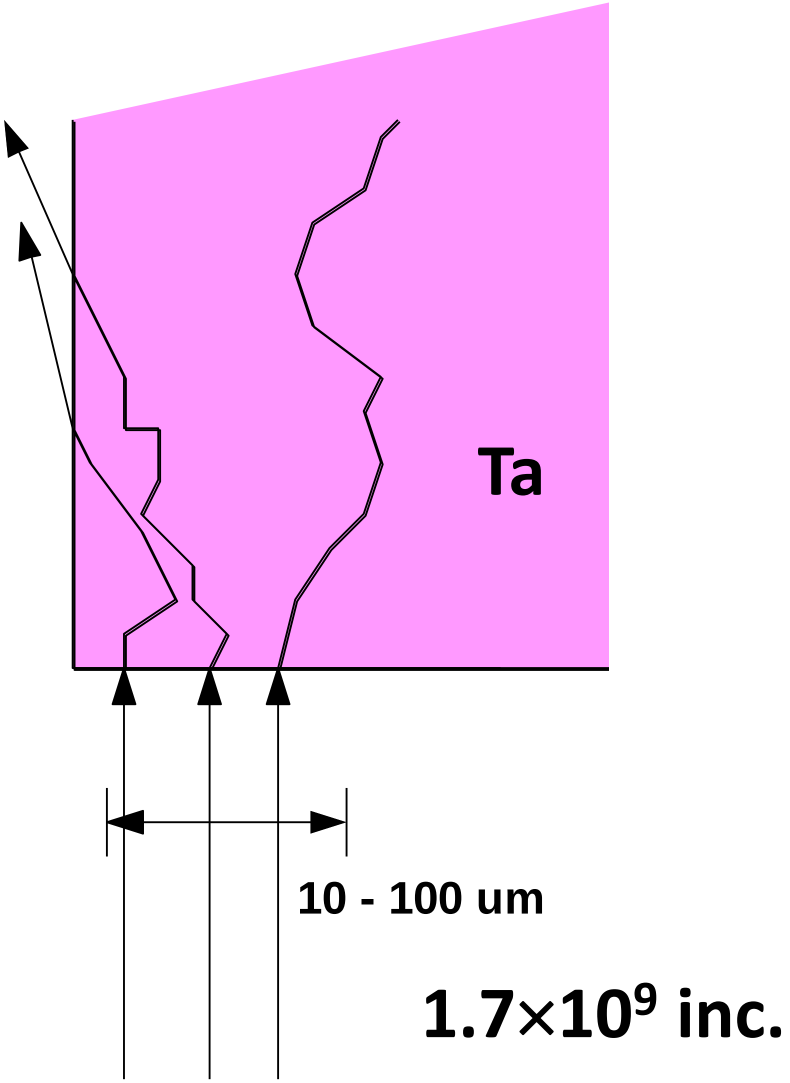
Picture of mask edge model

A little conservative, as the photons are spread out over 1 mm from the edge.

The generation is a uniform distribution from 10-100 um from the edge.

The actual distribution falls off as we move away from the edge.

