Preliminary Look at a FCC-ee IR Layout

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for the FCC-ee optics meeting

Mar. 11, 2016

Outline

- Introduction
- Machine parameters
- Initial IR layout
- Initial SR study
- 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**

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

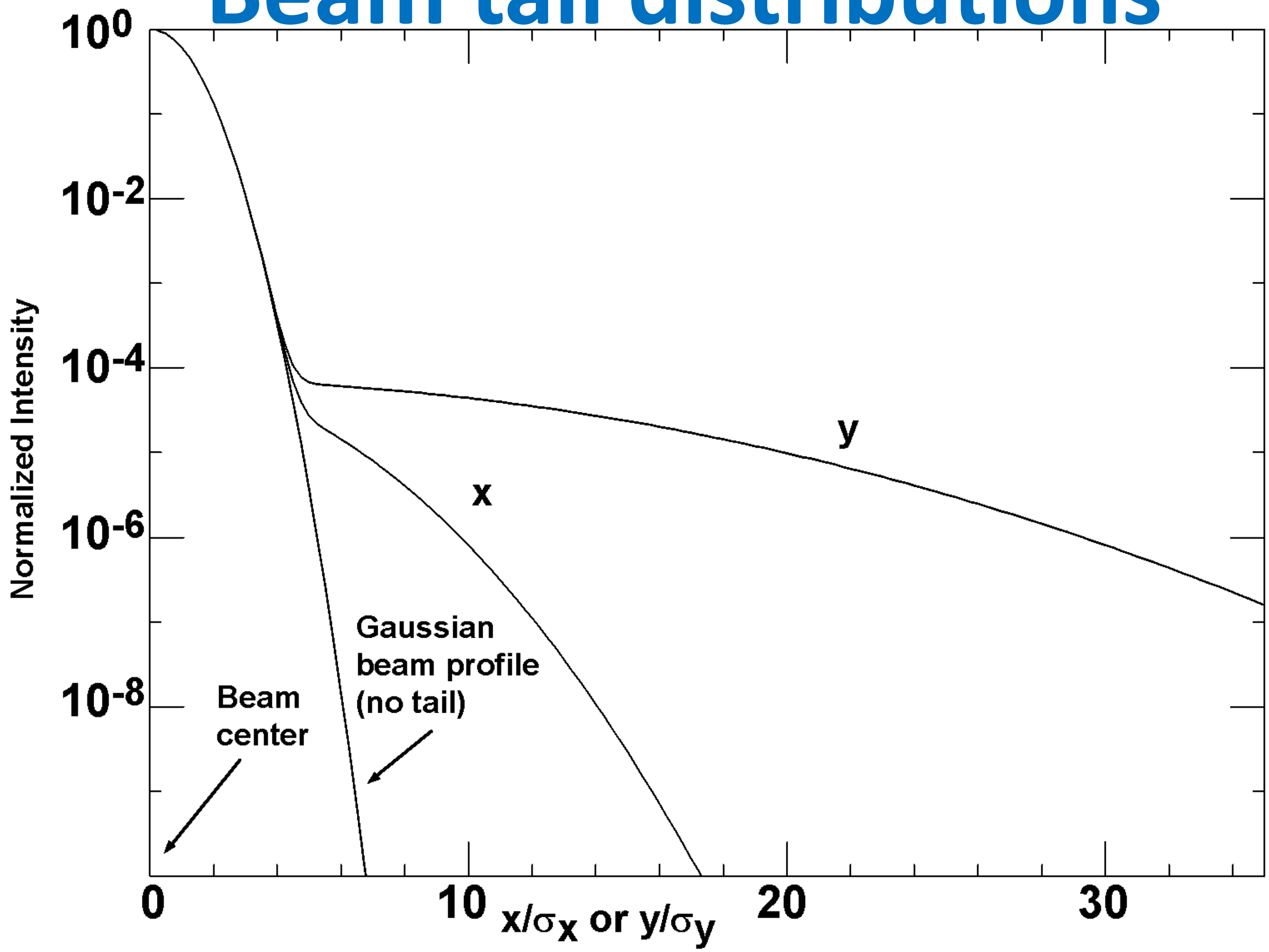
Magnet	L (m)	Z face (m)	G (T/m)
Q1C1	1.6	2.2	97
Q1C2	1.6	3.8	97
Q2C1	1.25	5.7	61.5
Q2C2	1.25	6.95	61.5

- Beam pipe aperture 24 mm dia.
- SR masks 20 mm dia.

