IR Vacuum Concept

R. Kersevan, M. Gil Costa, CERN-TE-VSC

Workshop on the mechanical optimisation of the FCC-ee MDI

30 Jan 2018, 08:30 → 9 Feb 2018, 17:30 Europe/Zurich

37-R-022 (CERN)

NOTE: This presentation has been prepared at the last minute; it is, basically, the same presentation that has been given a year ago or so (see below), with a quick update about development of a short prototype of the vacuum system in the arcs, to be installed inside the dipole and quadrupole prototype magnets of A. Milanese.

Synchrotron Radiation with SYNRAD+

R. Kersevan, M. Ady, CERN-TE-VSC-VSM

FCC-ee MDI workshop

16 Jan 2017, 09:00 → 27 Jan 2017, 13:00 Europe/Zurich

37-R-022 (CERN)

R. Kersevan, FCC-ee MDI Workshop, CERN, 16-27/1/2017

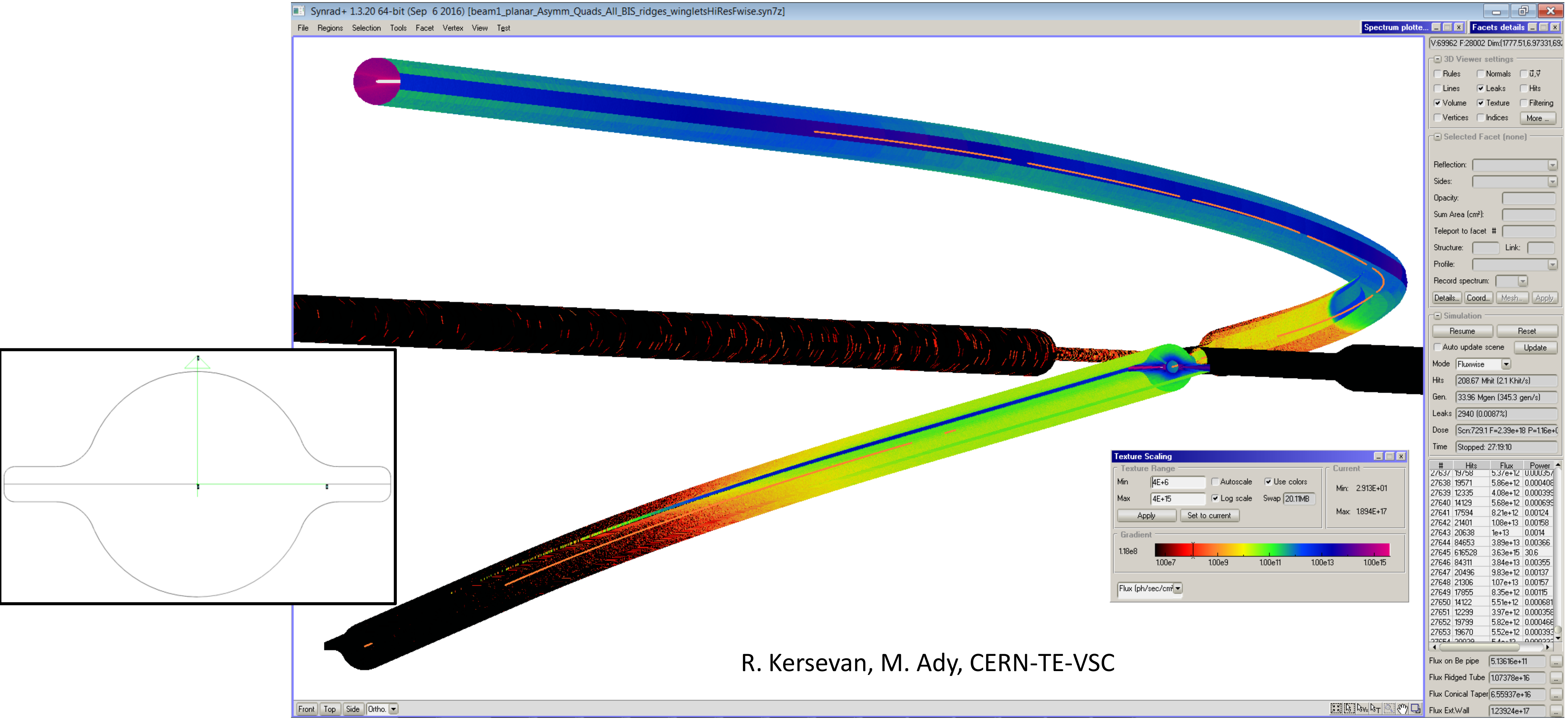
Ray Tracing with SYNRAD+ in FCC-ee IR

R. Kersevan, M. Ady, CERN-TE-VSC-VSM

- The geometry for the ~680 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 at FCC Week in Berlin).

Source: R. Kersevan, FCC-ee MDI meeting #8, 12/12/2016

SYNRAD+: SR flux along one ~680 m-long arm of the interaction region of FCC-ee (175 GeV T-pole machine; 6.632 mA; Z-pole study to be done)



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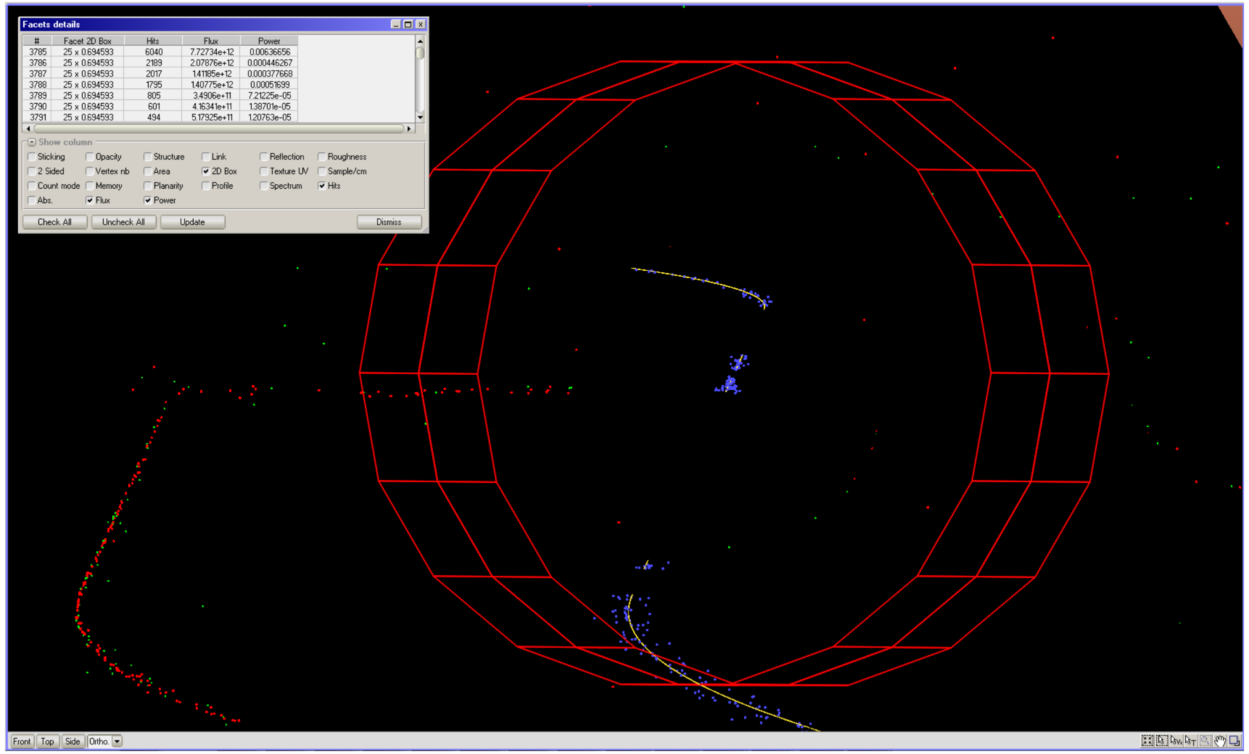
One arm of the IP chambers: ~ -347 m to ~ +337 m;

