Synchrotron Radiation simulations in the IR

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- The geometry for the +/- 640 m around the IP for the latest T-pole lattice (as per K. Oide's file on AFS) has been created;
- One beam only has been modelled (assuming the other one is symmetric): it includes 9 dipoles and 9 quadrupoles;
- Two version of the geometry have been created: one with a symmetric opening of the IP quadrupole focusing doublets (20 mm ID) and one with an "exit" doublet chamber twice as big in radius (40 mm ID), following the prescription to let the trapped HOM in the IP "escape" and dissipate their power elsewhere (see previous meetings, this series);
- A third variant of the geometry has included a "winged" geometry, i.e. a chamber cross-section "à-la-SUPERKEKB" which allow the positioning of short localized absorber (to reduce the photon scattering and improve the shielding of high-energy photons, see end of my presentation at FCC Week in Rome);
- → Neither the photon absorbers nor the bellows/contact fingers have been included yet, ←
- → This work does NOT aim to take the place of the analysis already done via GEANT4 and/or other calculations (H. Burkhardt et al., M. Sullivan et al.) but simply wants to show the potential of a different code, SYNRAD+, as far as the calculation of photon flux and power on sensitive equipment is concerned (like the Be pipe at the IP);
- The main purpose of this analysis is to prepare a geometry for simulating the pressure profiles (aiming at presenting this as a poster at FCC Week in Berlin, if accepted).

From Meeting #8, 12 Dec 2016

SYNRAD+: SR flux along one ~640 m-long arm of the interaction region of FCC-ee (175 GeV T-pole machine; 6.632 mA)

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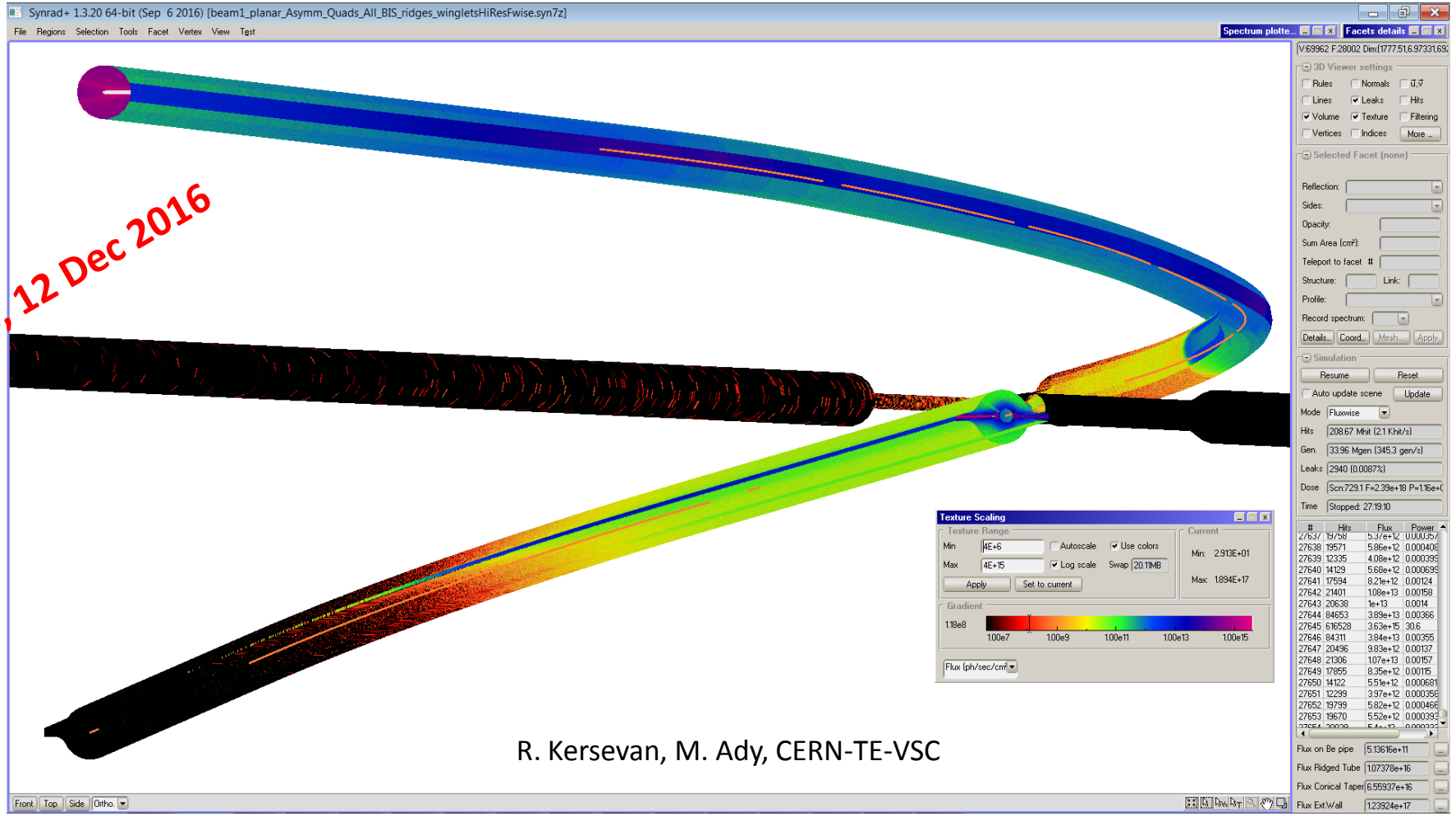

One arm of the IP chambers: ~ -347 m to ~ +337 m;

Round pipe (70 mm ID) everywhere except along the incoming beam, which has winglets;

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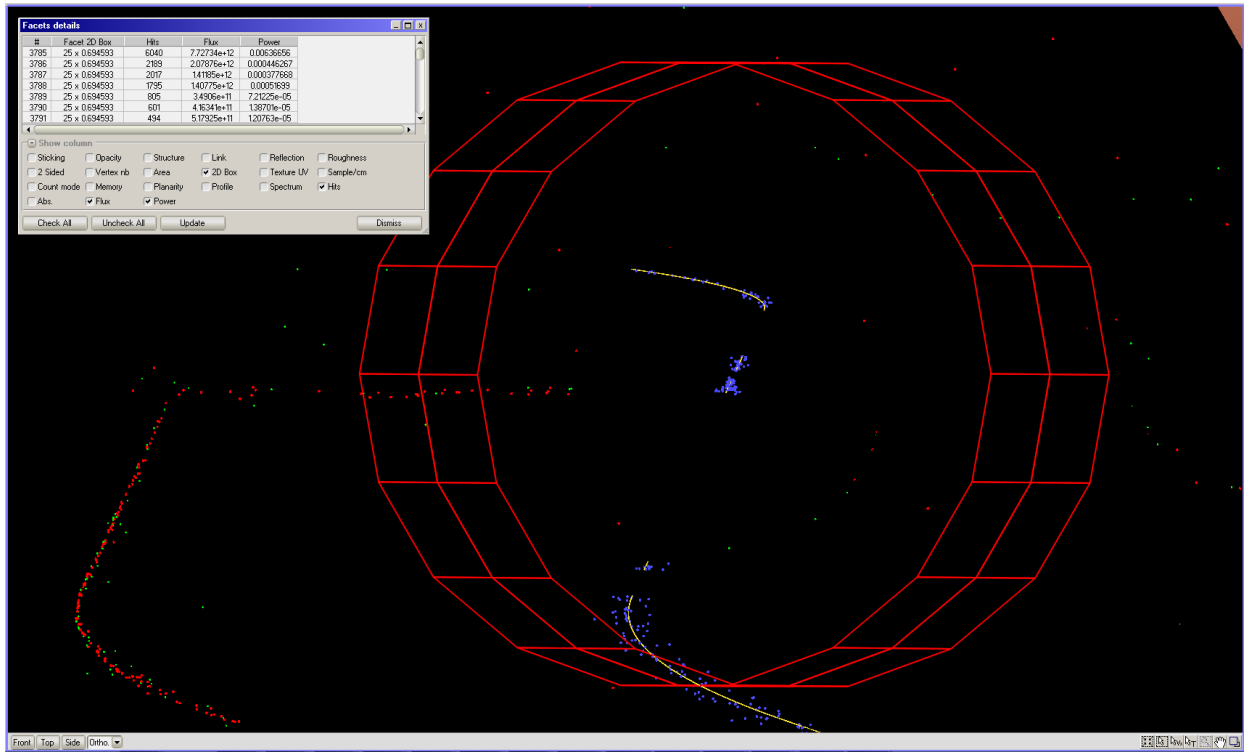