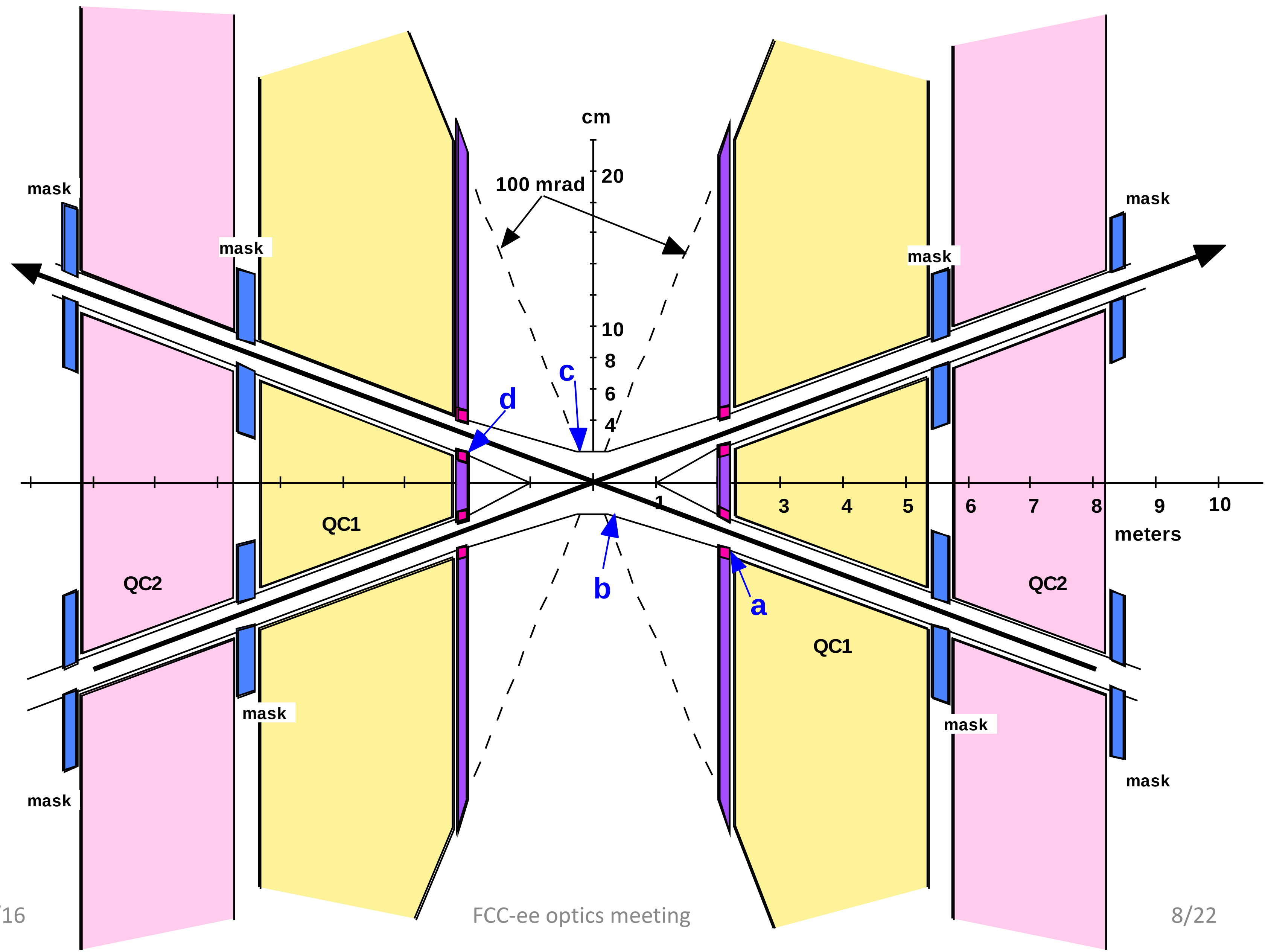
Final Focus SR study

- **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 ε_{tot} x β_y x 10 (>20 mm)
- **Beam tail distribution (halo)**
- **Ray tracing out to (half aperture):**
  - 15 σ_x
  - 50 σ_y