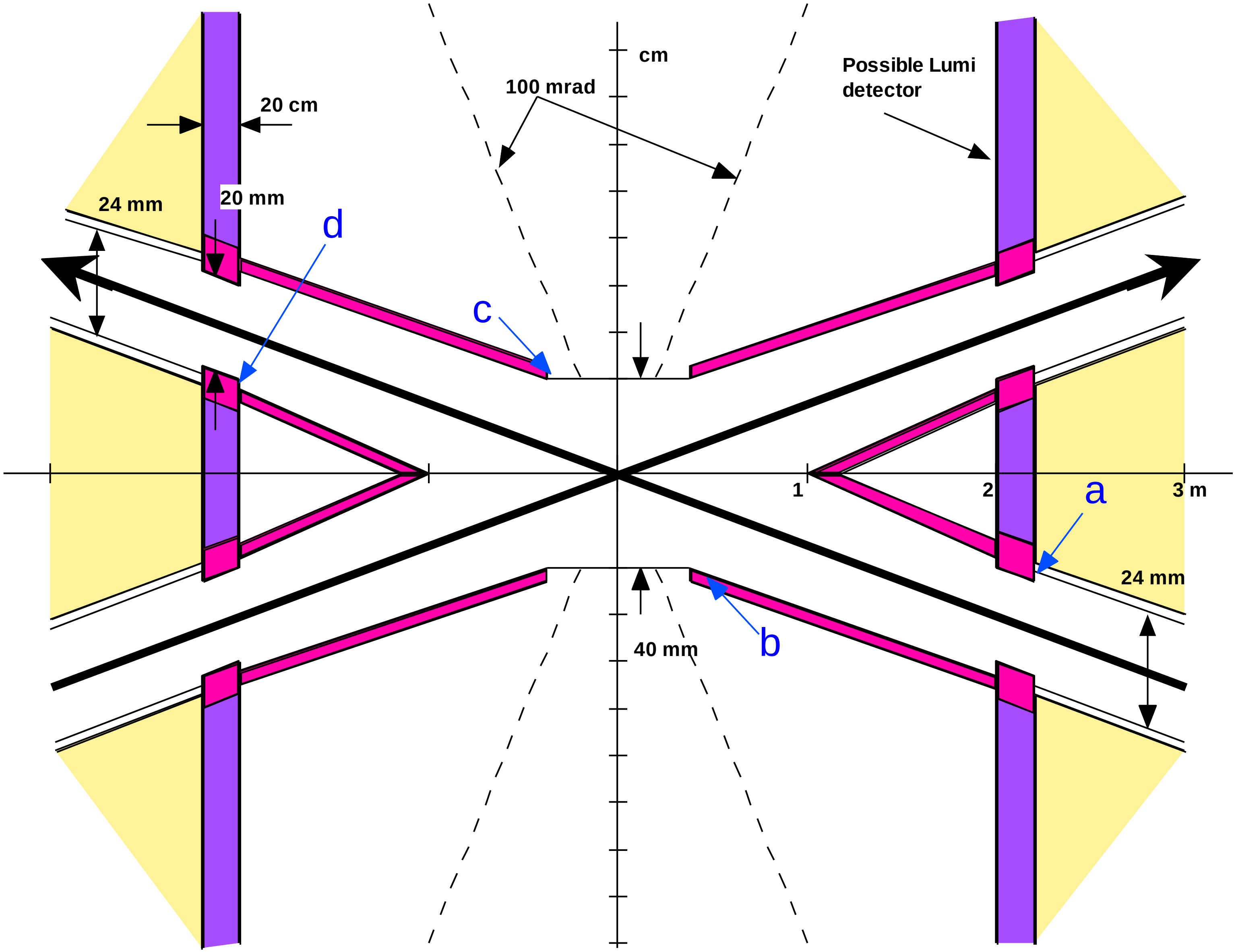
A more detailed study can produce a more accurate result.



Shielding around the IR beam pipes

- Based on the forward scatter rate from the upstream quad faces, without shielding there is a high rate of photons into the central detectors near the IP beam pipe
- For a forward (or back) scattered photon hitting the beam pipe 0.5 m from the quad face the angle of incidence is ~40 mrad
- Using this angle on various Ta layers one gets the following rates/xing through the Ta