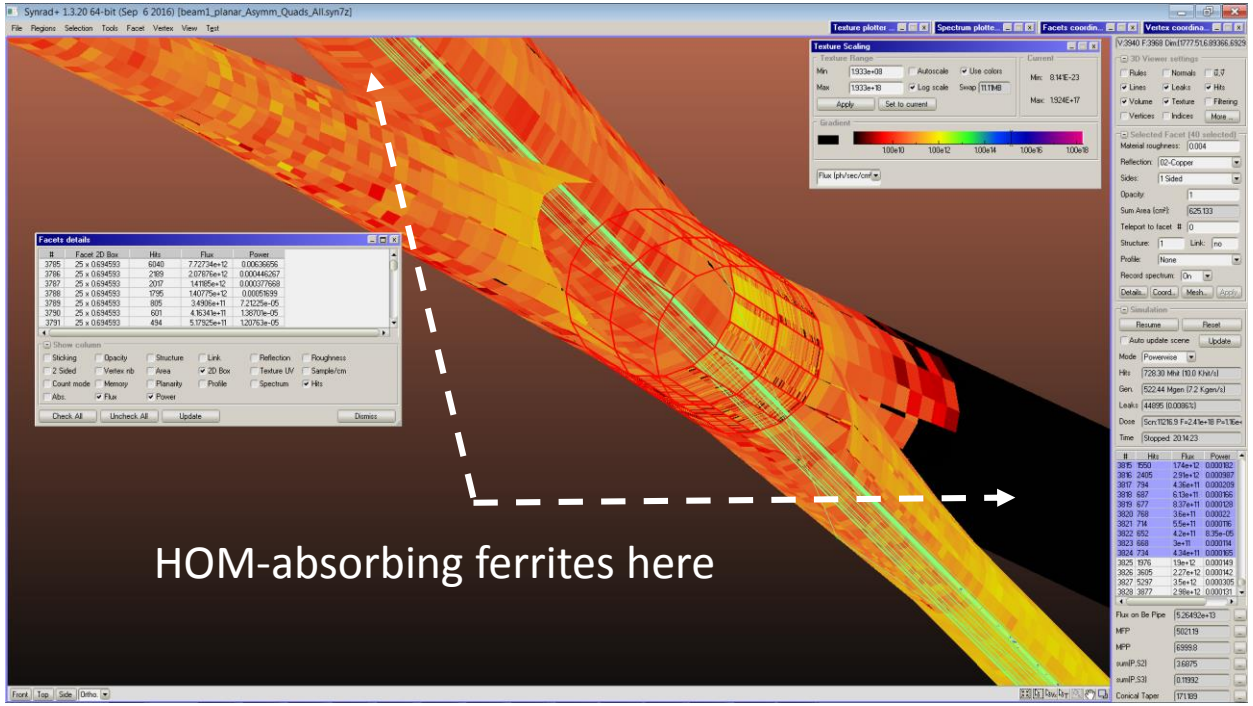

View of the source points (blue) and centroid trajectory (yellow); Red and Green points are locations of absorbed/reflected photons;
Red lines represent the 50 cm-long Be pipe

Zoom into the IP region: 50 cm-long Be pipe and local photon flux density distribution;
A total of 5.26E+13 photons hit the Be pipe;