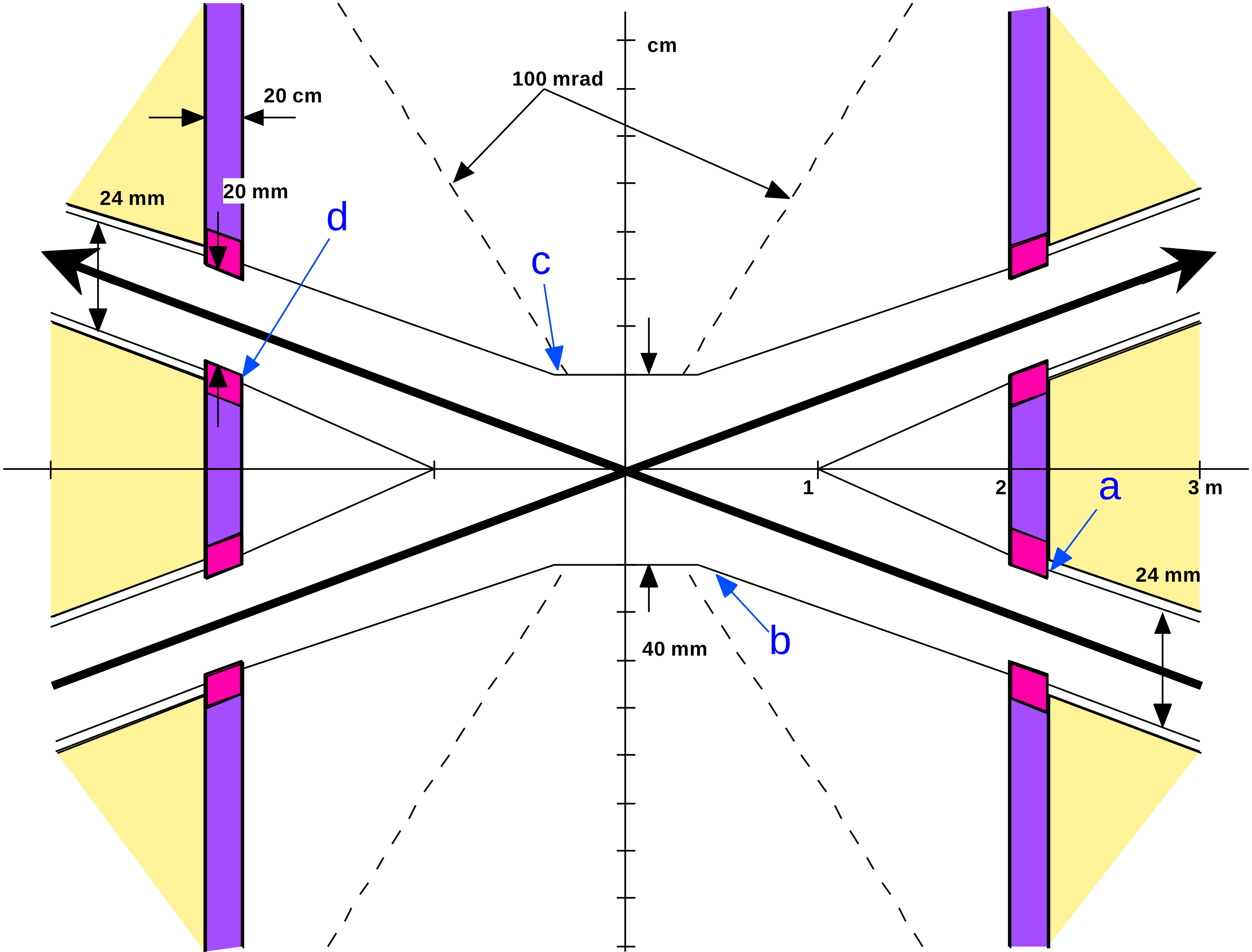
Beam tail distributions



IR Layout


cm
20
100 mrad
10
8
6
4
c
d
b
a
mask
mask
mask
mask
mask
mask
mask
mask
QC1
QC2
QC1
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				
	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