Beam pipe shield



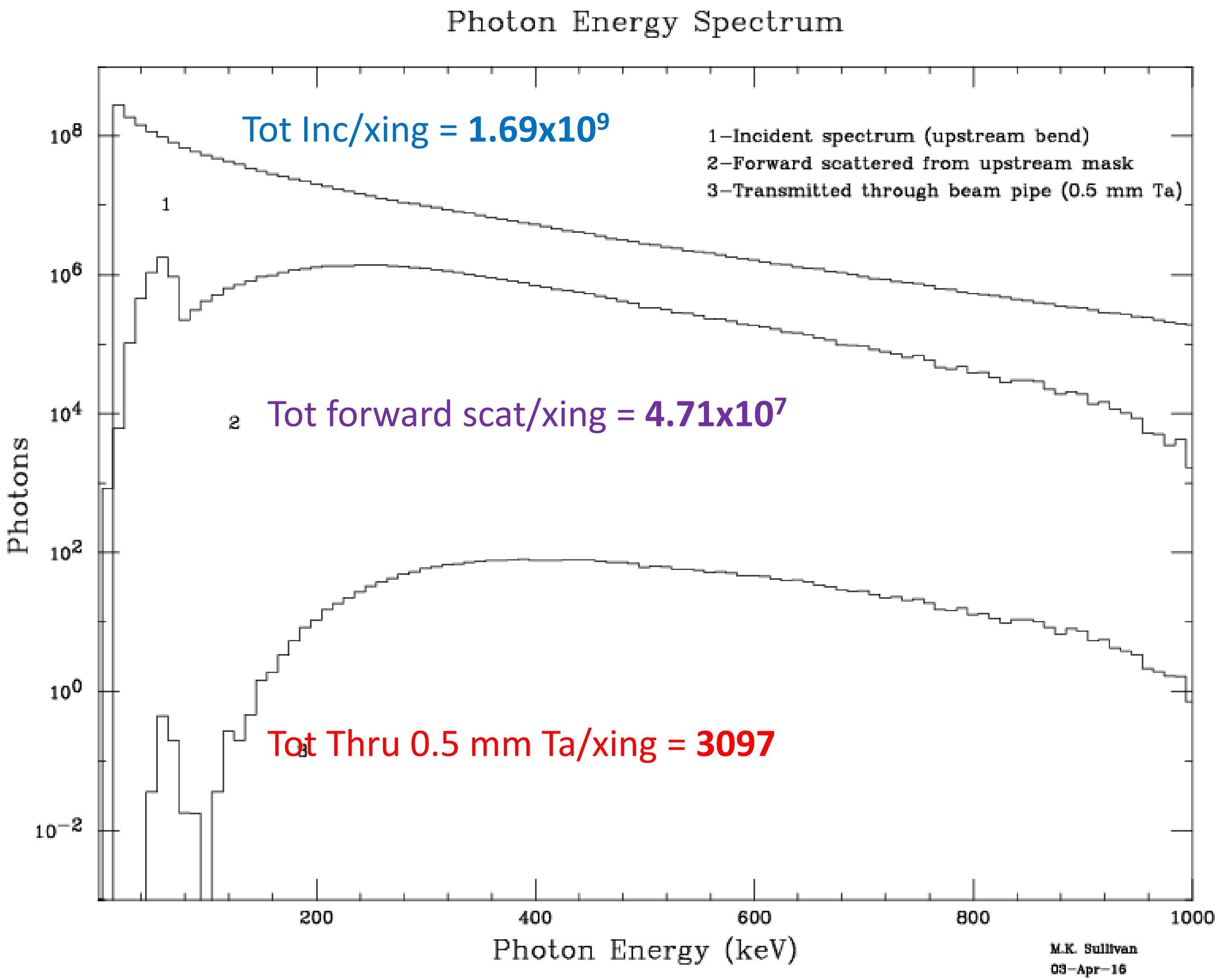
Forward scattered rates through a Ta shield around the pipes

- We use a Ta shield from 0.5 m to 1.5 m from the IP (within 0.7 m of the source)