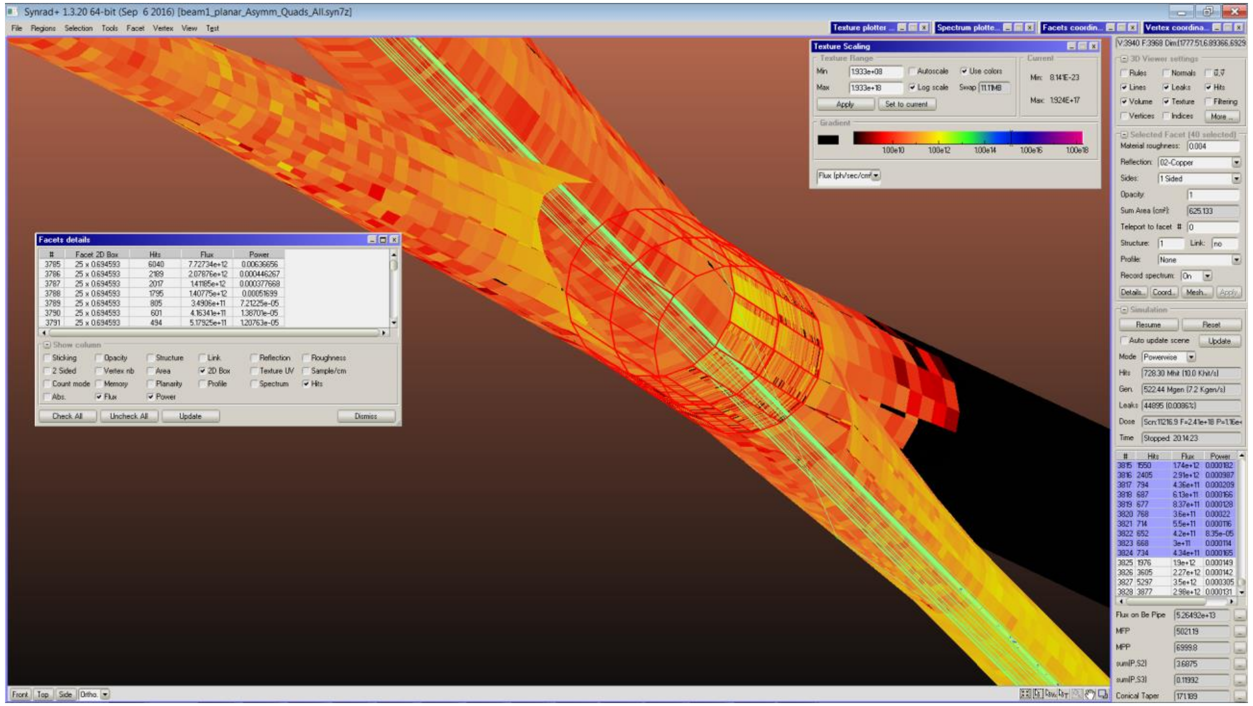
Round pipe (70 mm ID) everywhere except along the incoming beam, which has winglets;

→ NO BEAM HALOS!... to be done... ←

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

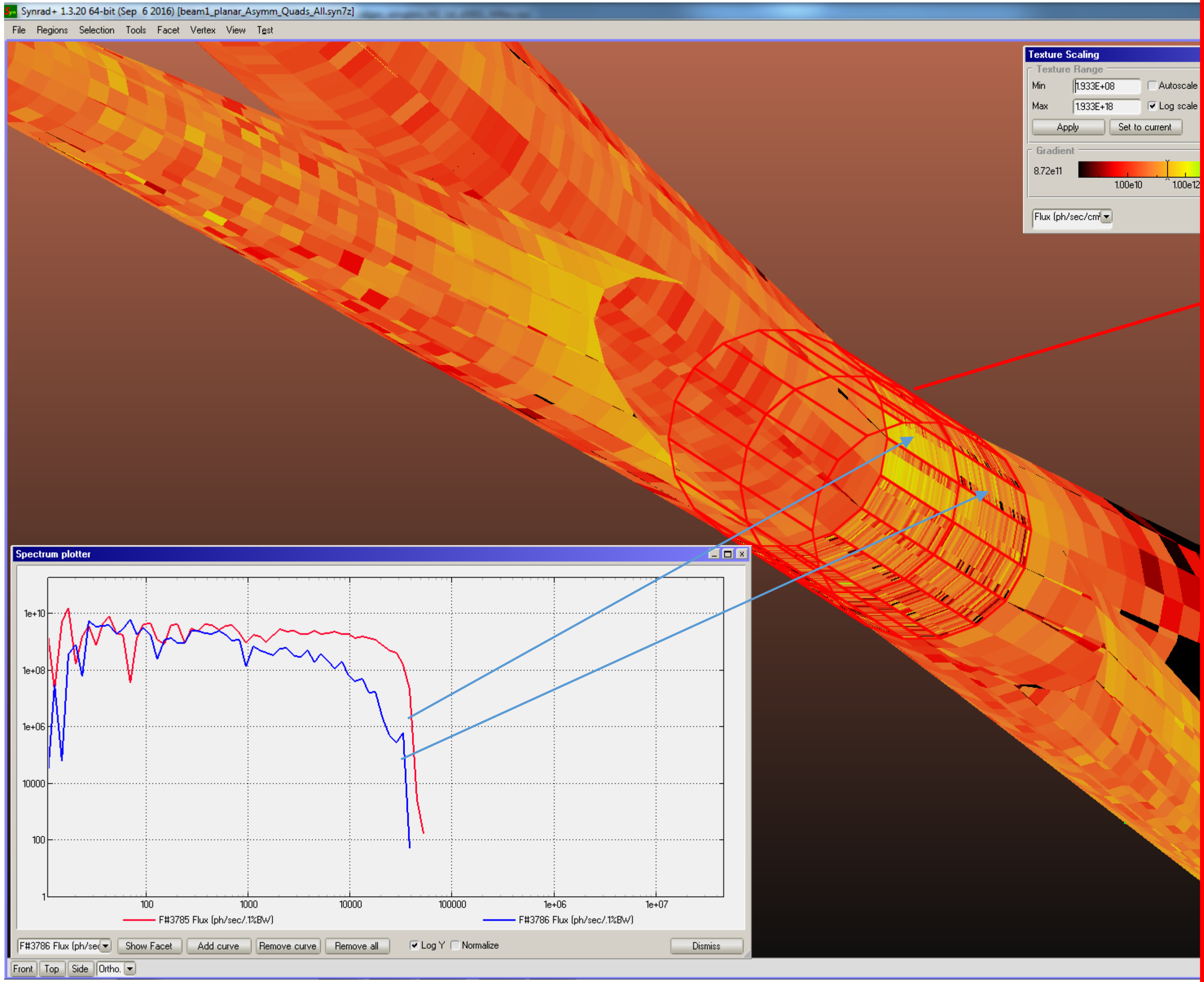


View of the source points (blue) and centroid trajectory (yellow); Red and Green points are locations of absorbed/reflected photons;
Red lines represent the 50 cm-long Be pipe



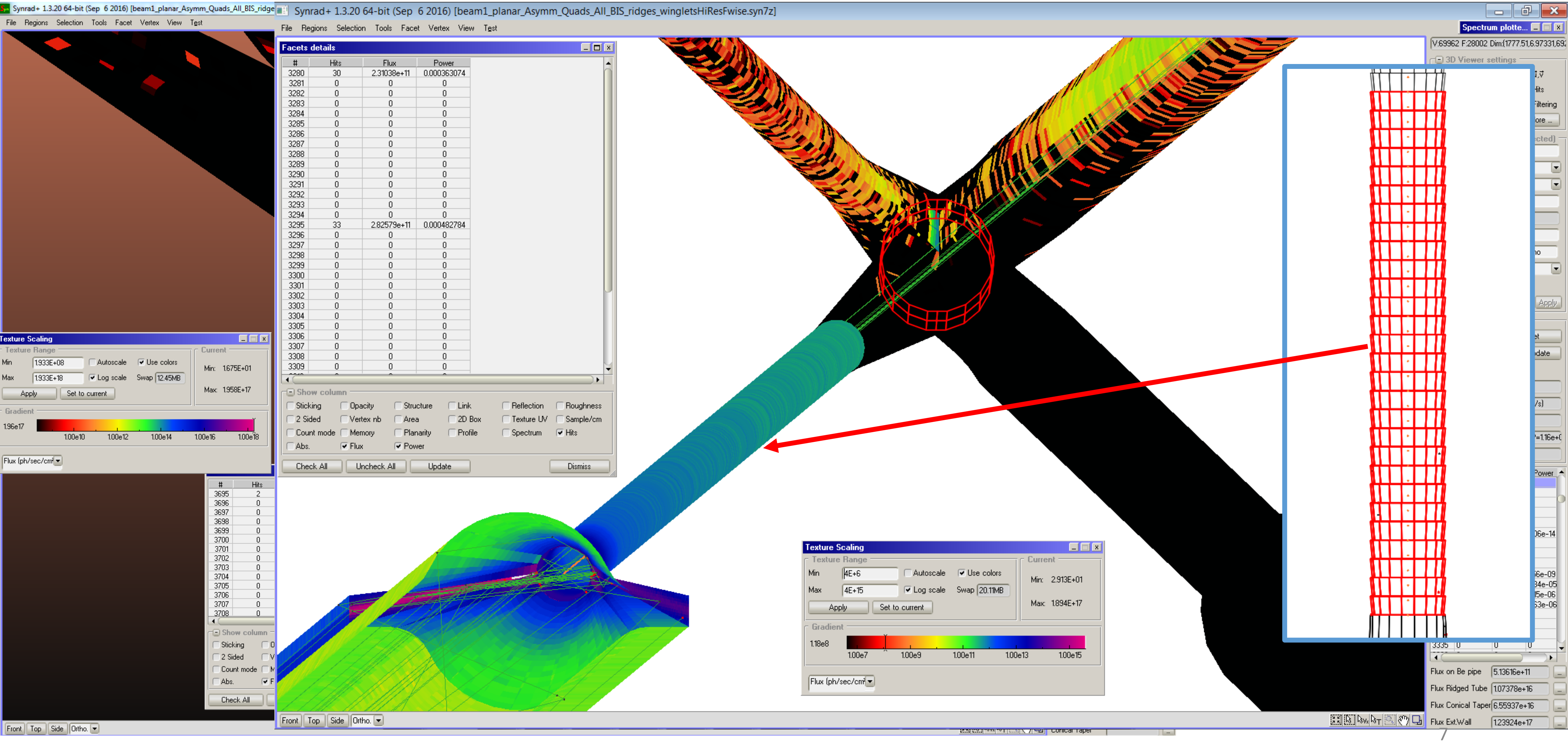
Zoom into the IP region: 50 cm-long Be pipe and local photon flux density distribution;
A total of 5.26E+13 ph/s hit the Be pipe;