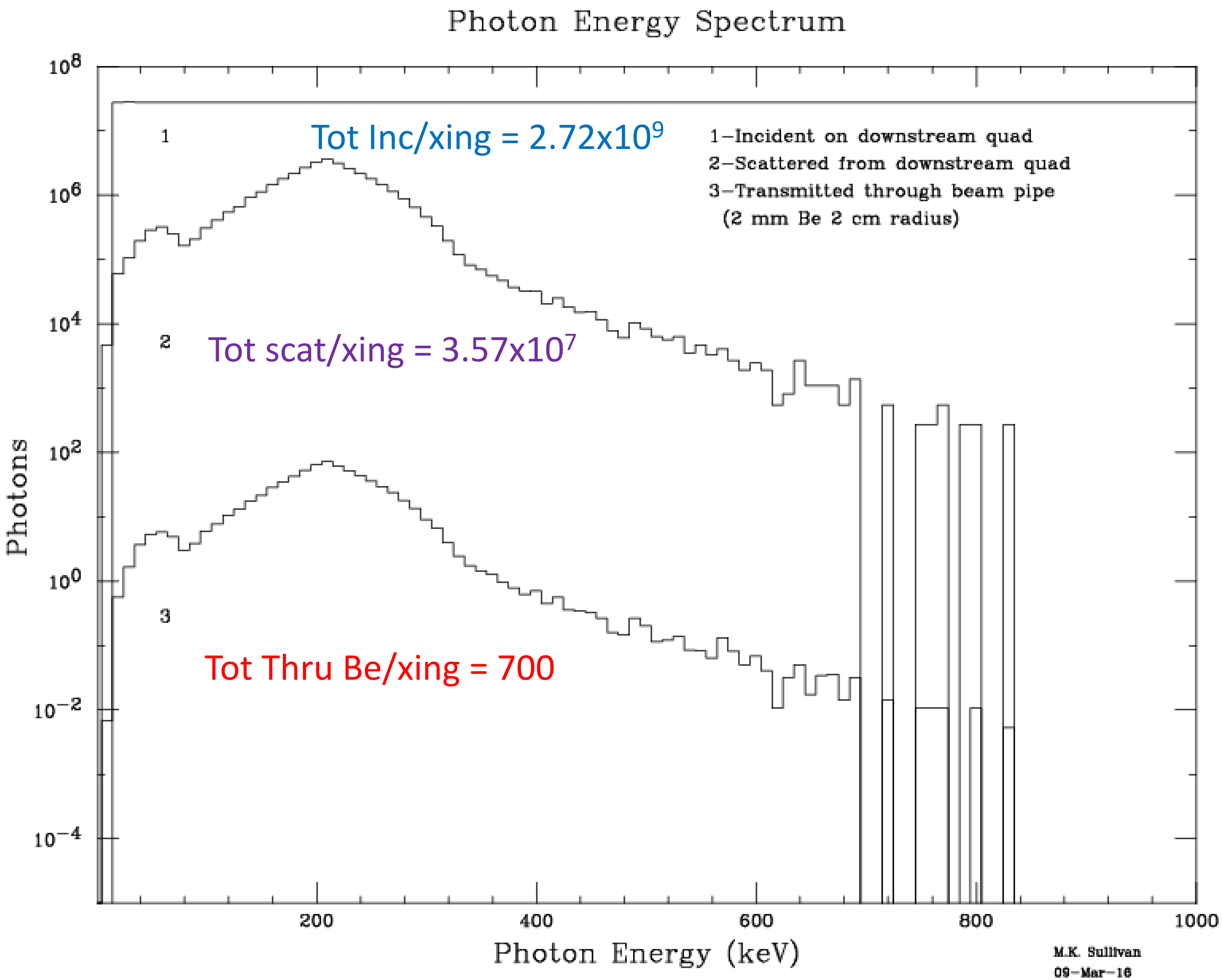
- Notes:
  - All γs are from beam particles that are 40-50σ in the vertical
    - Very high energy γs. These numbers are MeV photons.
  - Hits at points b and c are with a 10 mm radius beam pipe
  - No hits at b and c if the beam pipe radius goes to 15 mm
  - Drawing shows a 20 mm radius beam pipe

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 for 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

- **There are enough hits on the downstream quad face to cause a significant backscatter rate to the IP beam pipe**
  - About 1.3% backscatter
  - The SA fraction of the IP beam pipe from the quad face is about 1.76×10^{-5}
  - The result is about 700 photons/crossing go through a 2 mm Be beam pipe with an average energy of 200 keV for each beam