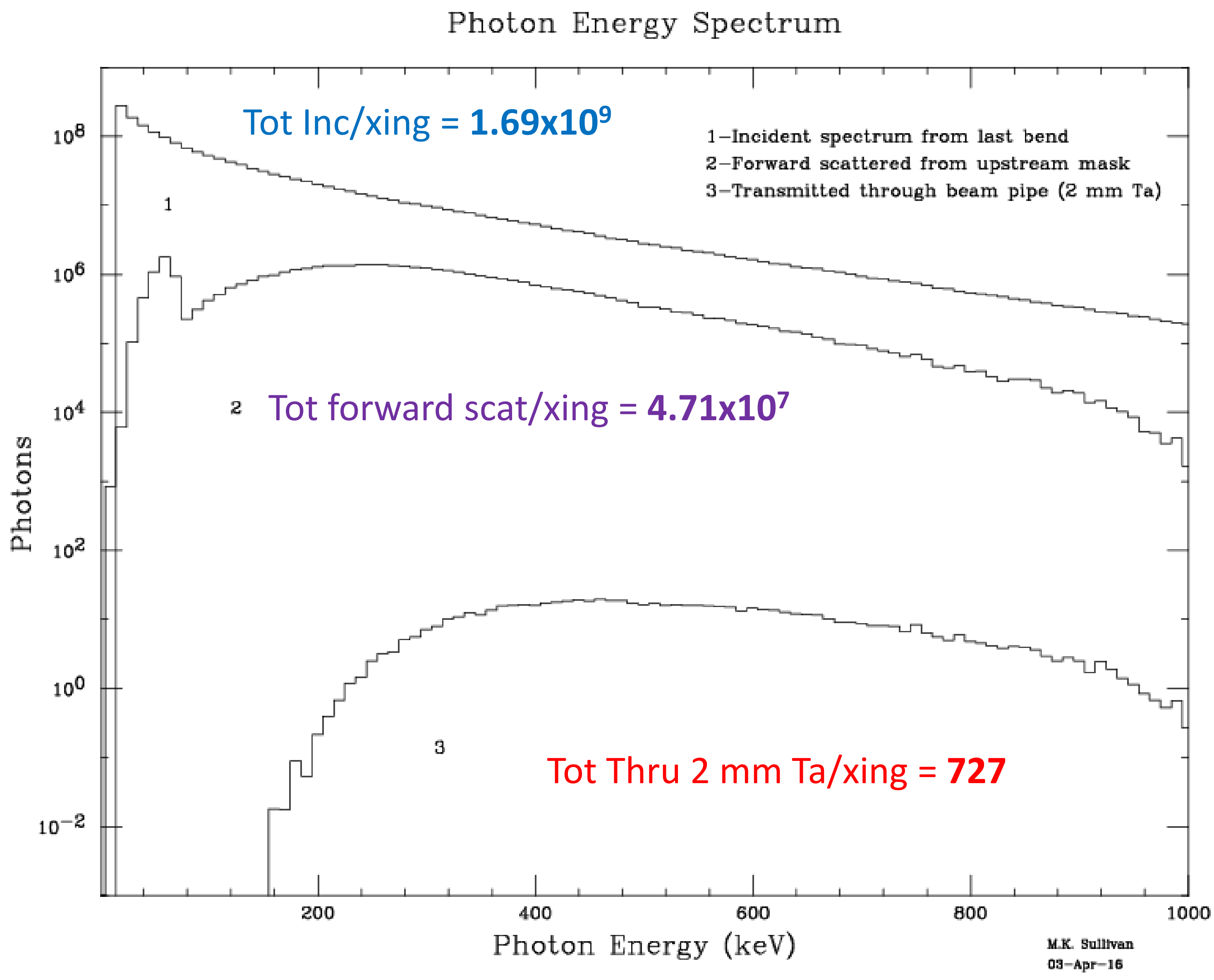
Ta thickness	γ rate thru Ta shield/xing
2 mm	727
1 mm	1602
0.5 mm	3097

These are all reasonable rates

Energy spectrum for 0.5 mm Ta shield



Energy spectrum for 2mm Ta shield



The Z machine

- First look at running at the Z
  - 45.6 GeV
  - SR critical energies much lower
    - 100 keV soft bend → 1.7 keV
  - Beam emittances lower
  - Used High luminosity β^* values