From Meeting #8, 12 Dec 2016

Photon flux spectrum on the two highest-flux facets of the Be pipe

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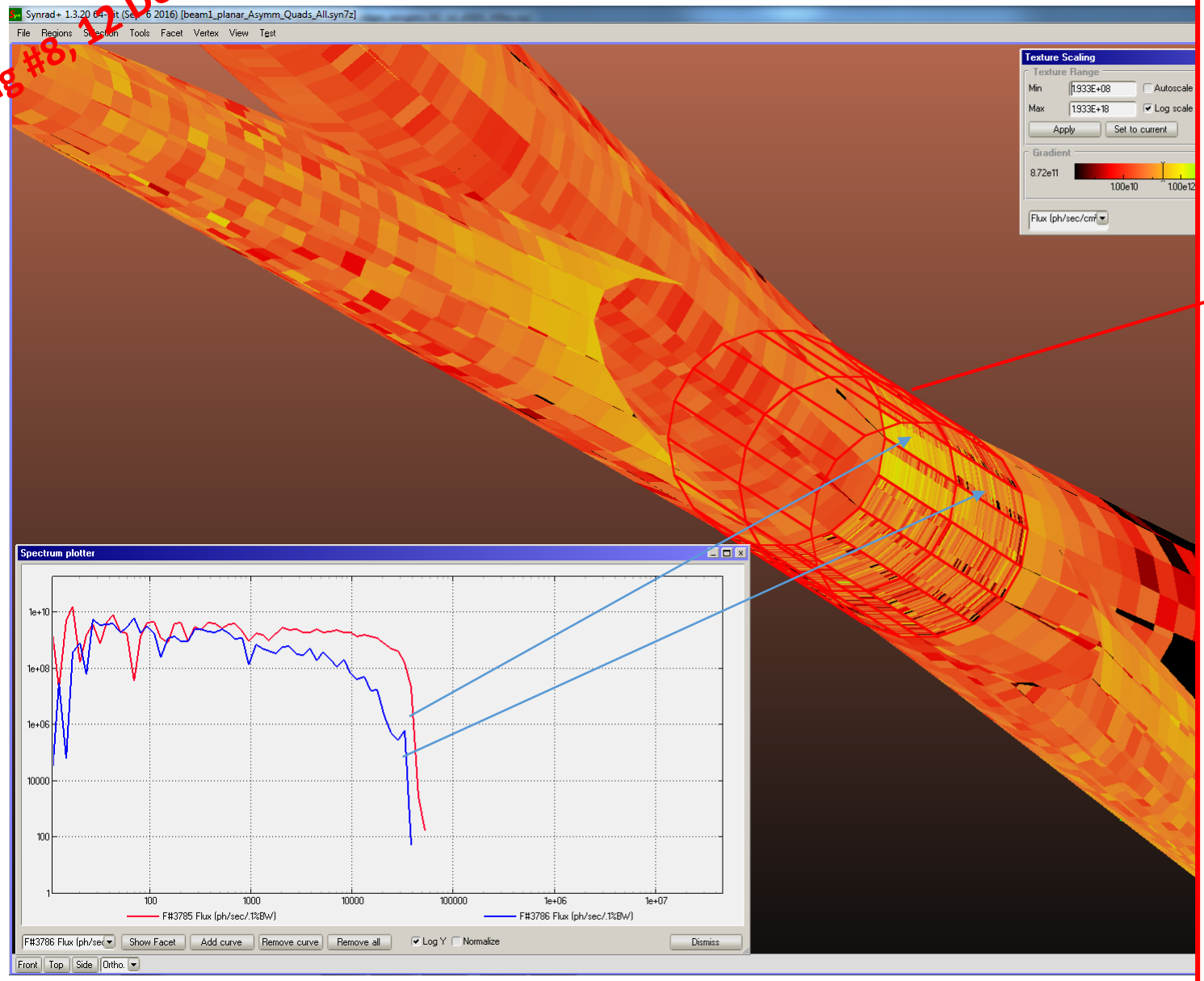
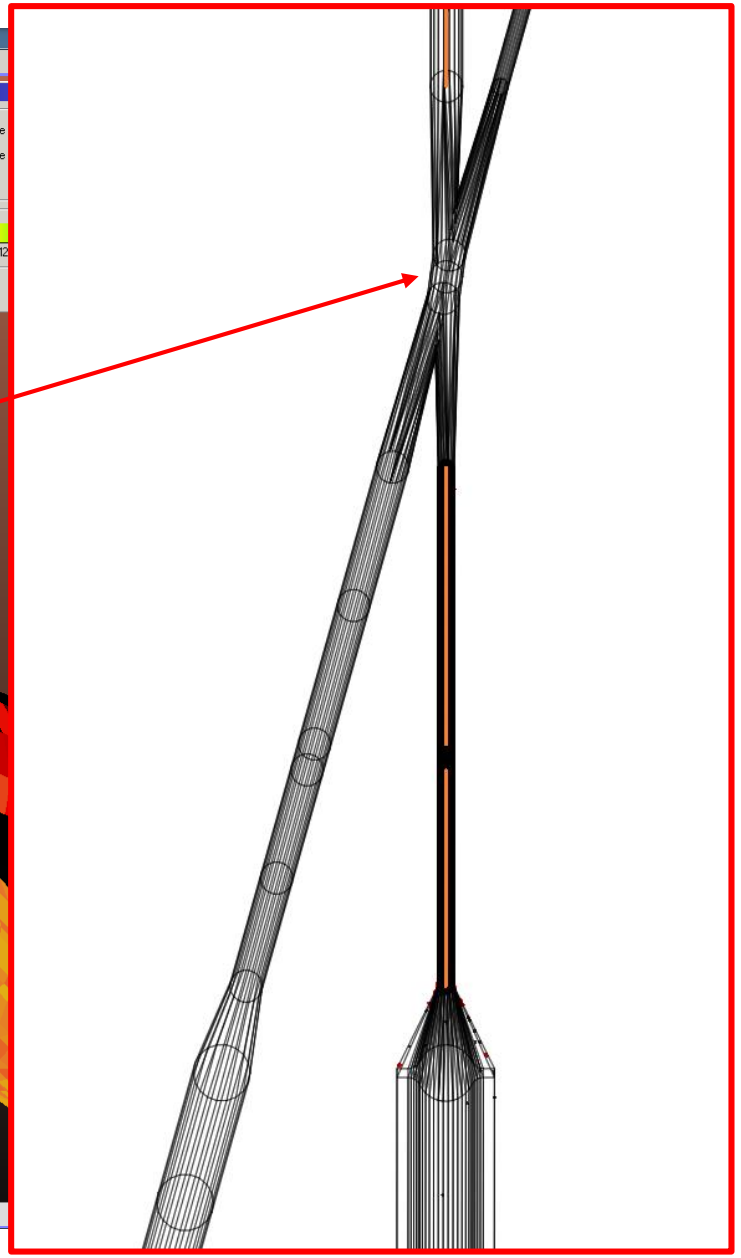
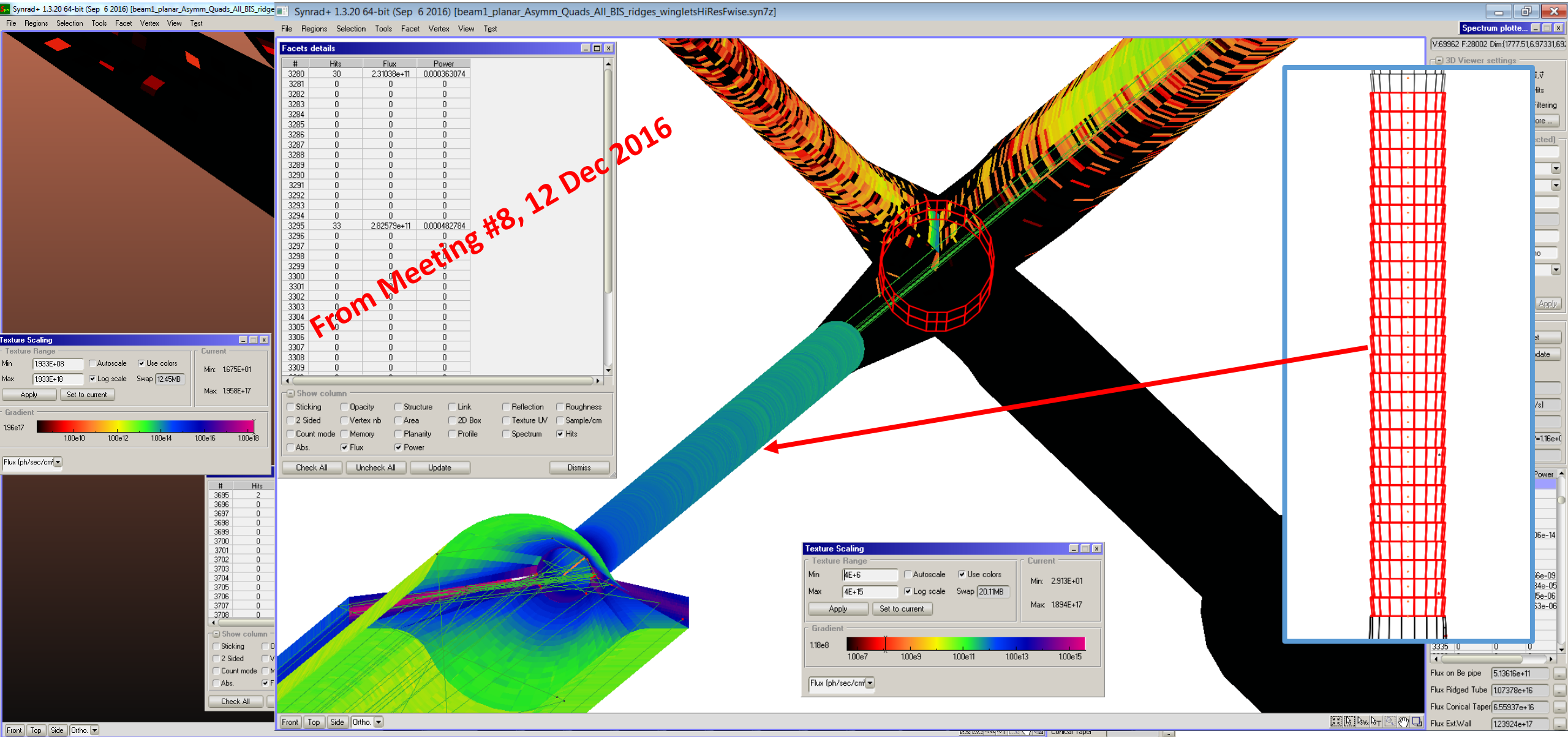
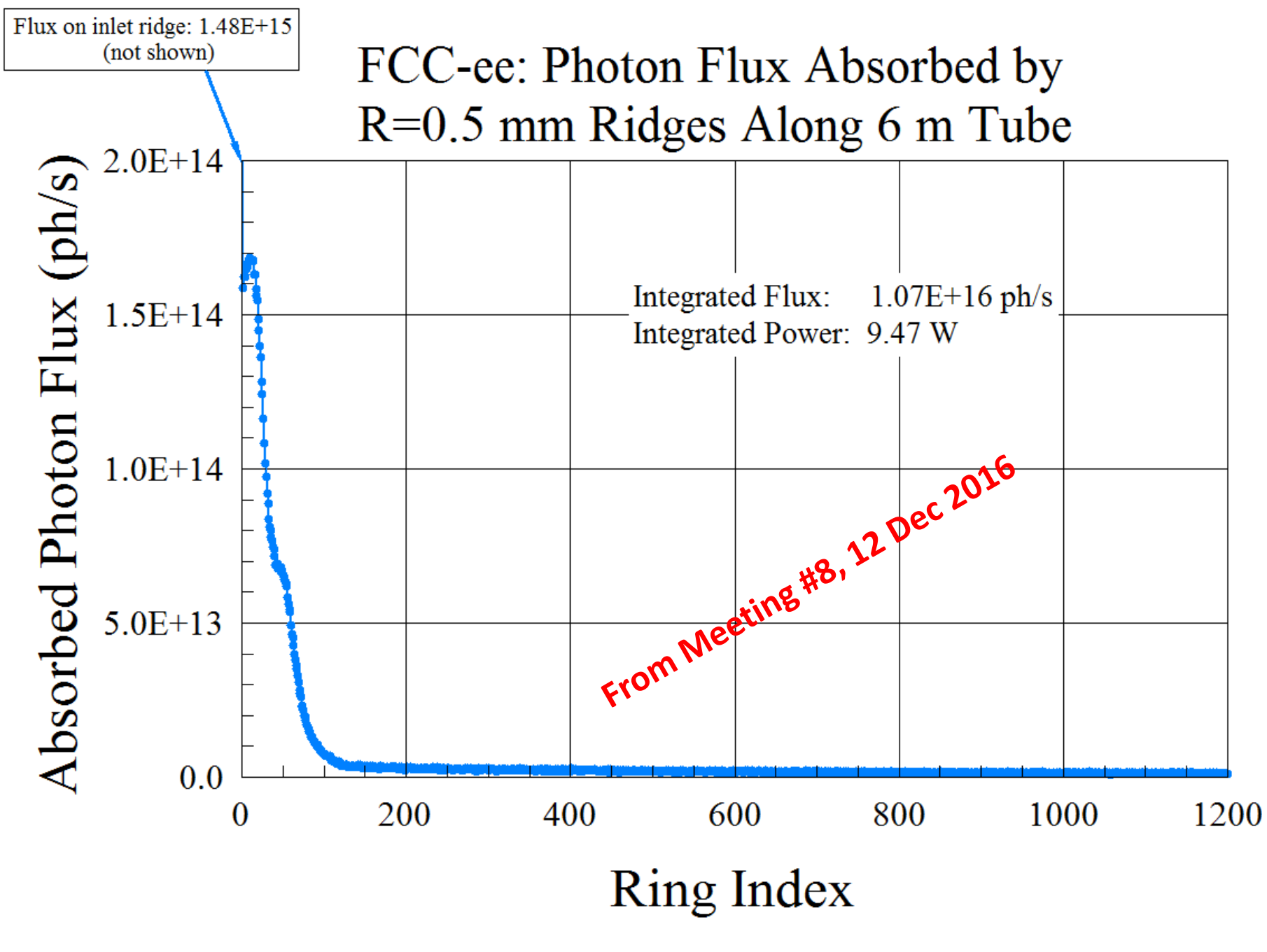