Photon Energy Spectrum
Tot Inc/xing = 2.72x10^9
1–Incident on downstream quad
2–Scattered from downstream quad
3–Transmitted through beam pipe
(2 mm Be 2 cm radius)
Tot scat/xing = 3.57x10^7
Tot Thru Be/xing = 700
Photons
Photon Energy (keV)
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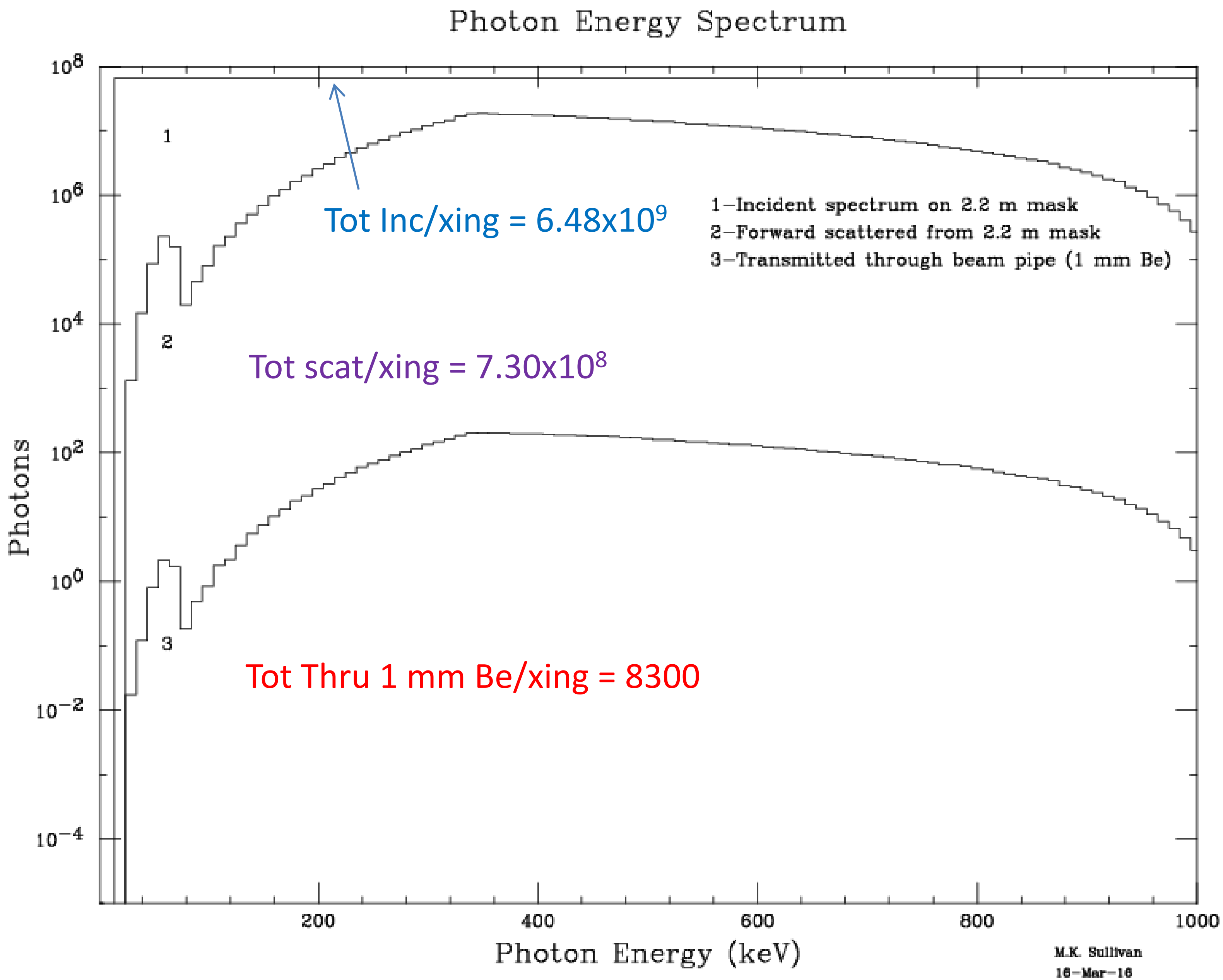
09–Mar–16

Upstream Mask of FF quad at 2.2 m

- **There are also enough hits on the upstream quad face to cause a significant backscatter rate to the IP beam pipe**
  - About 13% forwardscatter
  - The SA fraction of the IP beam pipe from the quad face is about 1.34×10^{-5}
  - The result is about 8300 photons/crossing go through a 1 mm Be beam pipe with an average energy of 500 keV for each beam