Machine parameters used in following very Initial IR Z design

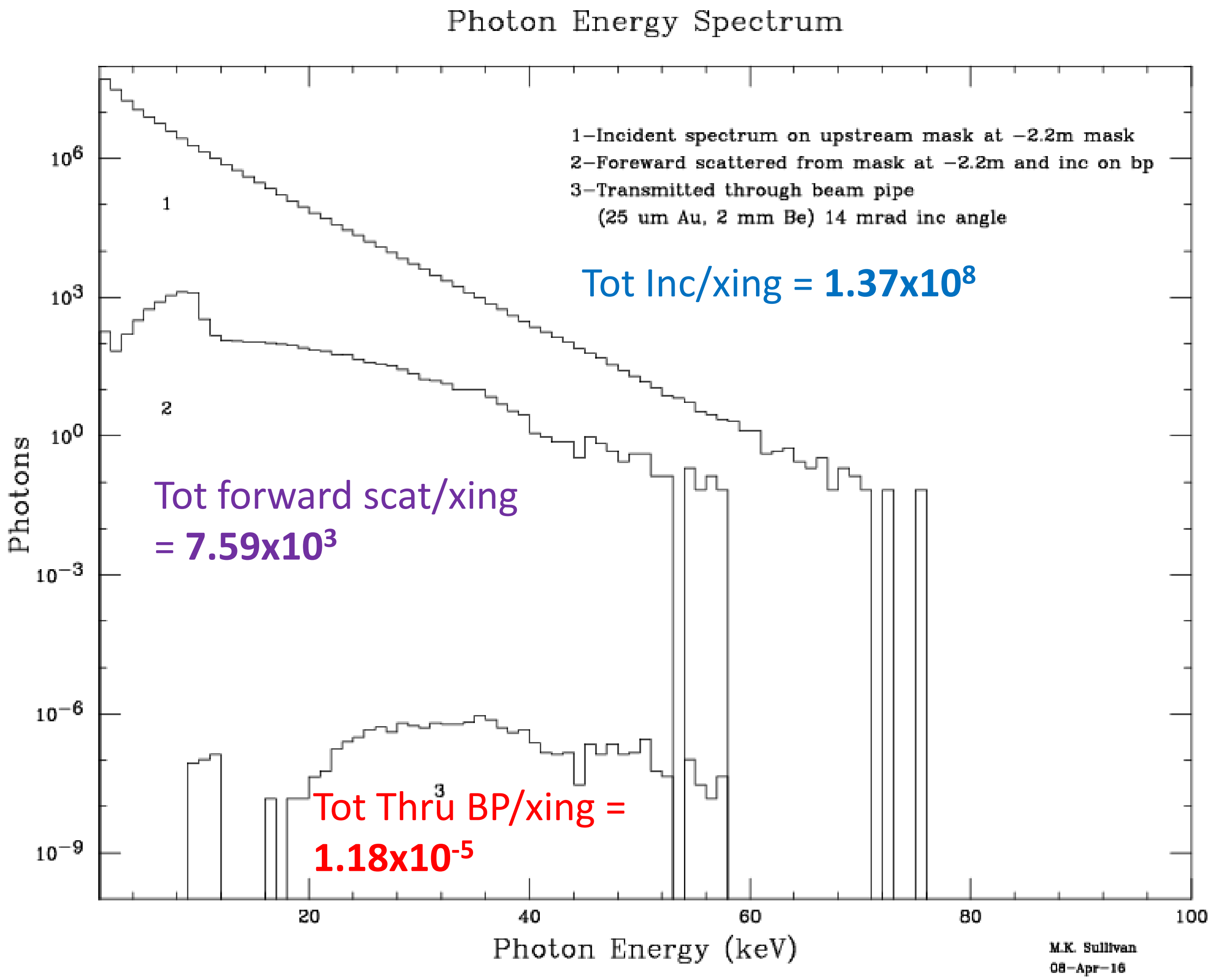
- Beam Energy 45.6 GeV
- β_x^*/β_y^* 500/1 mm
- $\varepsilon_x/\varepsilon_y$ $0.2\text{x}10^{-9}/1.0\text{x}10^{-12}$ m-rad
- σ_x/σ_y 10 μm /32 nm
- L* 2.2 m
- Crossing angle ±15 mrad
- Beam current 1.45 A
- e/bunch $1.0\text{x}10^{11}$
- # bunches 30180