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

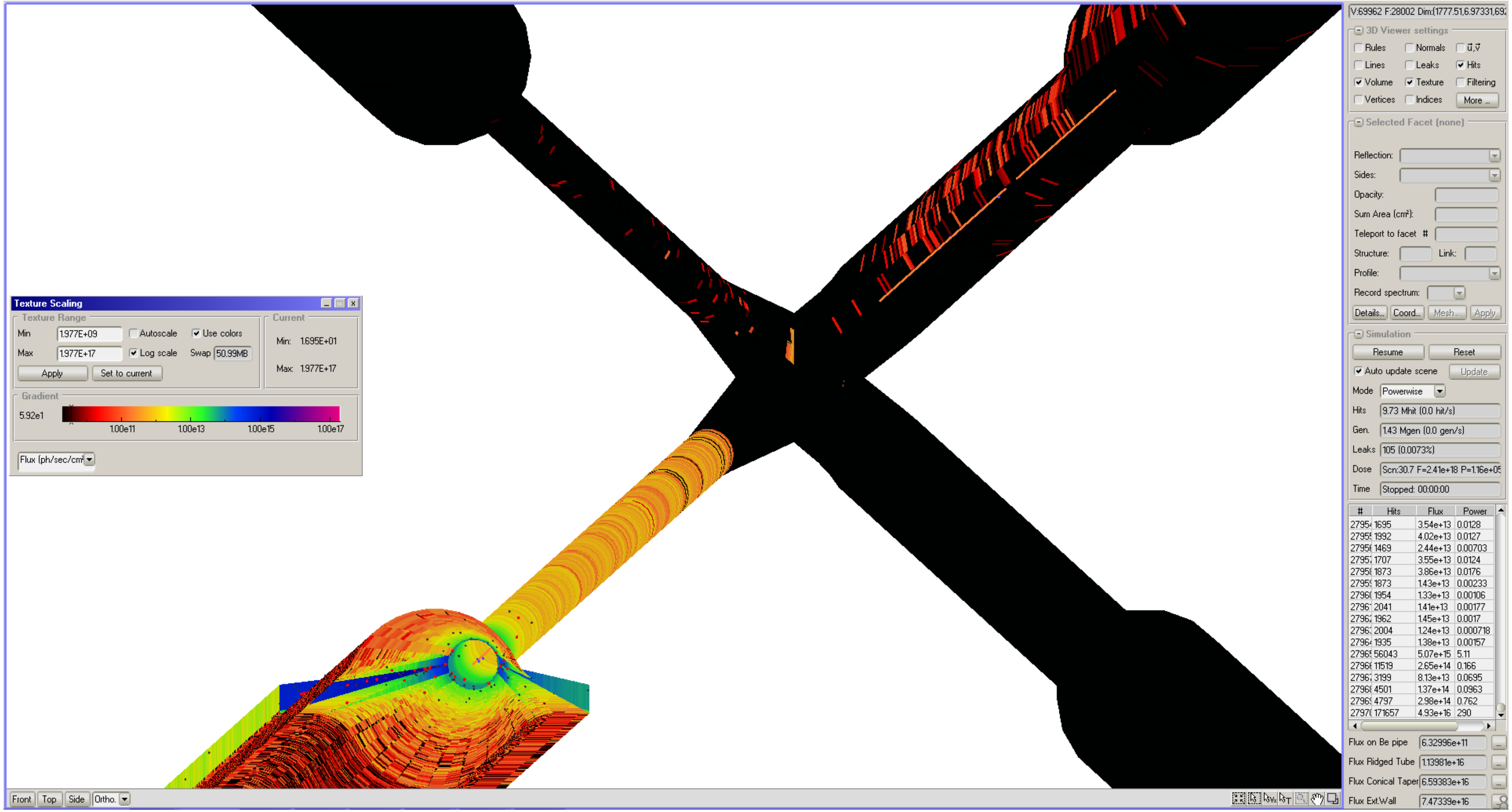


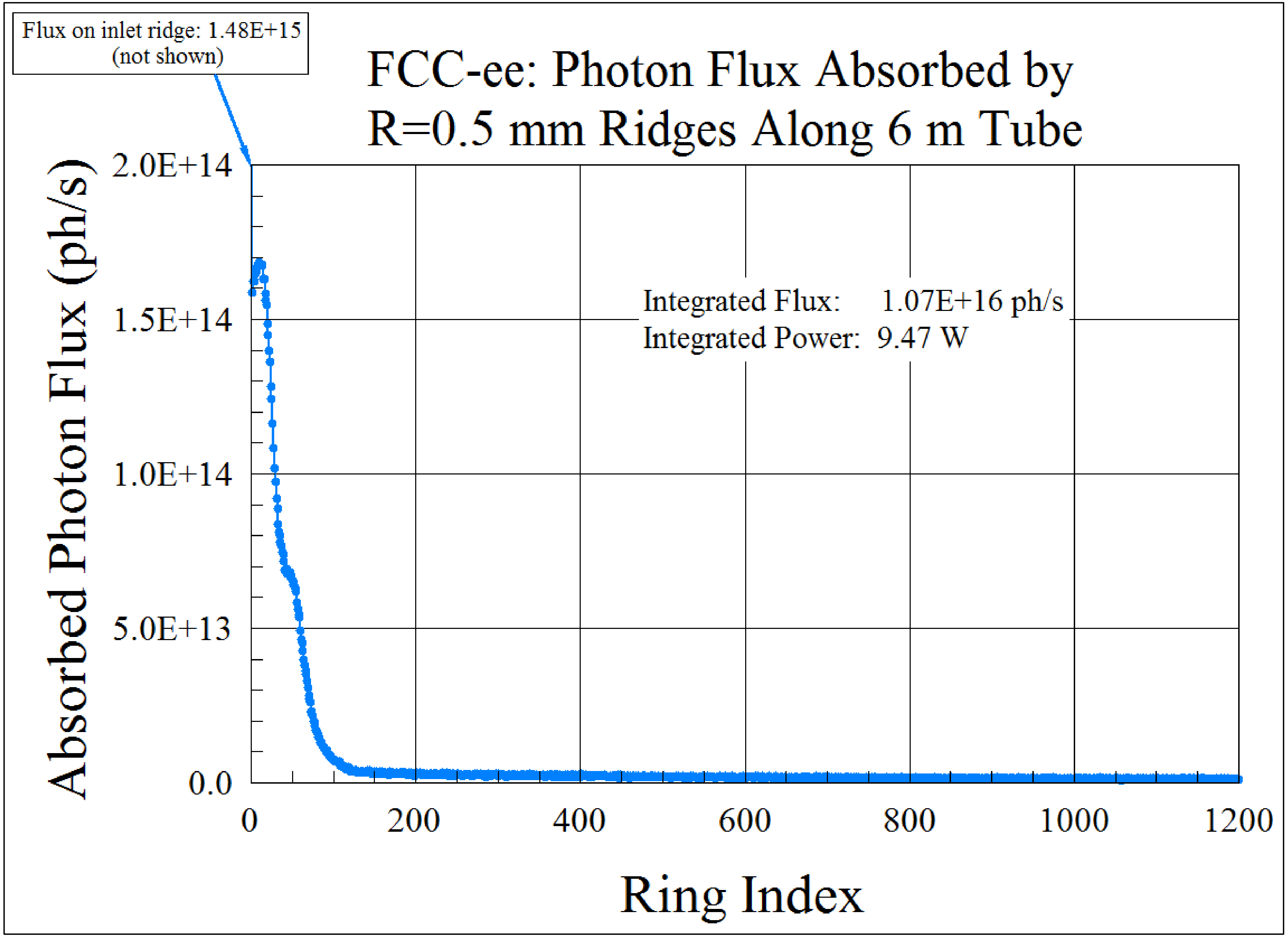
NEW IR GEOMETRY AS PER A. NOVOKHATSI ET AL.