Photon Energy Spectrum
Photons
Photon Energy (keV)
1
2
3
1–Incident spectrum on 2.2 m mask
2–Forward scattered from 2.2 m mask
3–Transmitted through beam pipe (1 mm Be)
Tot Inc/xing = 6.48x10^9
Tot scat/xing = 7.30x10^8
Tot Thru 1 mm Be/xing = 8300
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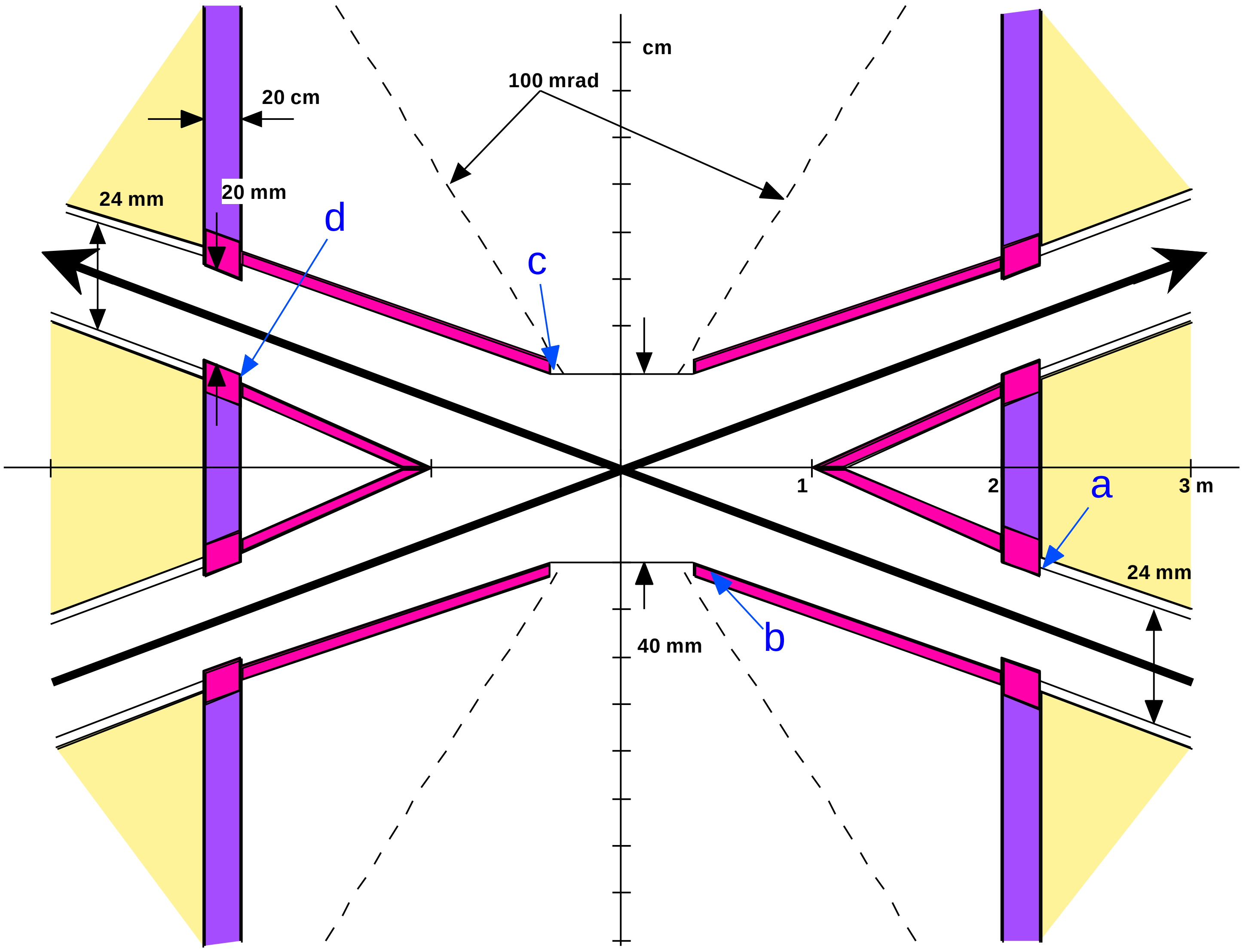
Shielding around the IR beam pipes

- Based on the backscatter rate from the downstream quad faces, without shielding there is a high rate of photons into the central detectors near the IP beam pipe
- For a backscattered 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