Final Focus parameters for Z

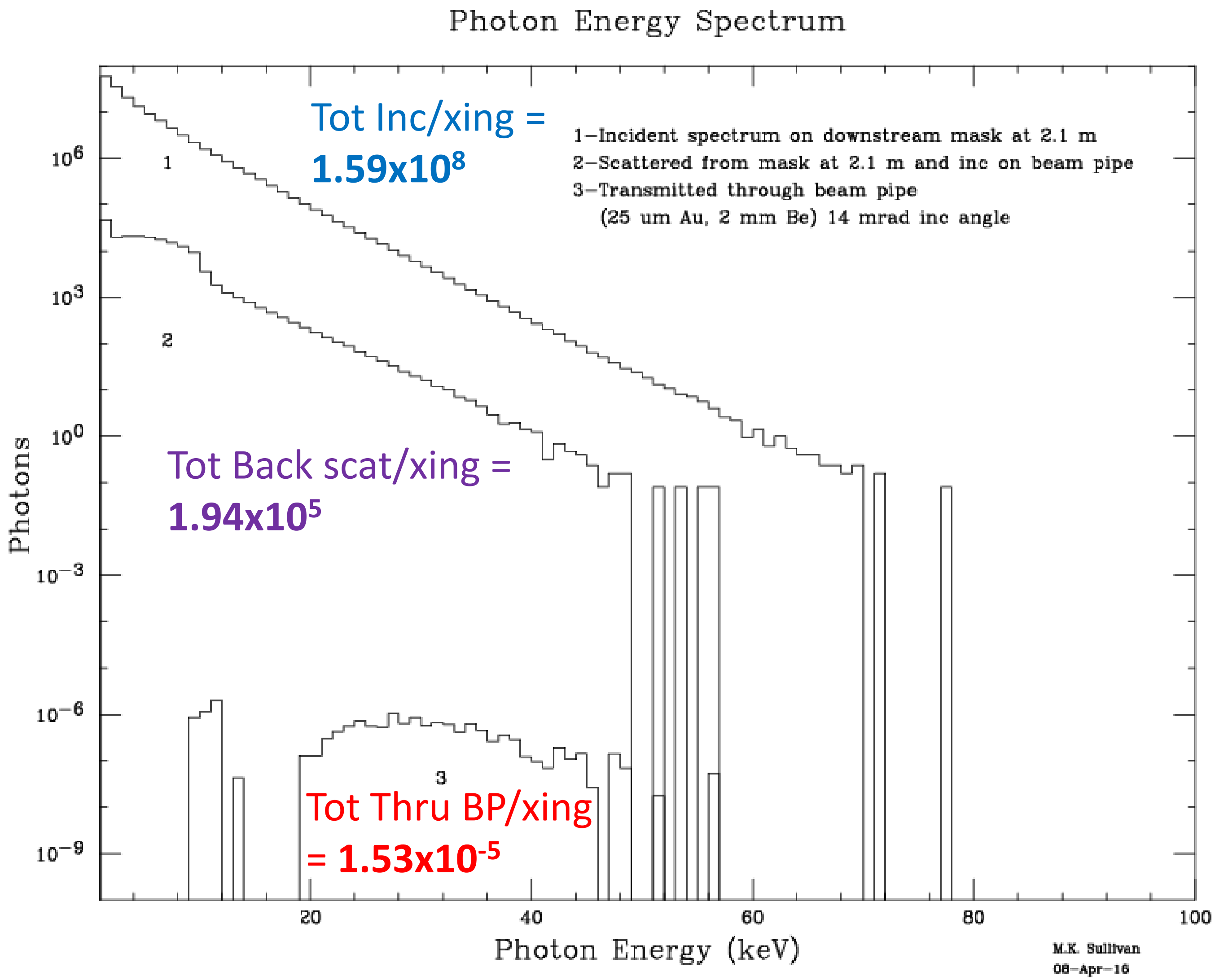
Magnet	L (m)	Z face (m)	G (T/m)
Q1C1	1.6	2.2	25
Q1C2	1.6	3.8	25
Q2C1	1.25	5.7	16
Q2C2	1.25	6.95	16