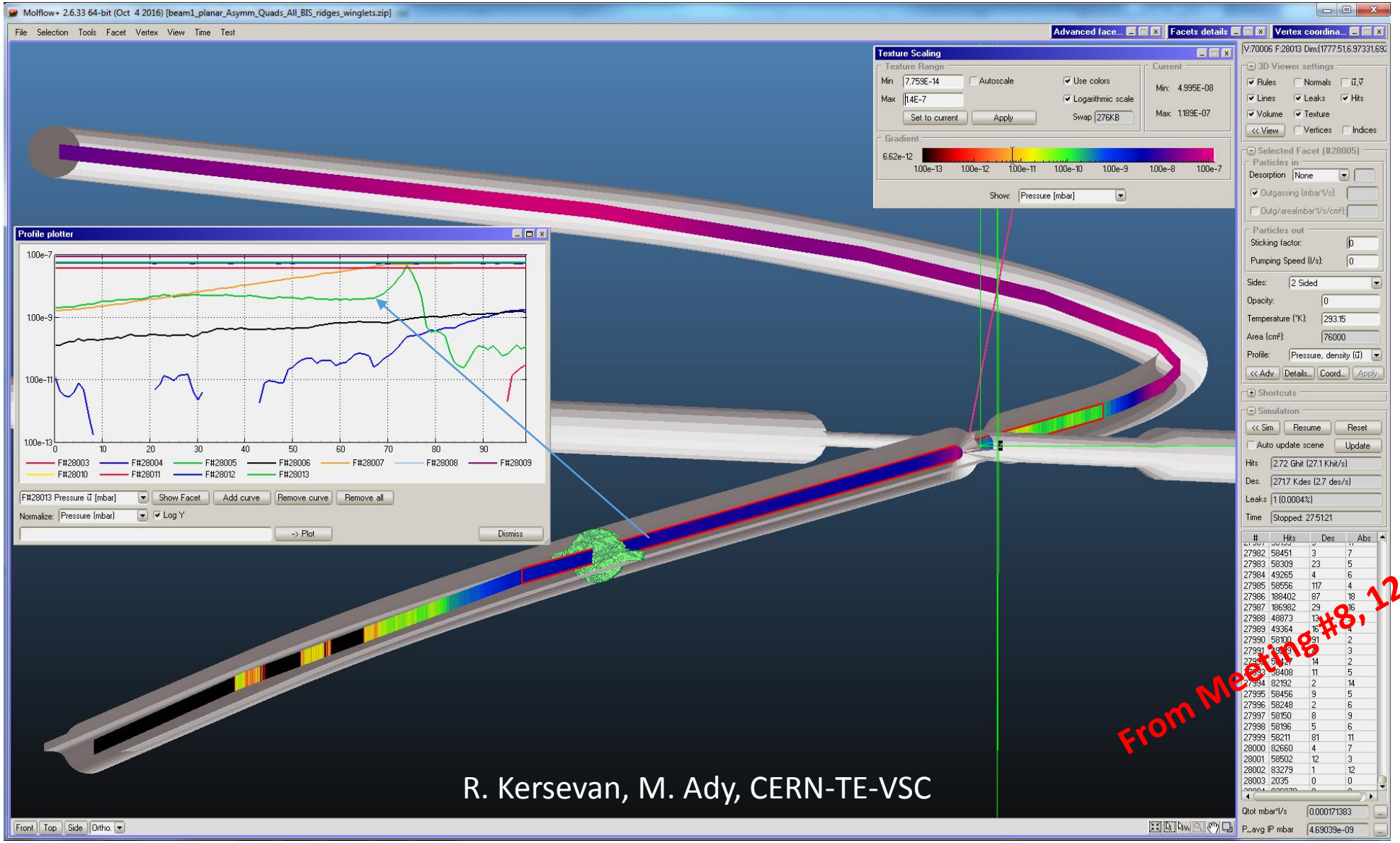
Effect of adding a “ridged” (sawtooth) profile to the 20 mm ID doublet quad pipe: reduces the flux onto Be pipe to virtually zero; (ridge/sawtooth: 0.5 radial, 5 mm step)



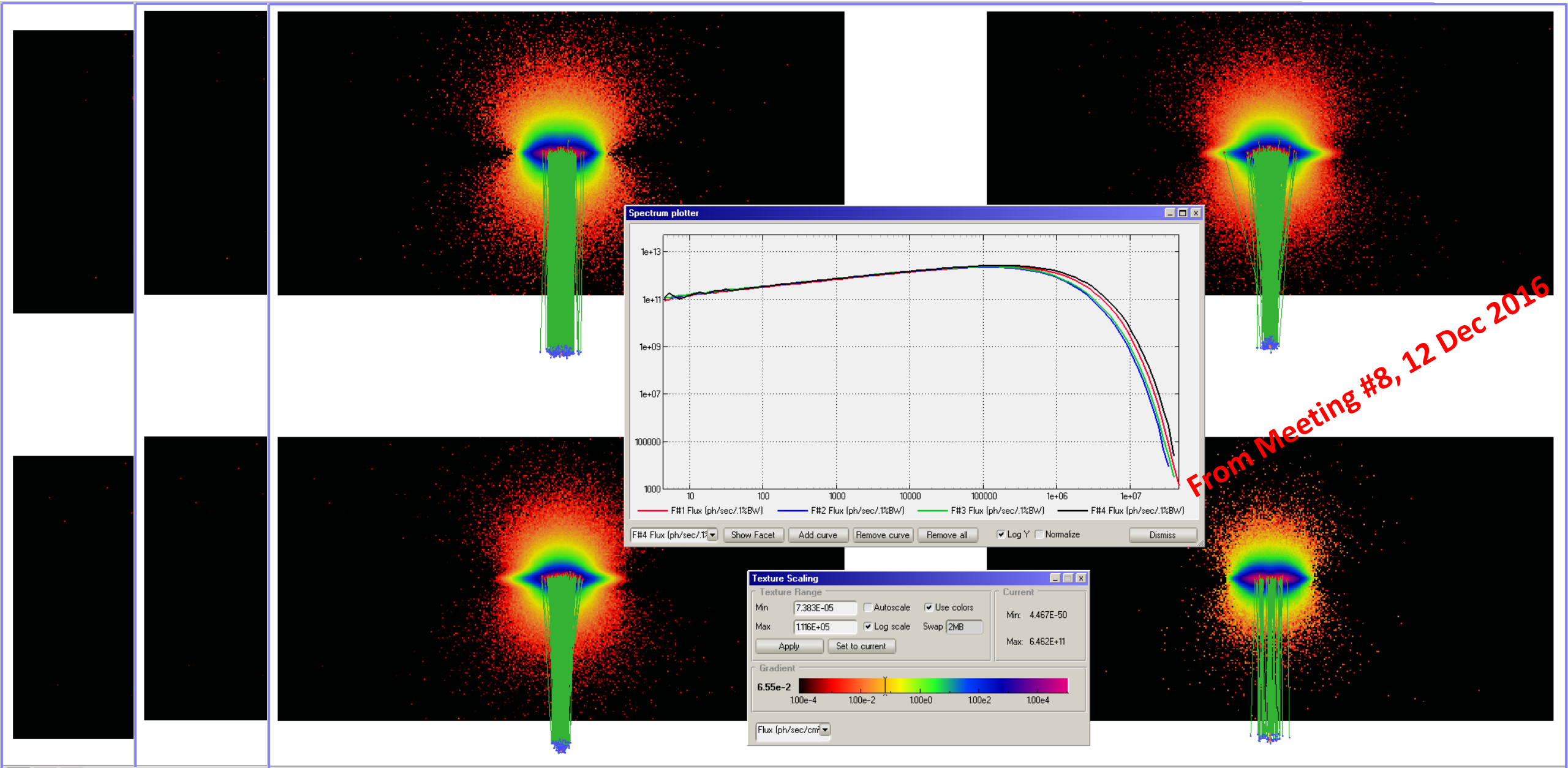
Slide added after the meeting



Molflow+: Pressure profile along one ~640 m-long arm of the interaction region of FCC-ee (175 GeV T-pole machine; 6.632 mA)



Synrad+: angular distribution of the SR generated along the 4 SC doublet magnets, viewed on a flat perpendicular screen placed at 63 m distance;



(very) preliminary conclusions:

From Meeting #8, 12 Dec 2016

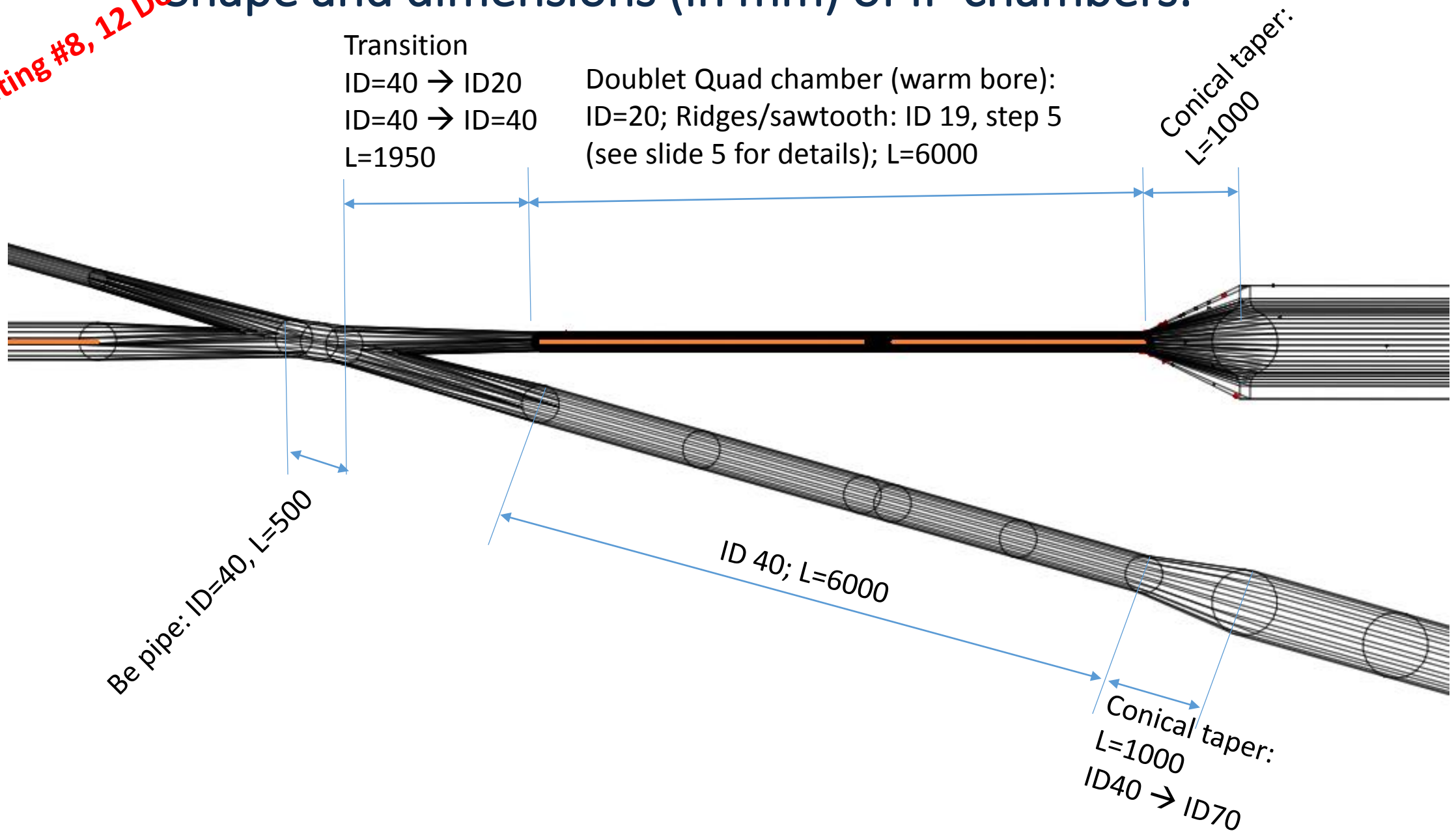
- The ray-tracing montecarlo code SYNRAD+ has been applied to the FCC-ee IP region;
- A model of approximately 645 m length around the IP has been made: for the time being it doesn't have details about many important vacuum components, which could change the way low-energy photons are scattered (low-energy='those photons with energies below the Compton threshold');
- It is evident that without a proper masking of the Be pipe, the pipe will get a non-negligible photon flux with photon up to several 10s keV: is this a problem for the detector's hardware and electronics?
- It is also evident that a rather simple to implement ridged (sawtooth-ed) geometry somehow machined on the internal part of the cold bore focusing doublet helps reducing a lot (virtually to zero) the photon flux on the Be pipe; it needs to be coupled to a larger-bore 'exit' tube (which would also be beneficial for avoiding trapped modes in the Be pipe area);
- The 4 quadrupole magnets of the doublet generate a rather large and extremely hard photon flux, with photons in the range of several TENS MeV energy: they mostly land on a small spot on the exit side of the beam, about 63 m downstream: careful shielding of that area must be envisaged;
- The same model, with additional details placed into it, will be used to calculate the pressure profiles along this area (material for FCC Week in Berlin… not discussed here);