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 mm radial, 5 mm step)

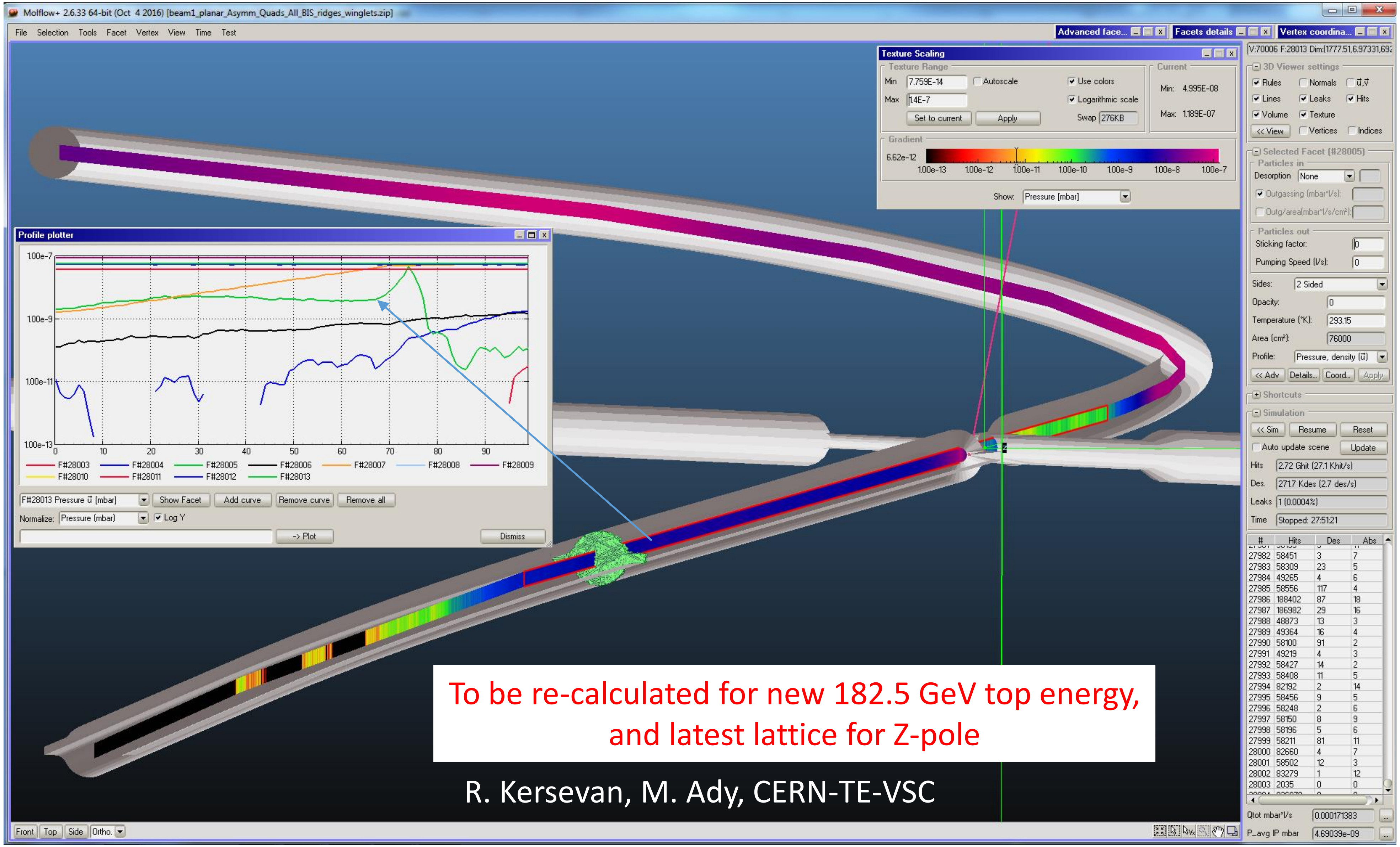


Adding a “ridged” (sawtooth) profile to the 20 mm ID doublet quad pipe: reduces the flux onto Be pipe to virtually zero; (ridge/sawtooth: 0.5 mm radial, 5 mm step)




Flux on inlet ridge: 1.48E+15 (not shown)
FCC-ee: Photon Flux Absorbed by R=0.5 mm Ridges Along 6 m Tube
Integrated Flux: 1.07E+16 ph/s
Integrated Power: 9.47 W
Absorbed Photon Flux (ph/s)
2.0E+14
1.5E+14
1.0E+14
5.0E+13
0.0
0
200
400
600
800
1000
1200
Ring Index

Molflow+: Pressure profile along one ~680 m-long arm of the interaction region of FCC-ee (175 GeV T-pole machine; 6.632 mA)



To be re-calculated for new 182.5 GeV top energy, and latest lattice for Z-pole

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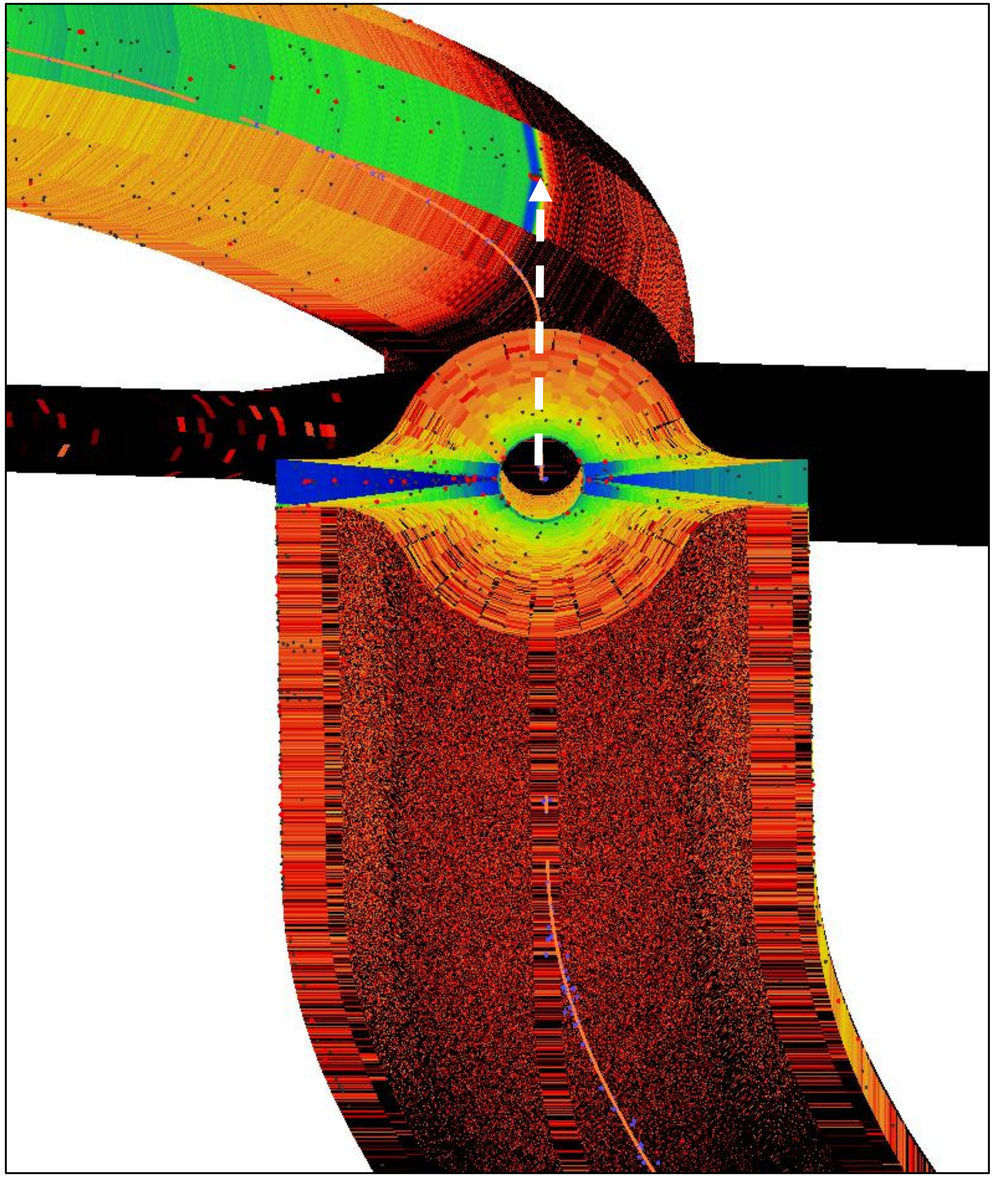
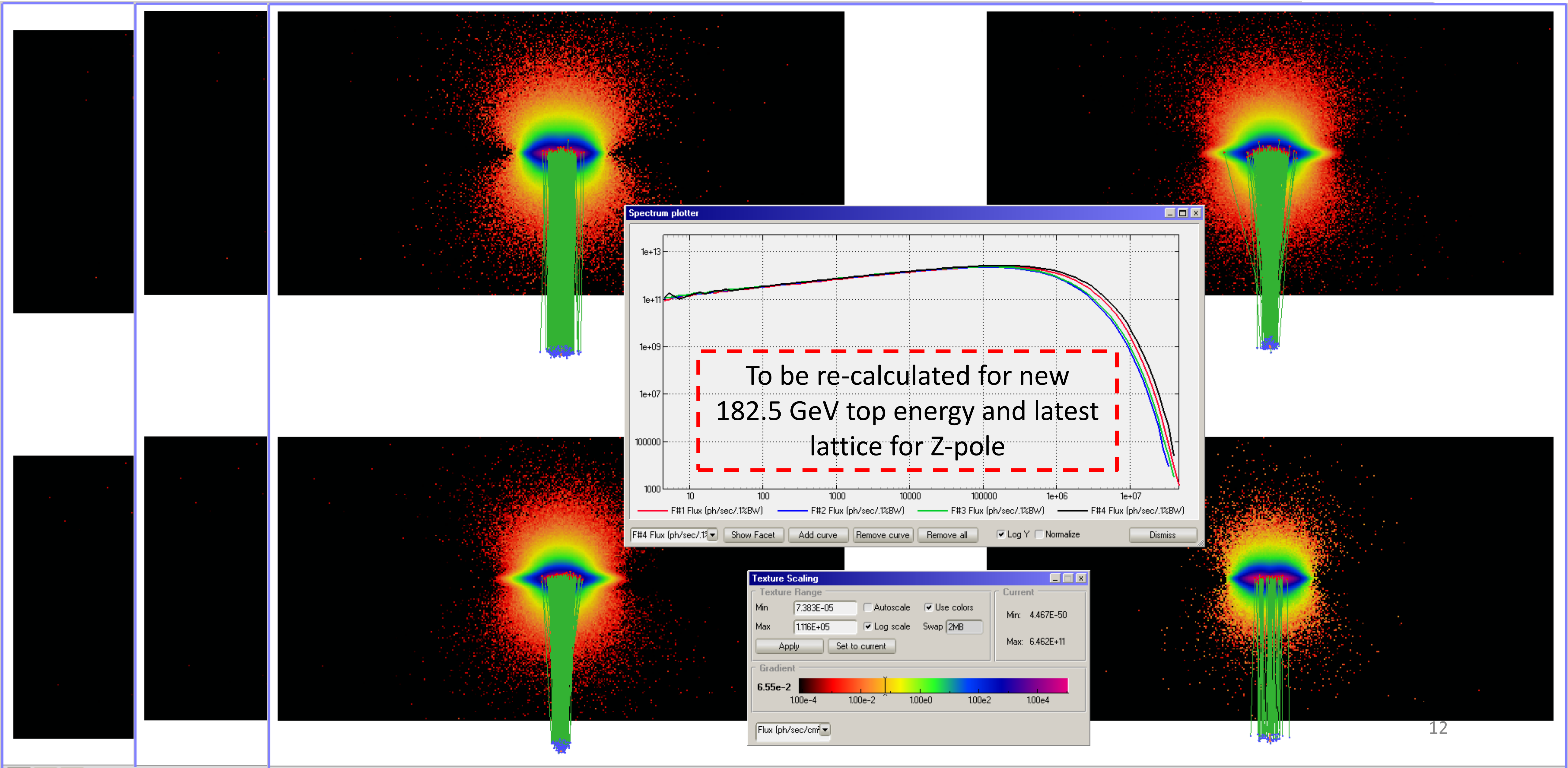