- Beam pipe aperture under magnets = 24 mm dia.
- SR masks near the magnets = 20 mm dia.

Forward scattered photons from upstream soft bend (12 Gauss)



Backscattered photons from downstream mask at the Z



Present IP BSCs

- **BSC for the Interaction Region**
  - $20\sigma_x$
  - $60\sigma_y$ (This may still be small)
    - PEP-II B-factory had $35\sigma_y$ with 5% coupling
    - FCCee has 0.1% coupling
    - Small vertical aperture means harder to beta squeeze (it will determine the lowest βy^*)
- **Ray tracing range for SR**
  - $15\sigma_x$
  - $50\sigma_y$

Some Issues

- **The beam particle density at high σ_x and σ_y**
  - Presently using tails shown in slide 7
  - Need to find out what dynamic aperture studies show. Does this look about right?
  - Where do instabilities start to come in?
  - Where do we need to collimate? How tight?
- **Bending magnets seem close to IP**
  - PEP-II HER bends were 80m away for 9 GeV beam
  - LEP soft bends were ~200m upstream

Have new design from Oide

Reduce rate at by 2 at least

Still more issues

- **FF magnet bores too small?**
  - Assume same magnets for all running conditions

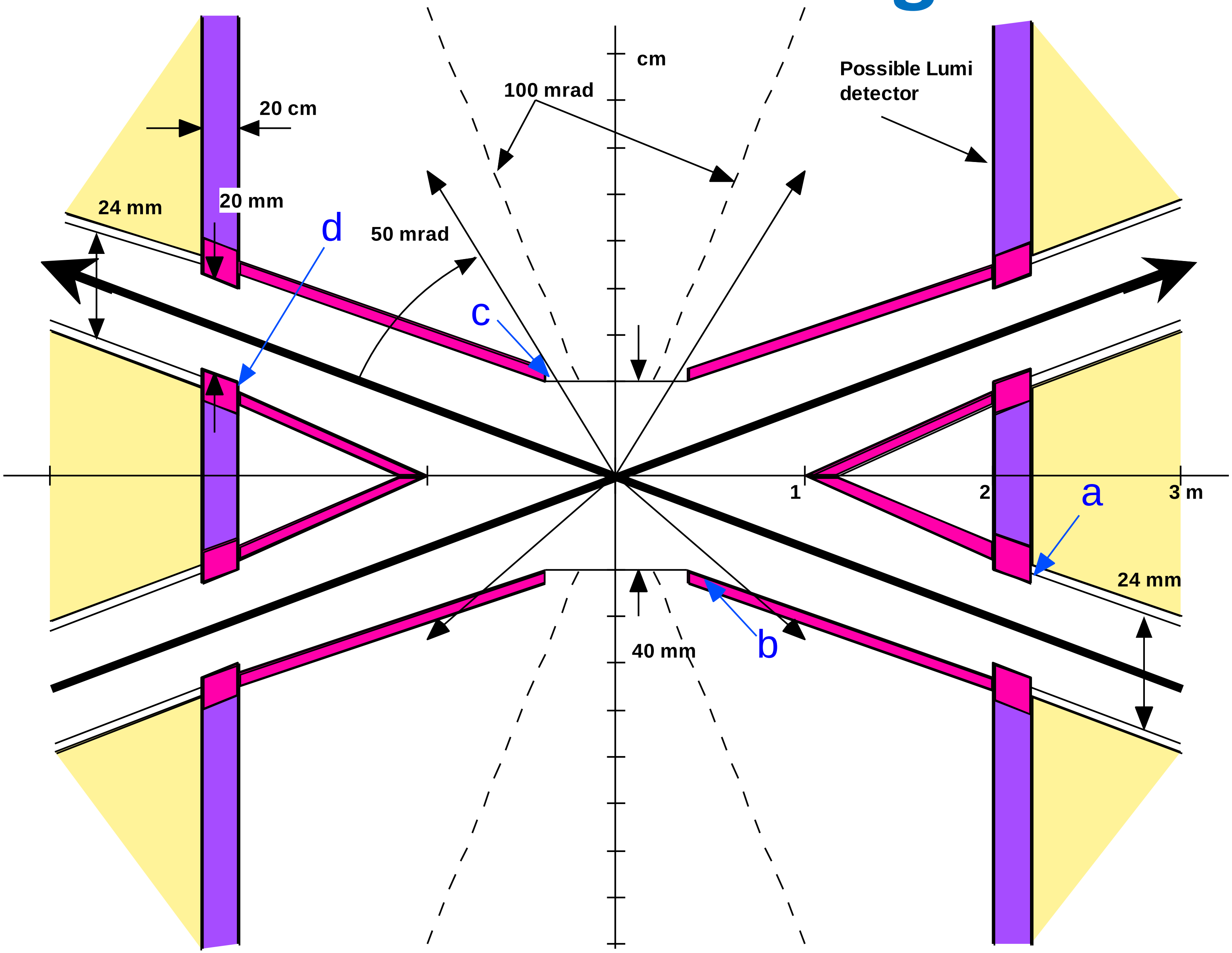
IP HOMs can't escape

- **Question about soft bend field**
  - For tt the soft bend is 49 Gauss
  - For Z the soft bend is 12 Gauss
    - This may be too low to reliably work at the Z?
- **Same IR for all running cases**
  - Z running looks OK
    - Perhaps smaller IP beam pipe?
  - What about Higgs running?
    - Photon critical energies higher than Z
    - Soft bend is now 36 keV – similar to the B-factories

Present working assumptions

- **Assume present BSCs are OK**
- **Tail particle density at high sigma (lifetime) is OK**