Thanks for your attention ☺

Slide added after the meeting

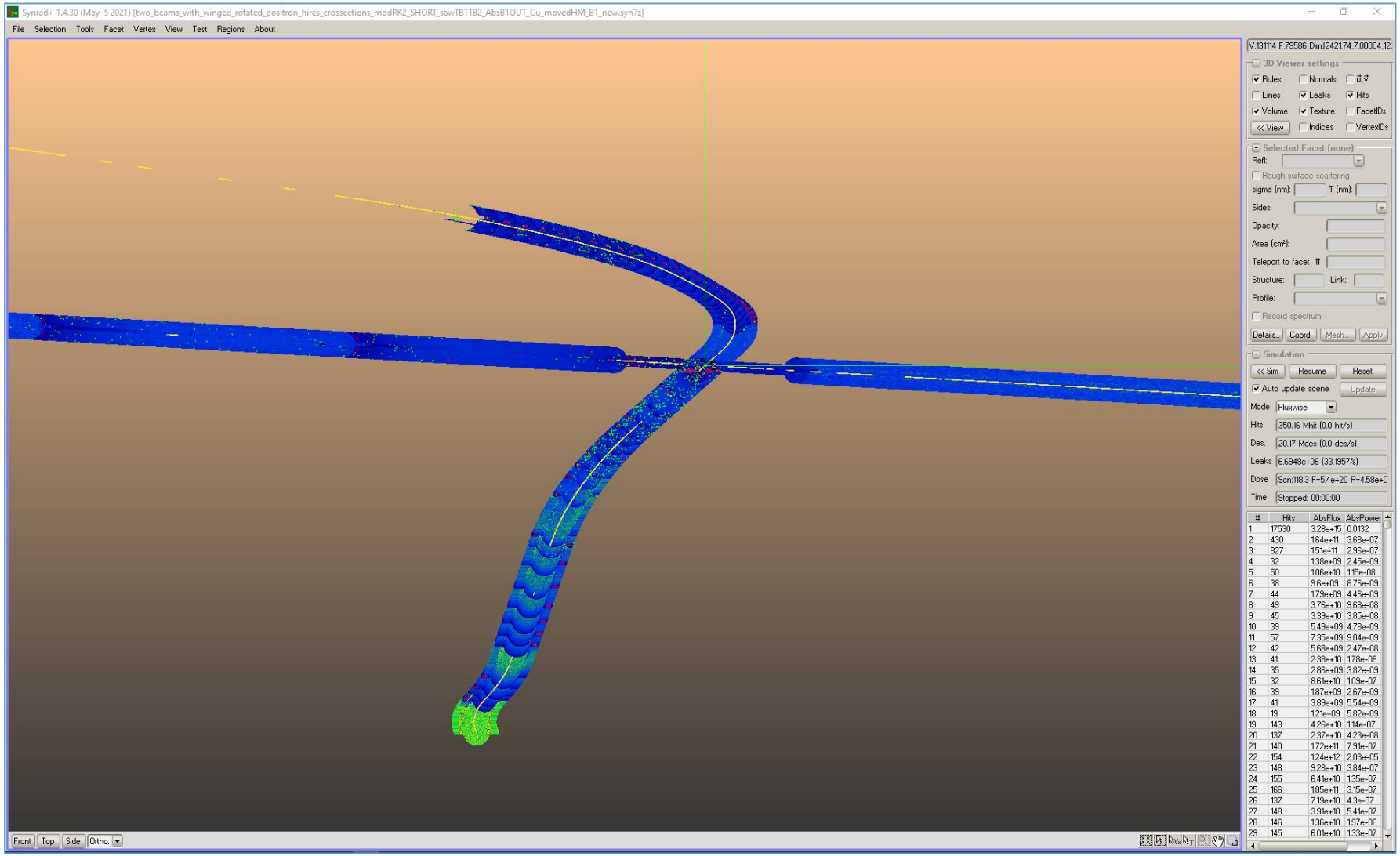
From Meeting #8, 12 Dec 2016

Shape and dimensions (in mm) of IP chambers:



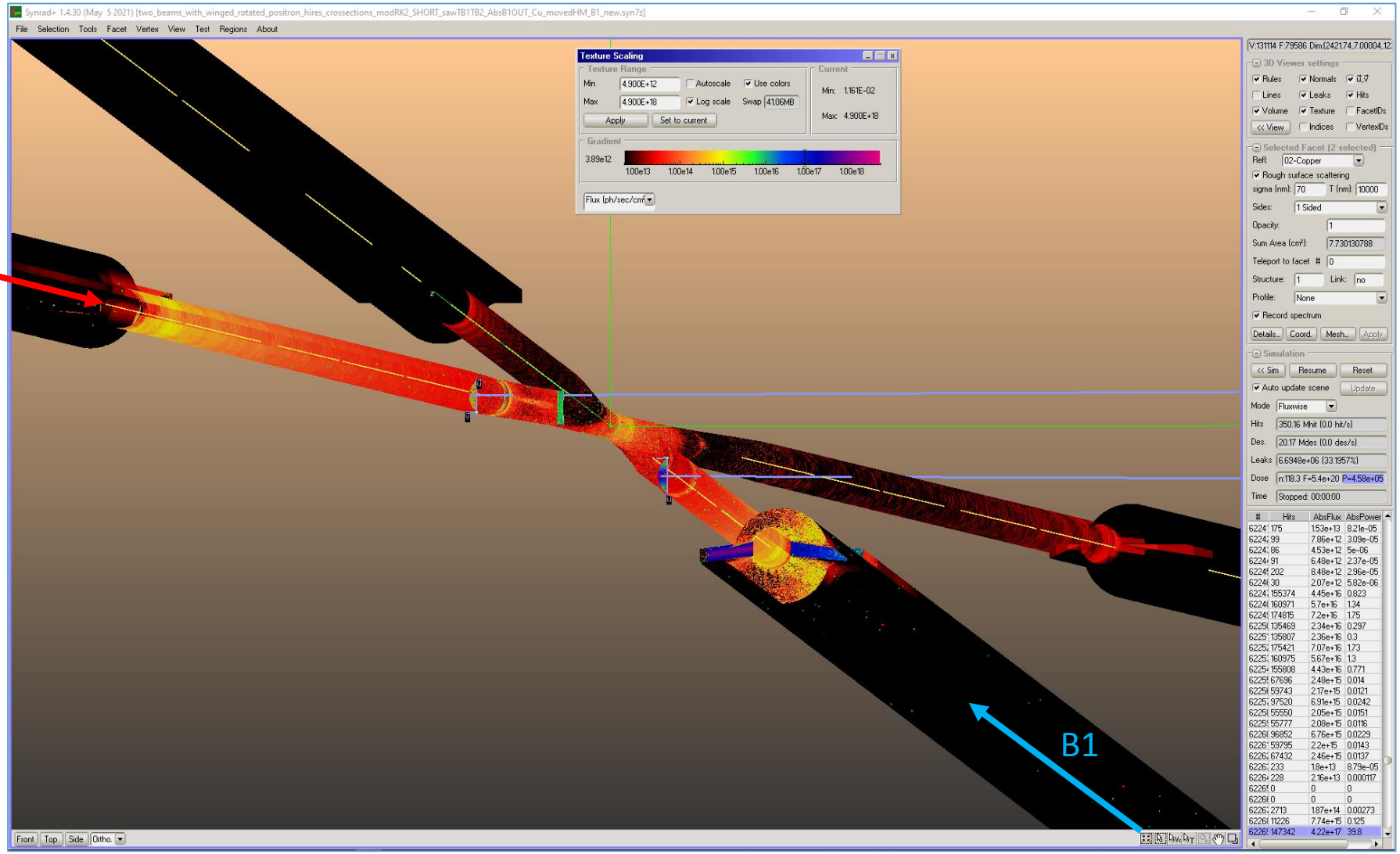
<u>Fast forward to 2021:</u> new lattices, new optics, new (smaller) Be chamber, new “X” chamber without HOM ferrite absorbers, and more changes…

45.6 GeV



-610 m to +246 m model of the MDI area, two beams, asymmetric IP absorbers (B1 moved, B2 original pos.)