Average distance travelled by SR photons generated in the 2 doublets is ~ 63 m

Conical taper immediately before final focusing doublet

NO SR ABSORBERS HAVE BEEN MODELED IN THIS SIMULATION

Synrad+: angular distribution of the SR generated along the 4 SC doublet magnets, viewed on a flat perpendicular screens (4x2 cm^2) placed at 63 m

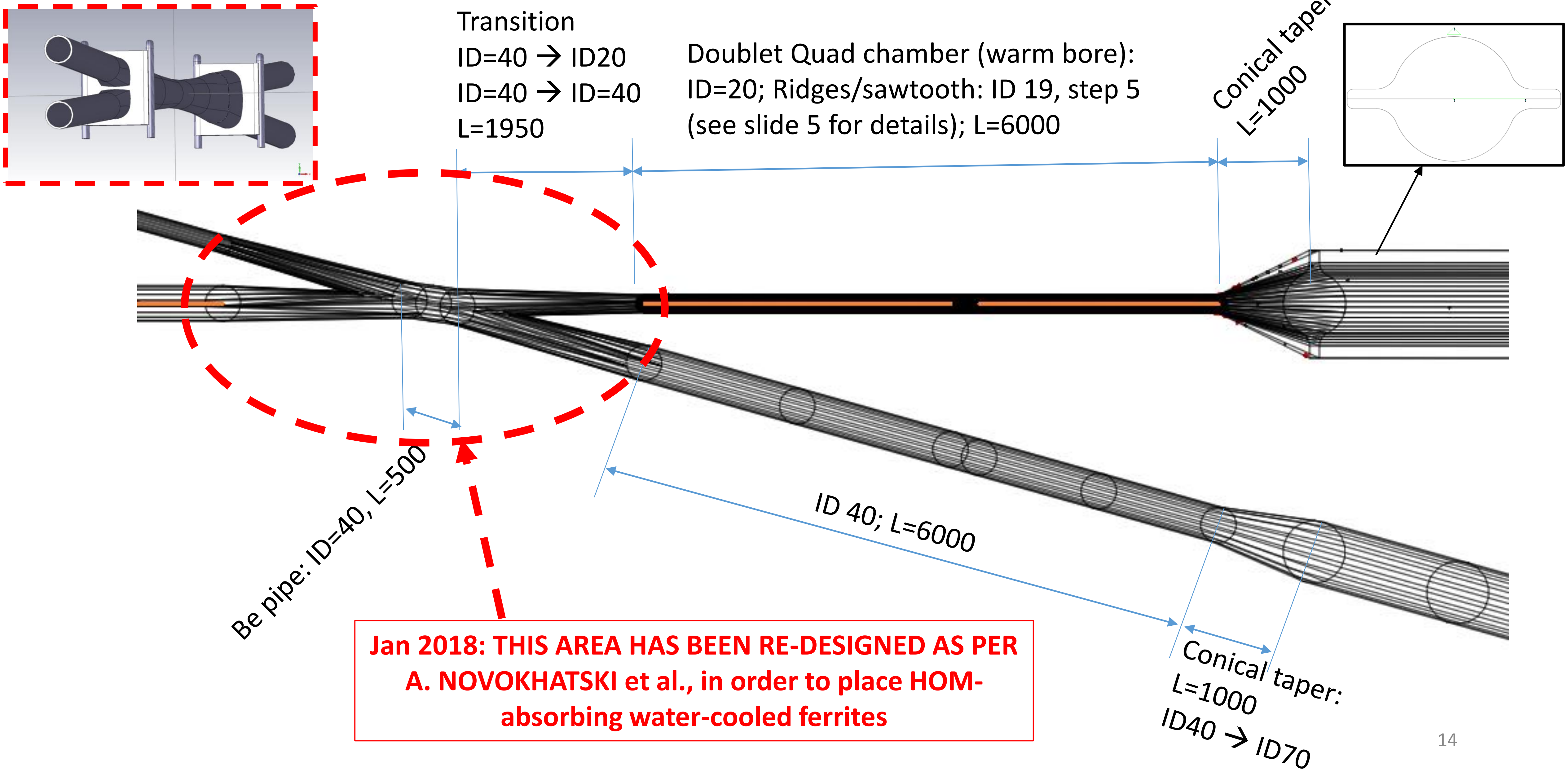


Preliminary conclusions:

- The ray-tracing montecarlo code SYNRAD+ has been applied to the FCC-ee IP region;
- A model of approximately 680 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', ~100 keV);
- It is evident that without a proper masking of the Be pipe, the pipe will get a non-negligible photon flux with photons up to several 10's keV: is this a problem for the detector's hardware and electronics? YES
- It is also suggested that a rather simple to implement ridged (sawtooth-ed) geometry somehow machined on the internal part of the warm bore focusing doublets helps to reduce 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 (see several presentations from E. Belli et al.);
- The 4 quadrupole magnets of the doublet generate a rather large and extremely hard photon flux, with photons reaching the energy range of several TENS MeV (@top energy): they mostly land on a small spot on the exit side of the beam, about ~63 m downstream, past the detector: careful shielding of that area must be envisaged;