- **Detector needs a precision lumi monitor**
  - Primarily for Z running (see next slide)
- **Size of IP beam pipe is 20 mm radius for tt**
  - 15 mm is barely OK. There is no margin and we have not put in any orbit distortions
  - Anything less than 15 mm and the final focus quadrupole radiation starts to hit vertically
    - **Critical energies are much higher (>1 MeV)**

Lumi detection angles



What to do next

- **Do a forward scatter simulation** ✓
- **Look at Z machine parameters** ✓
- **Check what a higher field soft bend does**
  - Try this at the Z

  Looks like it should be fine
- **Look at Higgs machine parameters**

Summary

- **Very preliminary IR design for tt machine**
  - Checked backgrounds from backscattered and forward scattered photons
    - Multiply numbers shown by 2 to include both beams
  - Other backgrounds (BGB, Coulomb, Lumi, etc.) need study
    - What collimation is needed
    - What more shielding is needed
  - Need to get some look at Higg's (and more on Z) running issues with this design
    - Vast changes in soft bend critical energy
    - Need to look at quadrupole radiation

Optimize IP for separate runs?

Summary (2)

- **Initial look at Z machine**
  - Photon critical energies from soft bend very low
    - Easy to shield IP beam pipe with 25 um Au
  - Perhaps IP beam pipe can be smaller?
    - Need to check consequences of reducing diameter
  - Shielding around IP not needed for SR
    - But may still need something for beam particle bkgs
    - May be easier to use a precision lumi detector at the Z

Conclusion

- **A start --- A baseline for discussion**
- **As always, much more to do…**
- **Thanks!**