FLUKA status and plan

Sixth TLEP workshop
CERN, 16 -18 October 2013

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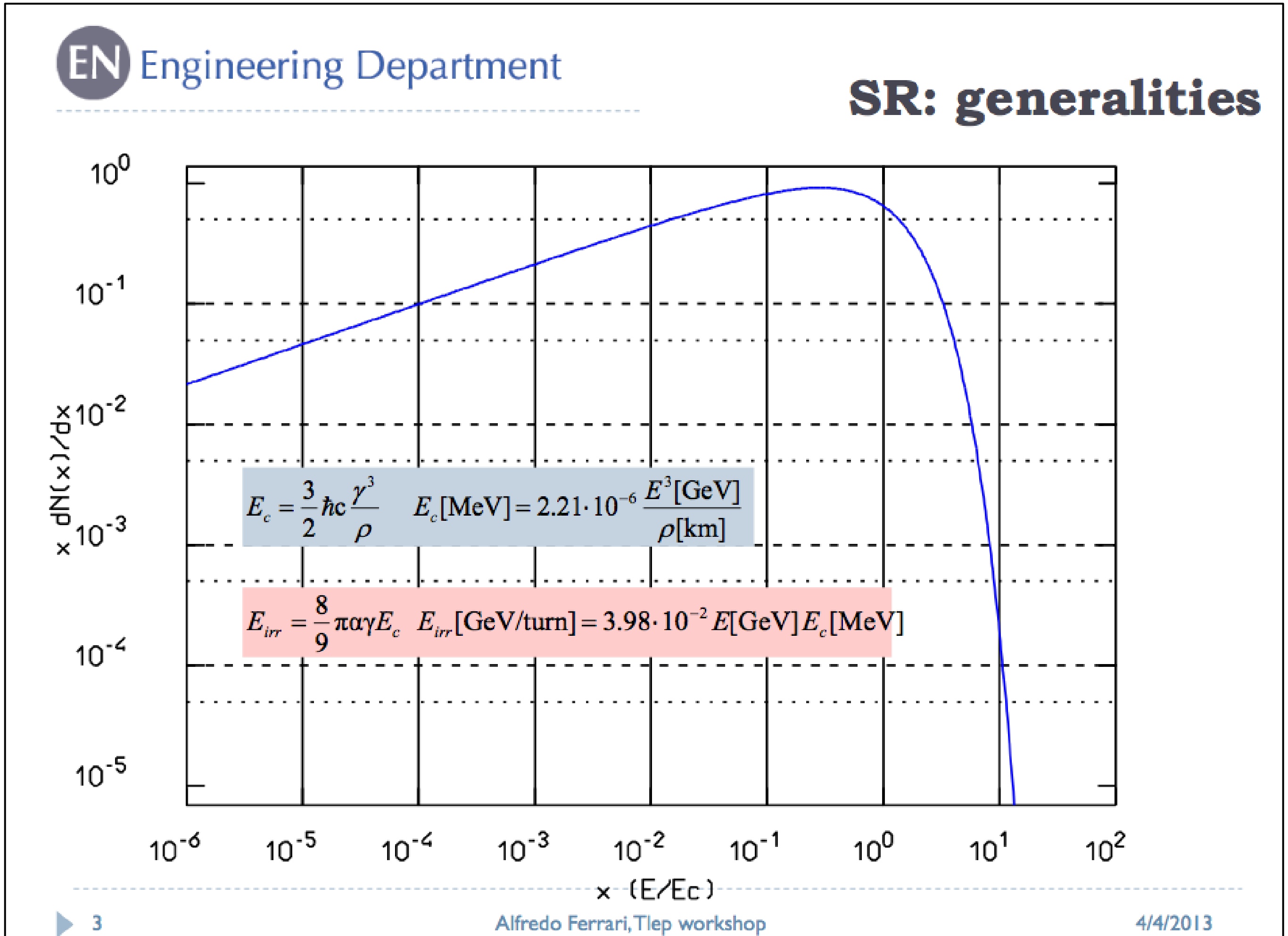
Outline