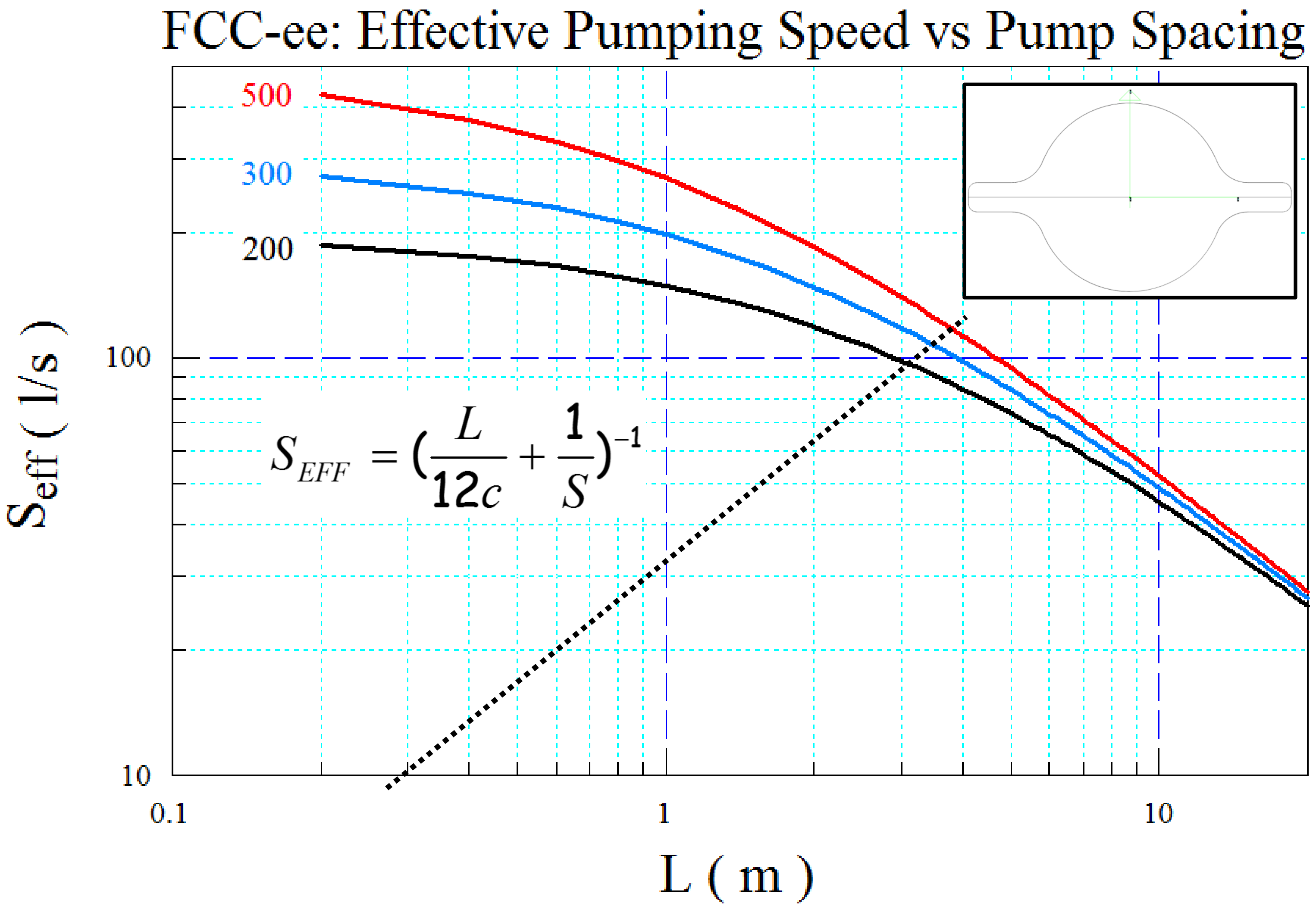
Bonus slides (following yesterday’s discussions):

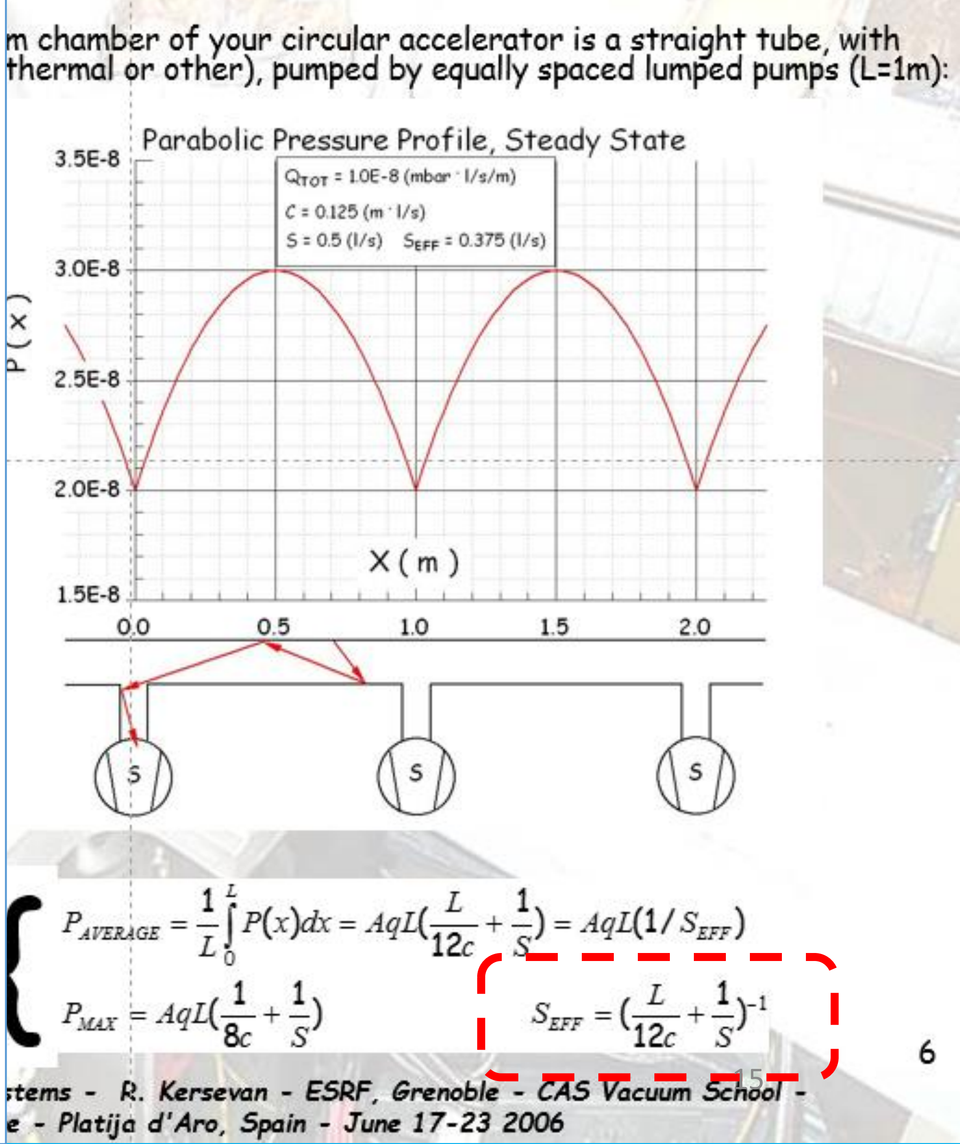
Shape and dimensions (in mm) of IP chambers:



Conductance limitation severely affects the effective pumping speed, and therefore the final pressure

Specific conductance of 70 mm ID, winged (SUPERKEK) cross-section: 48.65 l*m/s





Example: What average effective pumping speed would be necessary for the Z-pole machine in order to have an average pressure lower than 1.0E-9 mbar?

Photon flux: F (ph/s) = 8.08E+17 · E (GeV) · I (mA) = 5.34E+22 (ph/s)

If k=2.47E+19 (mol/mbar/liter), then the gas load Q is:

$$Q\,(\text{mbar·l/s}) = F\,(\text{ph/s}) \,/\, k(\text{mol/mbar/l}) \cdot \eta(\text{mol/ph})$$

with η= photodesorption yield.

→ Typically a machine is considered *vacuum conditioned* when η < 1.0E-6 (mol/ph):

$$Q'\,(\text{mbar·l/s/m}) = Q/\,2\pi\rho = 3.44\text{E-8}\,(\text{mbar·l/s/m})$$ (in the arcs, ρ ~10 km)

$$P_{avg}\,(\text{mbar}) = Q'\,(\text{mbar·l/s/m}) \,/\, S_{eff}\,(\text{l/s}) \cdot L(\text{m})$$

Solving for for S_{eff}, one gets: S_{eff} (l/s) = 34.42 · L(m) (dotted line at 45 deg on previous plot)

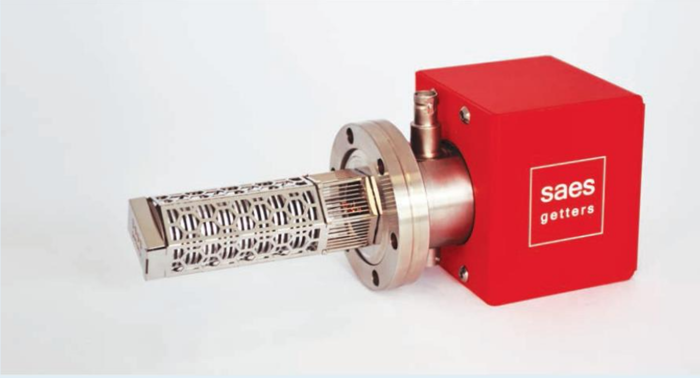
- This means that the Z-pole machine, due to its huge photon flux, would condition to P_{avg}<1.0E-9 only if 200 ÷ 500 l/s pumps are placed at a distance < 3 ÷ 4 m from each other;
- This, in turn, would mean that in the arcs one would need 19000 ÷ 25000 pumps/beam;
- Each lumped pump would in turn need pumping slots machined on the vacuum chamber: additional cost for machining, pumping plenum, flanges, cabling, etc...