New “X” chamber CAD model without HOM ferrite absorbers (INFN Frascati)
Photon scattering/reflection is angle- and energy-dependent (assumed Cu and/or NEG)



Close-up view of new IP “X” chamber geometry, with color textured surfaces covering 6 decades for the photon flux
Both beams, 45.6 GeV, 1390 mA; B1 has IP absorber moved upstream by 135 cm (inside warm bore of FF quad)

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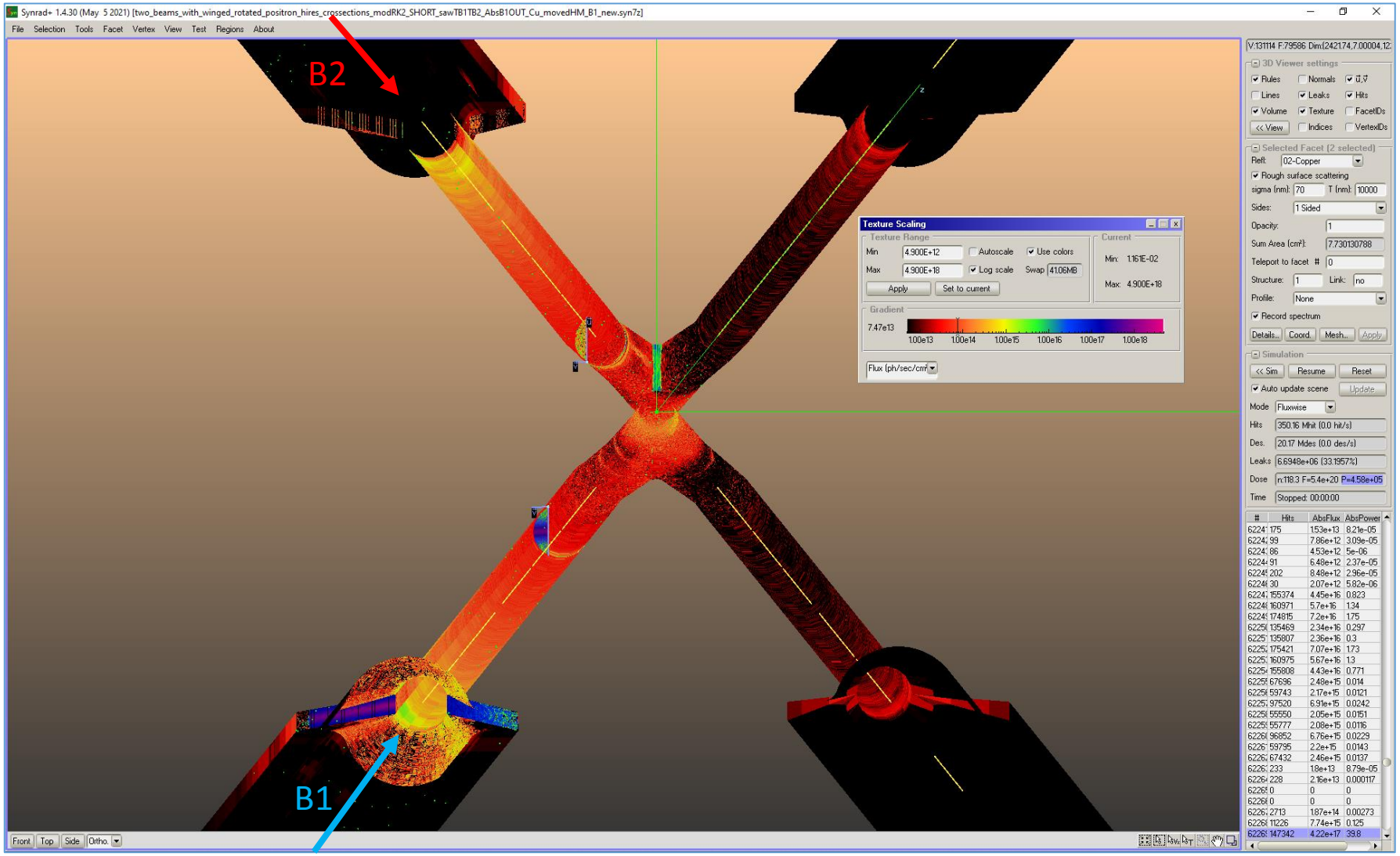

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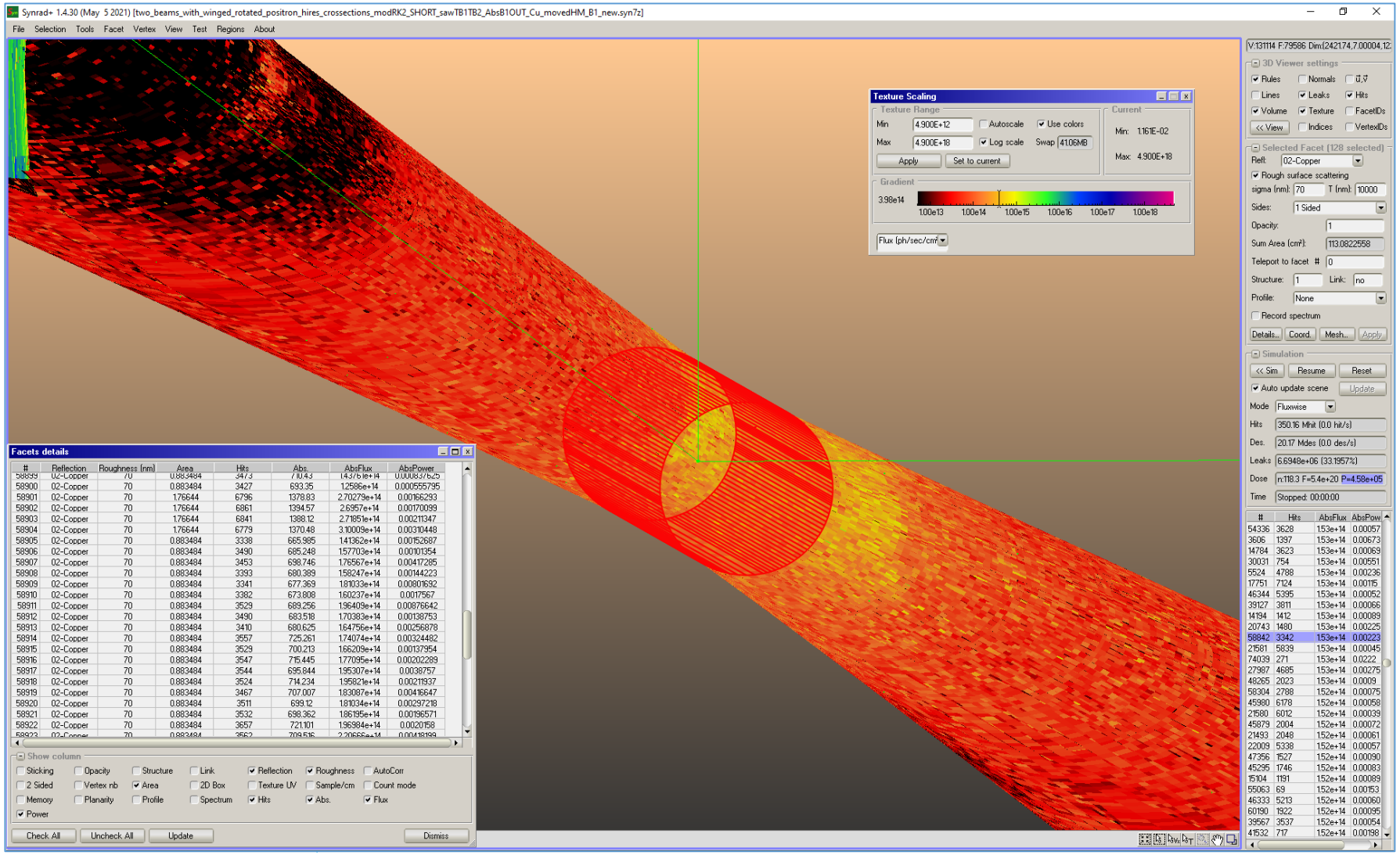

Central +/- 9 cm Be chamber in the center (facets in red). Very low photon fluxes impinging on Be pipe facets;
Total Power = 0.31 W; total Flux = $2.17 \cdot 10^{16}$ ph/s; Average photon energy is 88.7 eV