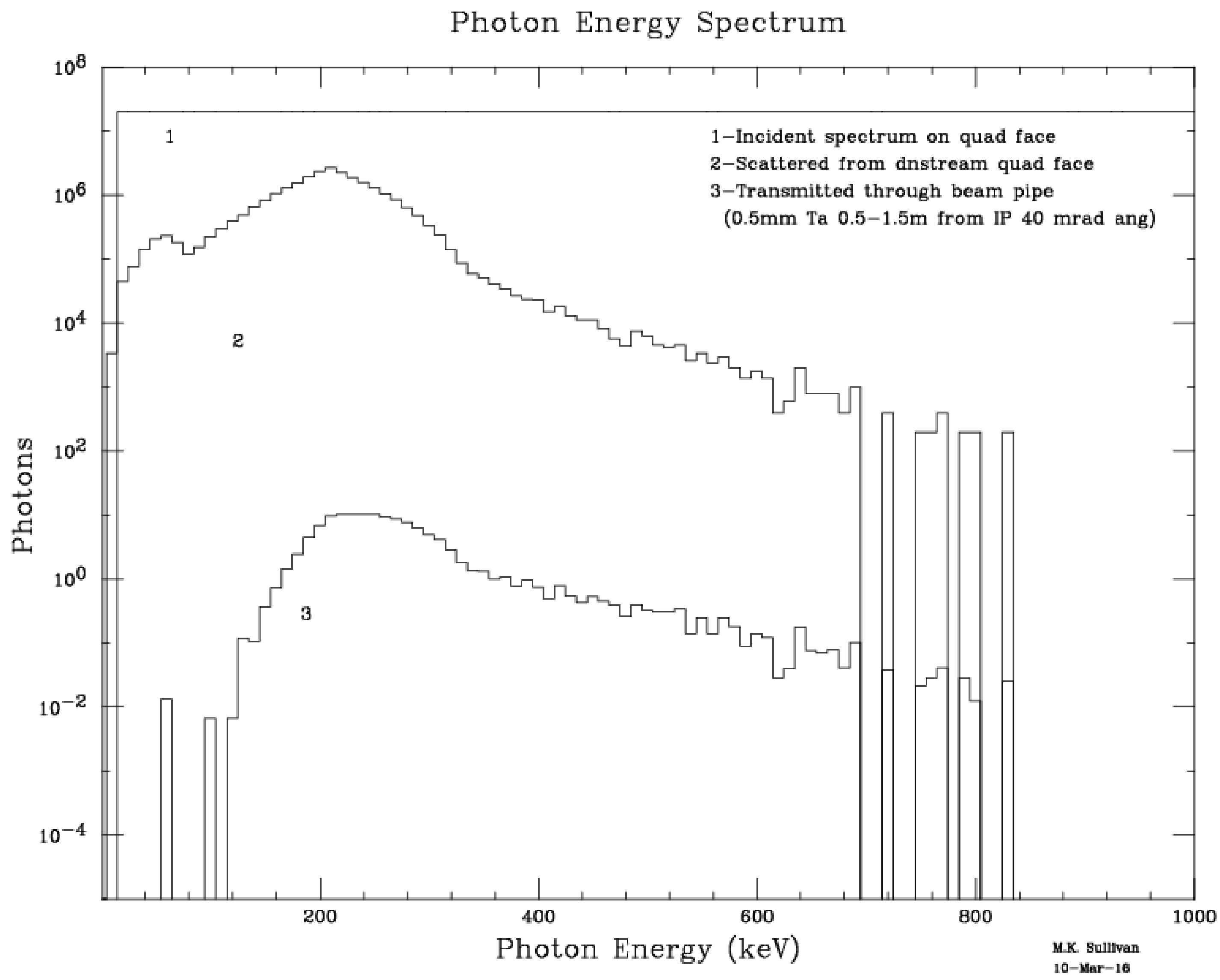
Beam pipe shield



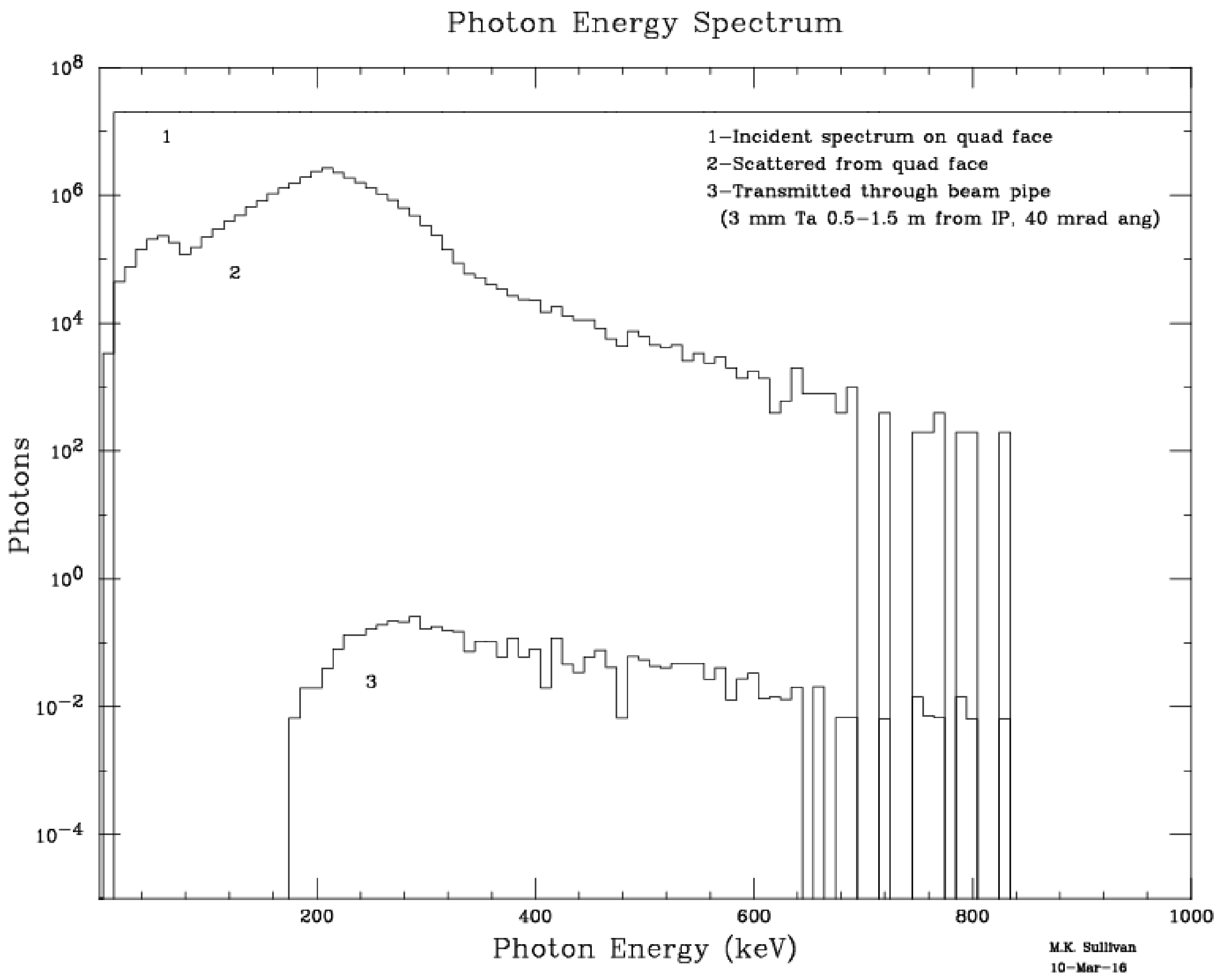
Backscattered rates through Ta shield

- We study the beam pipe shield using Ta from 0.5 m to 1.5 m from the IP (within 0.5 m of the source)
- Ta thickness Rate thru Ta shield/xing
- 3 mm 3.8
- 2 mm 11.7
- 1 mm 47.9
- 0.5 mm 127.9

Energy spectrum for 0.5 mm Ta shield



Energy spectrum for 3mm Ta shield



Questions/Issues

- **What is a good BSC?**
  - In X? Probably at least 15σ
  - In Y? PEP-II B-factory had ~35σ with 5% coupling
  - FCCee tt has 0.1% coupling so 50σ starts to sound small
  - Small vertical aperture means harder to beta squeeze (it will determine the lowest βy^*)

More Issues

- **What is the beam particle density at high σ_x and σ_y?**
  - Need to find out what dynamic aperture studies show
  - Where do instabilities start to come in
  - Where do we need to collimate
- **Why are bending magnets so close to IP?**
  - Tunnel size issue?
  - PEP-II HER bends were 80m away for 9 GeV beam
  - LEP soft bends were ~200m upstream

Still more issues

- **FF magnet bores too small?**
  - Same magnets for all running conditions? (presumably)
- **Question about soft bend field**
  - For tt the soft bend is 49 Gauss
  - For Z the soft bend is 12 Gauss. Is this OK?
- **Same IR for all cases?**
  - What about Higgs running?
    - Beam currents are higher
    - Luminosity is higher
  - What about Z running?
    - Currents are even higher

Critical energy goes down, but currents go up. Need to see how this IR design works and what the SR rates into the detector are.

Present working assumptions

- **Assume present BSCs are OK**
- **Tail particle density at high sigma (lifetime)**
- **Detector needs for precision lumi monitor**
  - Primarily Z running
- **Size of IP beam pipe is 20 mm radius**
  - 15 mm is just OK. There is no margin and no orbit distortions

What to do next

- **Do a forward scatter simulation** ✓
- **Check what a higher field soft bend does**
  - Try this at the Z
- **Look at Z machine parameters**
- **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 about 4 to include forward scatter sources and two beams
  - Other backgrounds (BGB, Coulomb, Lumi, etc.)
    - What collimation is needed
    - What more shielding is needed
  - Get some understanding of Higg's and Z running issues with this design
    - High beam currents may generate new issues

Conclusion

- **A small start**
- **As always, much more to do…**
- **Thanks!**