NEG pumps: the NEXTorr family (SAES Getters, Milan, Italy)

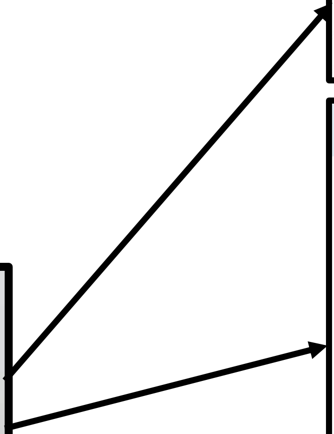
Integrated NEG pump with “small” noble ion-pump (~10 l/s)

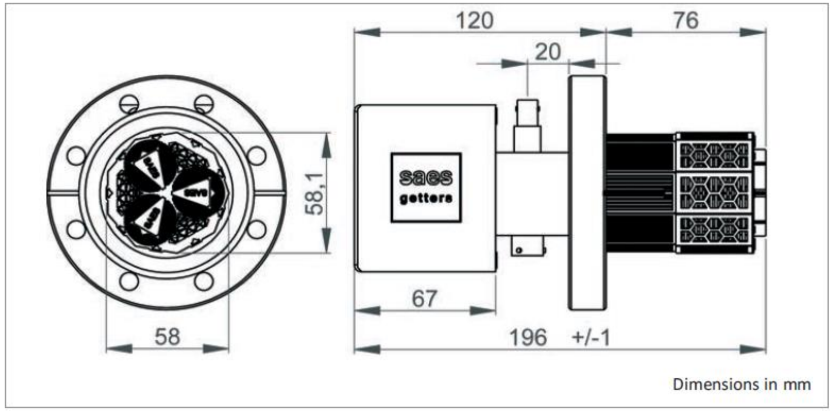
NEXTorr® D 100-5

NEXTorr® D 200-5



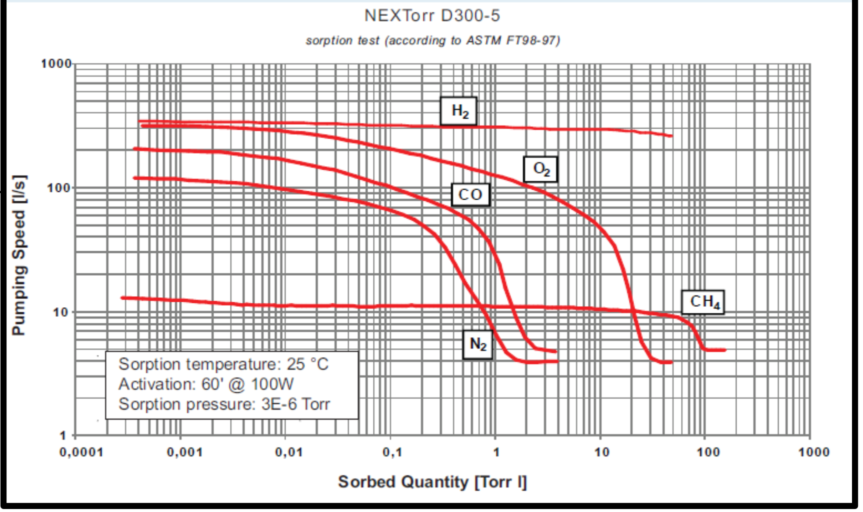
NEXTorr® D 300-5





Total pump weight (magnets included)	3.1 kg
Total pump volume	0.6 litre
Type of ion pump	Diode
Operation Voltage Ion Element	5.0 kVdc
Operation Voltage NEG Element	20 Vdc

Pumping speed curves for various gases



Twin-aperture magnets for FCC-ee and ante-chamber design compatibity:

NO SPACE FOR ANTE-CHAMBER AND PUMPING IN THE QUADS EITHER!... SPACE BETWEEN TWO QUAD CENTERS IS TAKEN BY LATEST QUAD YOKE

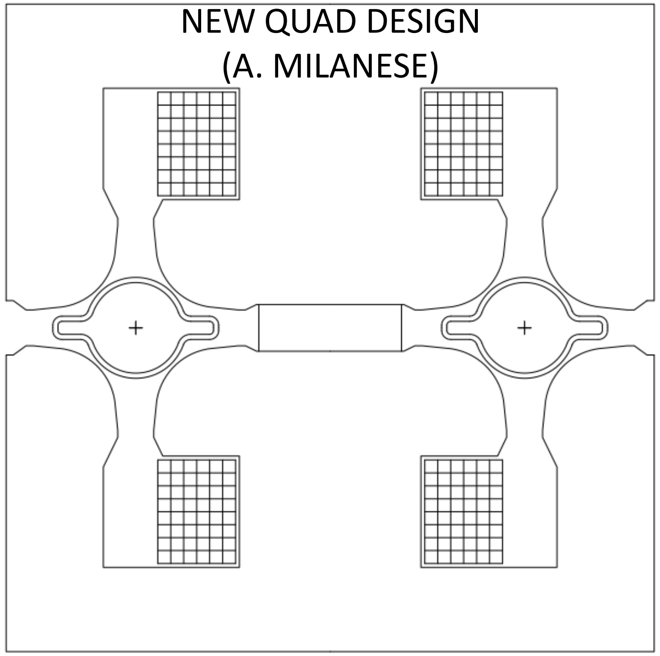
PHYSICAL REVIEW ACCELERATORS AND BEAMS **19,** 112401 (2016)

Efficient twin aperture magnets for the future c

A. Milanese
CERN-The European Organization for Nuclear Research, CH-
(Received 29 June 2016; published 2 Novemb

We report preliminary designs for the arc dipoles and quadrupoles of
After recalling cross sections and parameters of warm magnets used i
focus on twin aperture layouts, with a magnetic coupling between the ga
cost and reduces the electrical power required for operation. We also in
may be further optimized so as to optimally address any further con
vacuum system, and electric power consumption.

DOI: 10.1103/PhysRevAccelBeams.19.112401



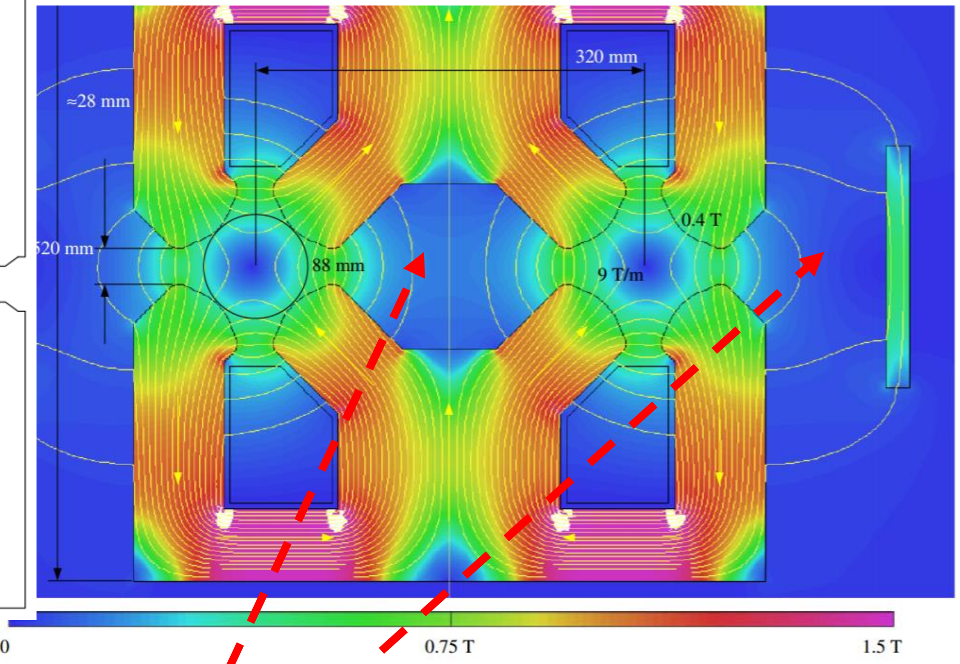


FIG. 7. First cross section of FCC-ee twin quadrupoles; the geometry is to scale with the twin dipole of Fig. 6 (field levels for 175 GeV).

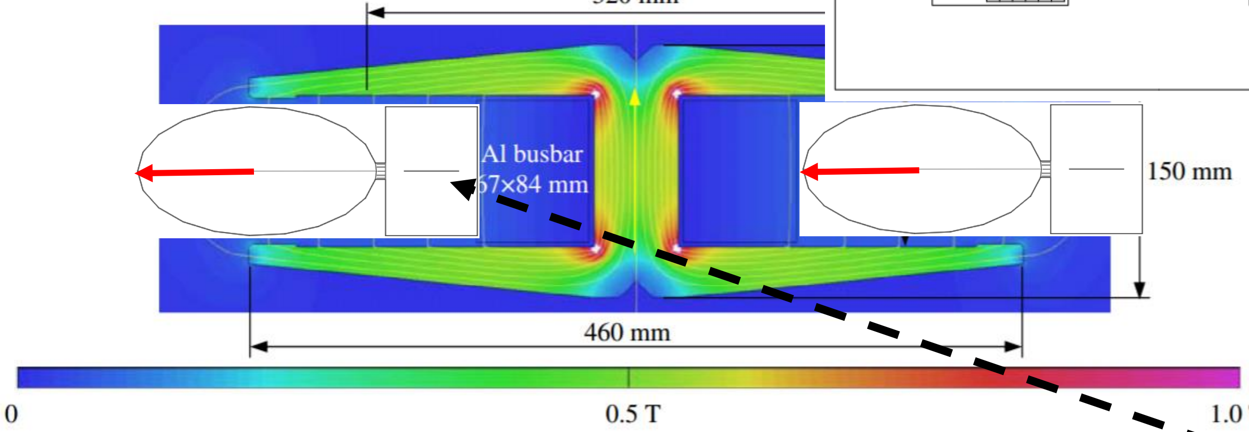


FIG. 6. First cross section of FCC-ee bending magnets with an I layout (field levels for 175 GeV).