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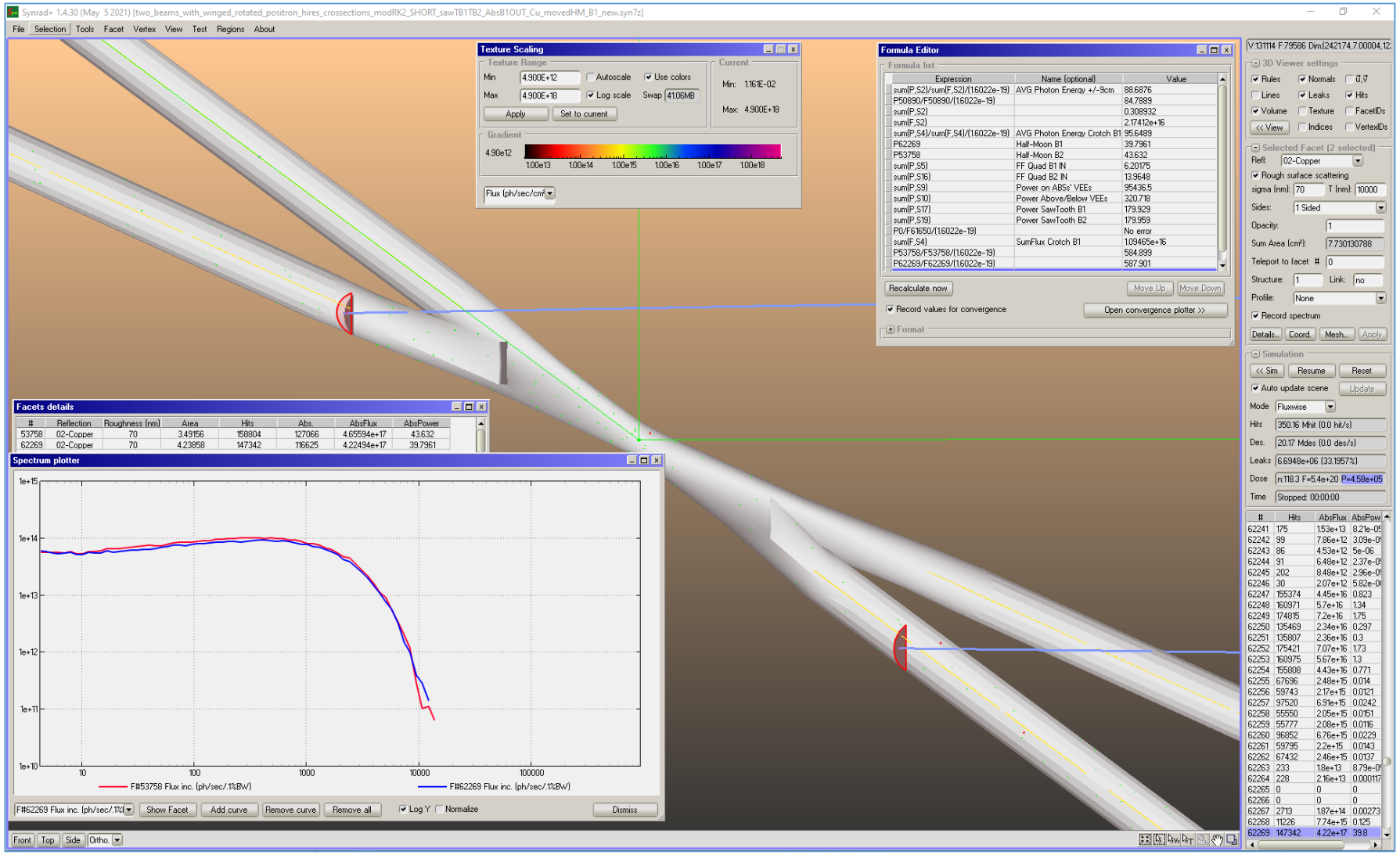
45.6 GeV

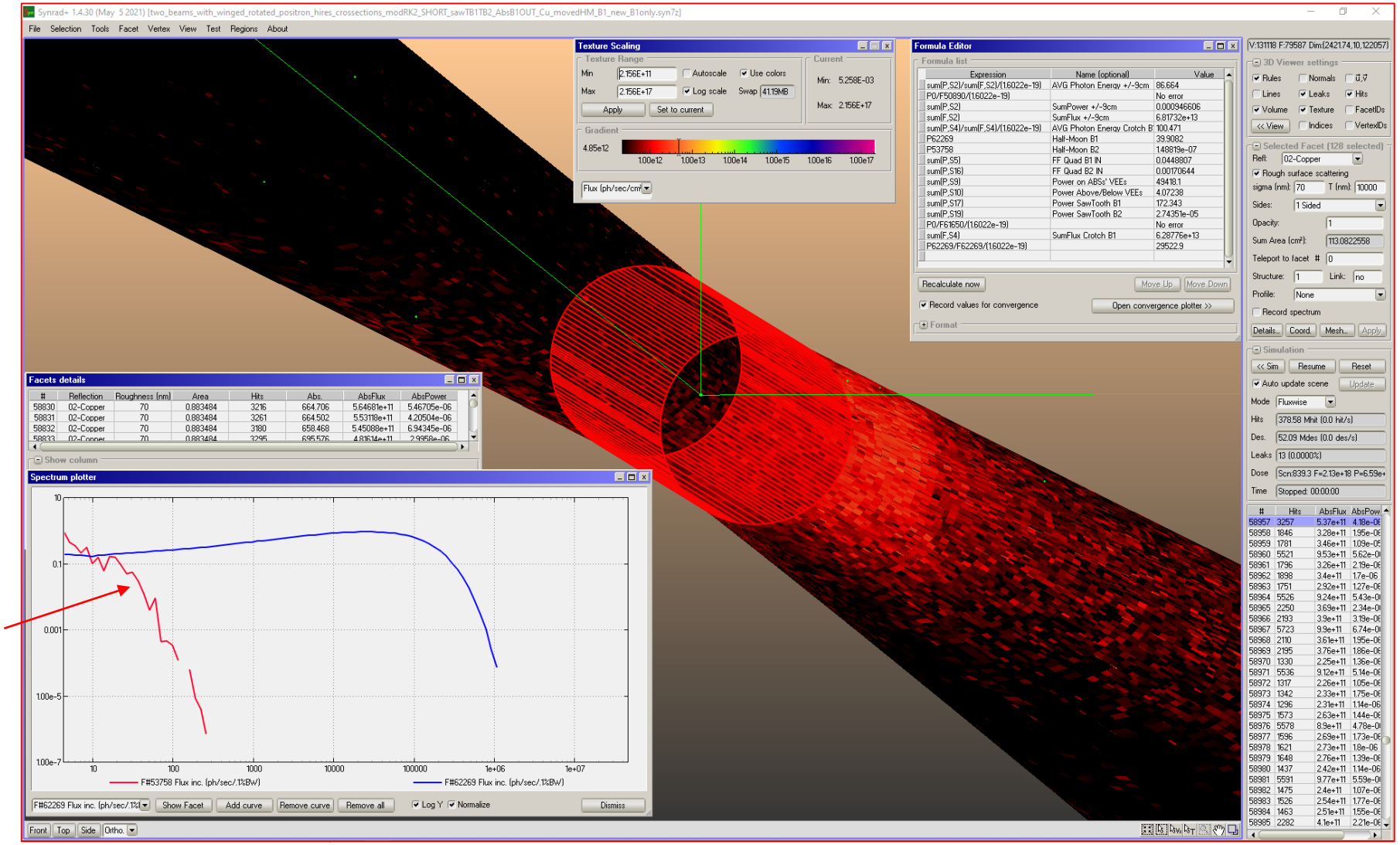


Central +/- 9 cm Be chamber in the center. Fluxes and SR spectra incident on two IP absorbers

SR Power = 39.8-43.6 W; total Flux = $4.22 \cdot 10^{17}$-$4.66 \cdot 10^{17}$ ph/s; Average photon energy is **<u>~585 eV</u>**

New “X” chamber CAD model without HOM ferrite absorbers (INFN Frascati)
Photon scattering/reflection is angle- and energy-dependent (assumed Cu and/or NEG)

182.5 GeV ONE BEAM ONLY!



B2 OFF: Absorber sees only SR photons generated by OTHER beam after multiple scattering

Central +/- 9 cm Be chamber in the center (facets in red). Very low photon fluxes impinging on Be pipe facets; **B1 ONLY**

Total Power = ~0.001 W; total Flux = $6.82 \cdot 10^{13}$ ph/s; Average photon energy is 86.7 eV

New “X” chamber CAD model without HOM ferrite absorbers (INFN Frascati)
Photon scattering/reflection is angle- and energy-dependent (assumed Cu and/or NEG)