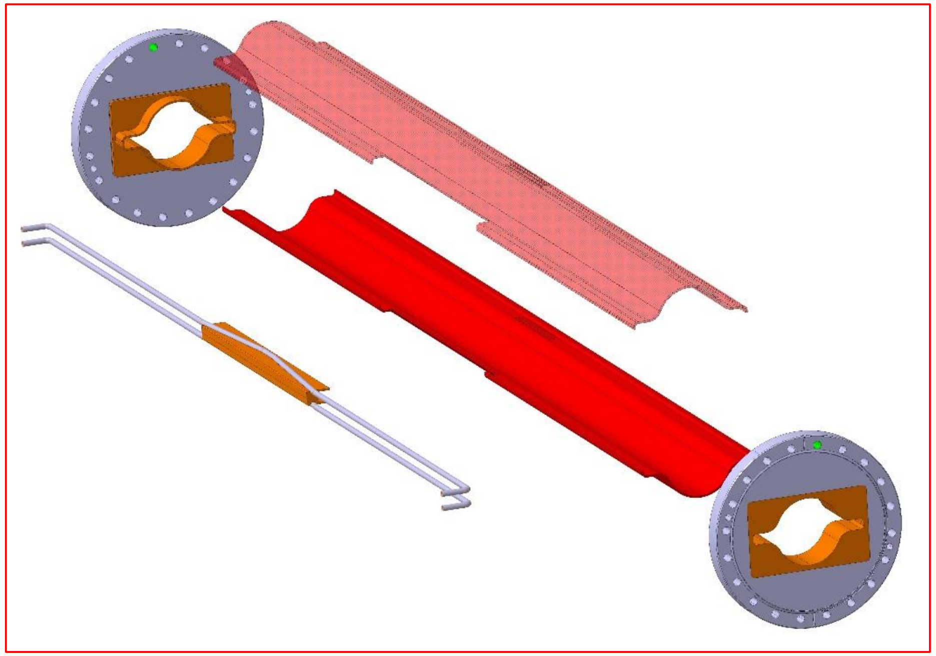
Space for antechamber????

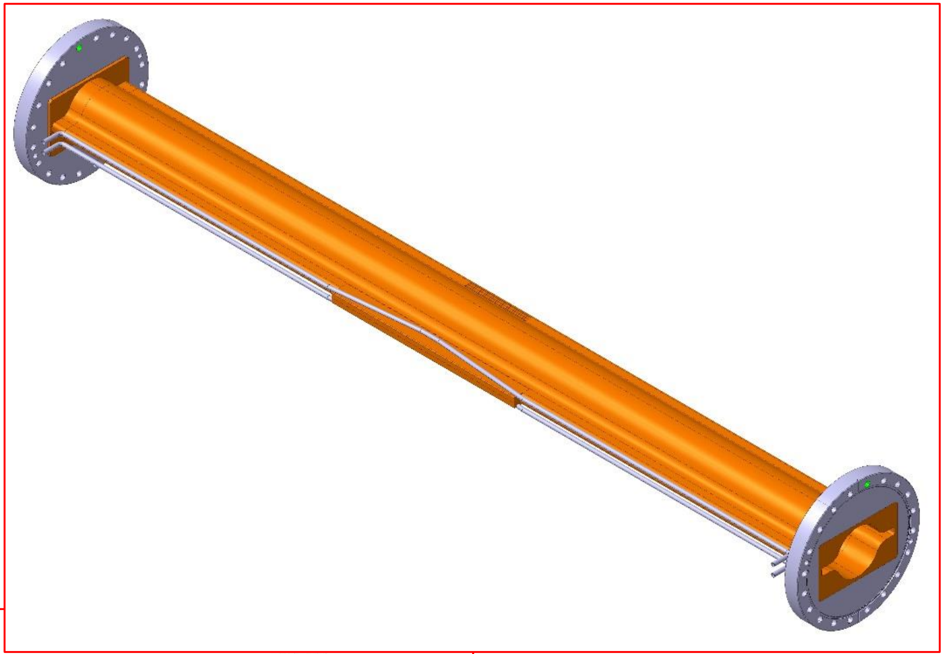
~~Yes for the quads…~~

…IMPOSSIBLE for one of the dipoles!

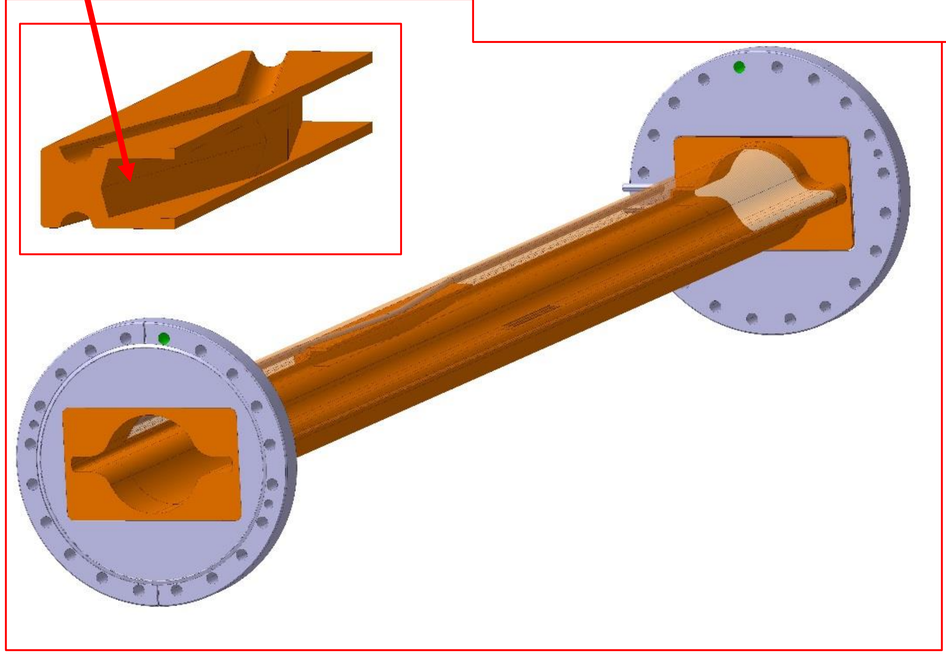
M. Gil Costa’s CAD model of the vacuum chamber prototype for the arcs:

Similar/same concept profile should be used for the “single chamber” collision area, where non double-aperture magnet will be necessary





The SR absorber geometry shown here is preliminary: the inclination of the “V” should be bigger;



Notes:

1. This is a model for a short prototype;
2. It shows regular circular flanges, ConFlat type: the machine should be equipped with SUPERKEKB-type ones (rectangular profile), in order to be able to install the flanges in the short axial space between magnets in the lattice (see my presentation at FCC Week 2017);

- The internal diameter of the round part is 70 mm;
- Wall thickness is 2 mm;
- Material is OFC copper;
- VC and absorber cooling pipes for real machine could be separated (ABS~ 3~5 kW, VC~ few 100s W from e-cloud/image curr.)

RECAP AND PRESENT STATUS:

1. The “best” (read “*most efficient*”) **vacuum chamber cross-section** capable of intercepting ~ all of the primary dipole SR in the arcs has been identified (see FCC Week 2017 talk): it is a **SUPERKEKB-type one**, with smaller ID (70 mm) on the circular part and smaller “winglets” in the plane of the orbit (**only 11 mm height**);
2. **Many, short (~ 300 mm max) SR absorbers** are located at variable distance from each other (lattice position-dependent): **they absorb about 3~5 kW of primary SR power**;
3. Wherever possible, each absorber has a **pumping port installed in front of it**, connected via **~100 mm-long pumping slots** machined on the internal winglet (minimal geometrical impedance contribution);
4. **The same concept is envisaged/proposed for the MDI region**, where the two beams run in **separated and single-yoke magnets** (I have not see a design for these magnets yet: **NO CAD MODELS AVAILABLE!**);
5. The SUPERKEKB-type chamber profile ends immediately before the focusing doublet: It is connected to a **custom absorber which protects/masks the following chambers up to the IP** (see M. Sullivan’s presentation, this workshop);
6. The IP area chambers include the **“new” chamber with two integrated water-cooled HOM-absorbing ferrites** (as per A. Novokatski’s presentation, this workshop, based on M. Gil Costa’s CAD model);
7. Space for at least **one efficient NEG pump in the IP area is allocated** (see M. Sullivan’s pres.), but needs to be integrated in the existing CAD model; the area is crammed with detector components and cables (anti-solenoids, cryostats, remotely-operated flanges (like SUPERKEKB?), supports, alignment etc…), plus the necessary water-cooling circuit’s pipes; **NEEDS CAREFUL SCRUTINY!**
8. **See also M. Sullivan list of “Mechanical issues” at end of his presentation;**