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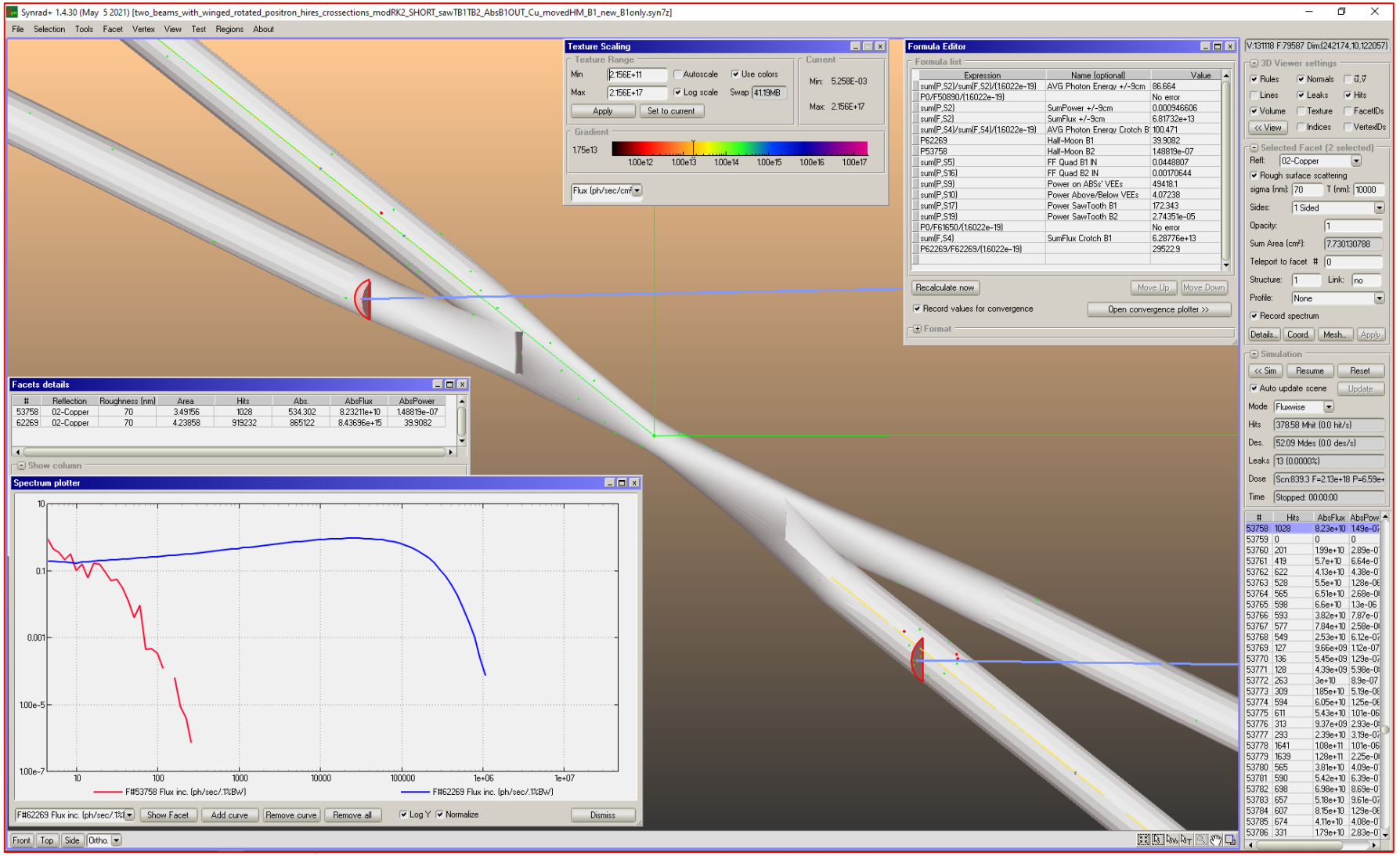
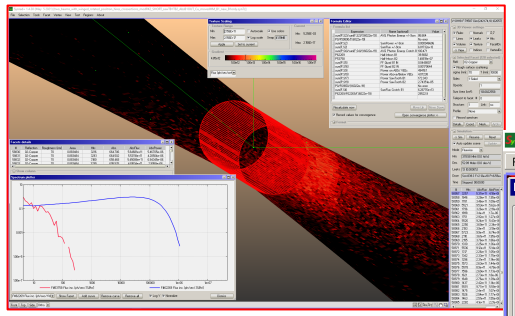


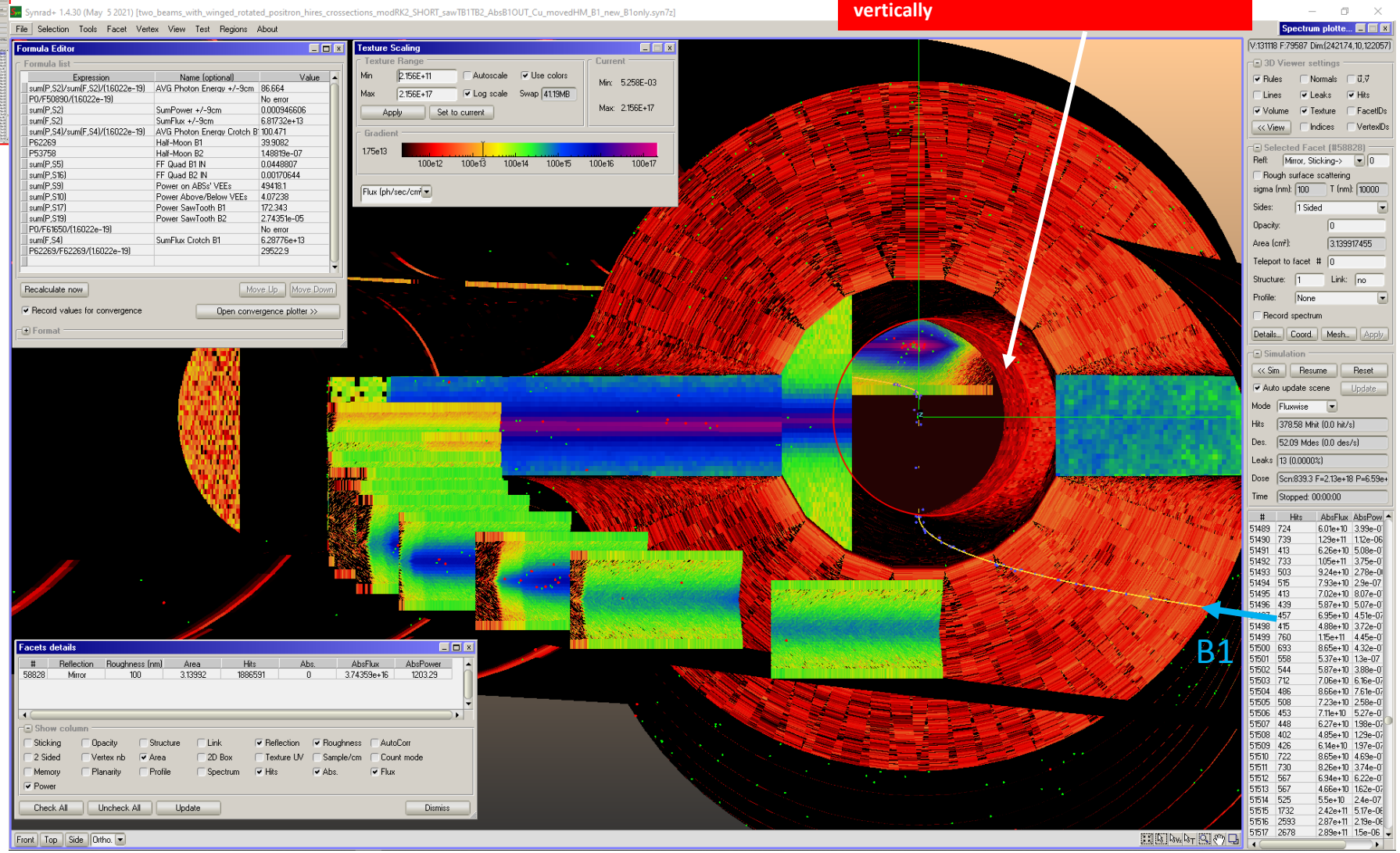
Central +/- 9 cm Be chamber in the center. Fluxes and SR spectra incident on two IP absorbers; **B1 ONLY**

SR Power = 39.9 W; total Flux = $8.44 \cdot 10^{15}$ ph/s; Average photon energy is ~**29.5 keV**



182.5 GeV ONE BEAM ONLY!

"crescent" is external side of +/- 9 cm Be pipe seen along B1 axis, slightly tilted vertically



Central +/- 9 cm Be chamber in the center (facets in red). Very low photon fluxes impinging on Be pipe facets; **B1 ONLY**

Total Power = ~0.001 W; total Flux = $6.82 \cdot 10^{13}$ ph/s; Average photon energy is 86.7 eV

Preliminary conclusions:

1. The new “X” IP chamber designed at Frascati, with new integrated IP absorber (half-moons) seem to be able to shield most of the IP from direct-hit photons generated upstream from the last weak dipole (91.7 keV crit. energy at 182.5 GeV)
2. A very small fraction of the dipole radiation (and the last non-FF quad as well) SR hits the external wall of the +/-9 cm Be pipe
3. The critical energy of this photon flux is very low, ~90 eV for both Z and ttbar energies
4. The position of one of the two half-moon absorbers has been changed, moved away from the IP by 135 cm, in order to see whether that may help reduce the SR flux on the “X” chamber: it does not do much good for that, but it may make a difference concerning the higher energy Compton scattered photons from the tip of the half-moon absorber which are generated rather isotropically and may irradiate forward into the Be pipe
5. The solid angle of the more distant half-moon absorber tip has a smaller solid angle of view of the Be chamber, so this may help reduce the Compton-scattered photons. Unfortunately the ray-tracing code SYNRAD+ doesn’t handle Compton effect, so another code is needed.