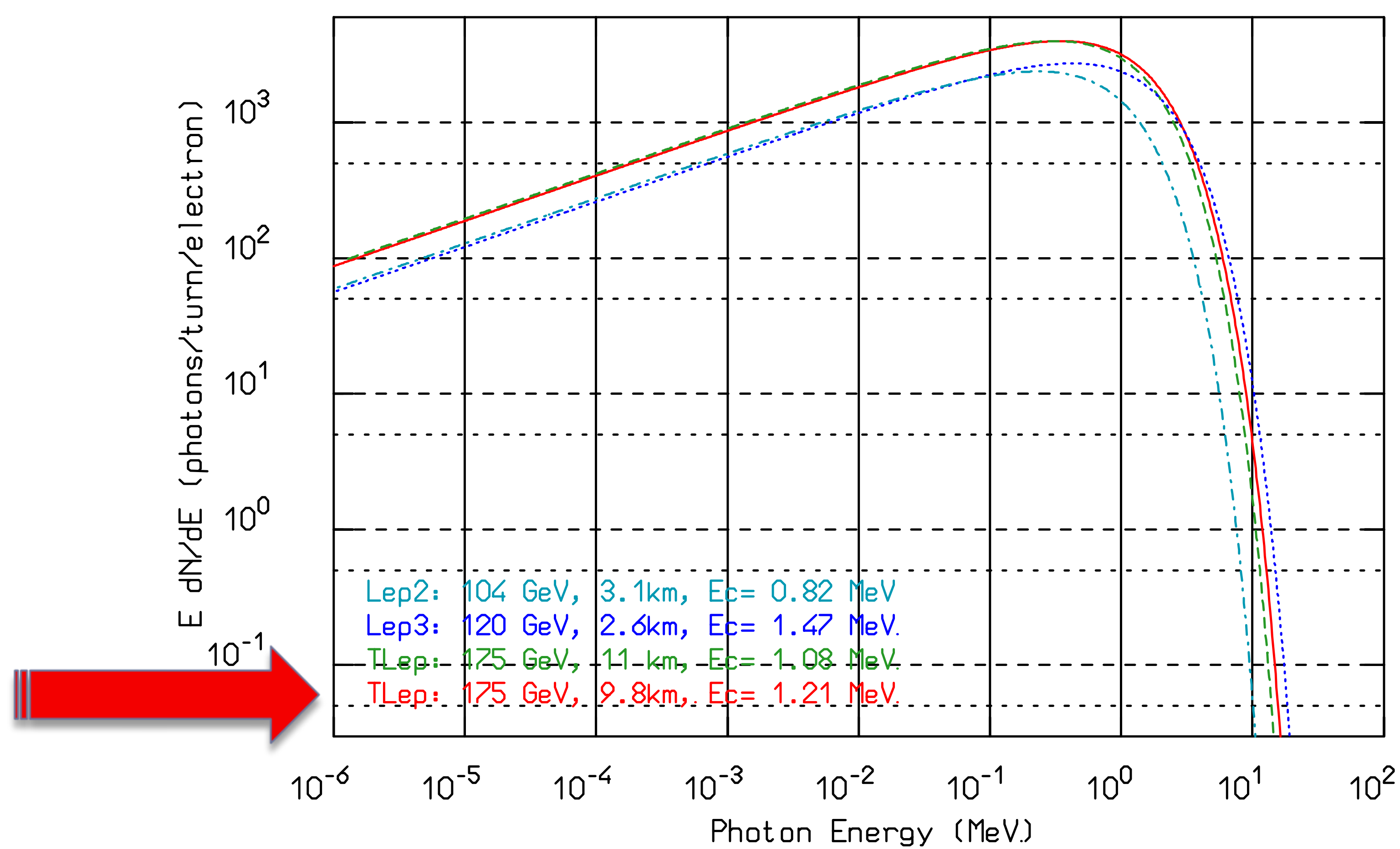
1. A few reminders about Synchrotron Radiation
2. FLUKA implementation
3. Some geometrical considerations
4. Results
5. Conclusions & Future works

SR Emission

Presented by A. Ferrari at the 4th TLEP workshop (April 2013)



SR Emission


E dN/dE (photons/turn/electron)
Photon Energy (MeV)
Lep2: 104 GeV, 3.1km, Ec= 0.82 MeV
Lep3: 120 GeV, 2.6km, Ec= 1.47 MeV.
TLep: 175 GeV, 11 km, Ec= 1.08 MeV.
TLep: 175 GeV, 9.8km,. Ec= 1.21 MeV.

Fluka implementation of SR

Engineering Department

FLUKA implementation of SR

- Sophisticated low energy photon transport including polarization effects for Compton (see next slide), photoelectric and coherent scattering, and full account for bound electron effects: already available in FLUKA since several years
- New: dedicated "generic" source for SR radiation accounting for:
  - ✓ Spectrum sampling
  - ✓ Polarization as a function of emitted photon energy
  - ✓ Angular distribution
  - ✓ Arbitrary orientation emitting particle vs magnetic field
  - ✓ Photon emission along arcs/helical paths

5 Alfredo Ferrari, Tlep workshop 4/4/2013

NEW

For more details see A. Ferrari at the 4th TLEP workshop (April 2013)

Assumed parameters

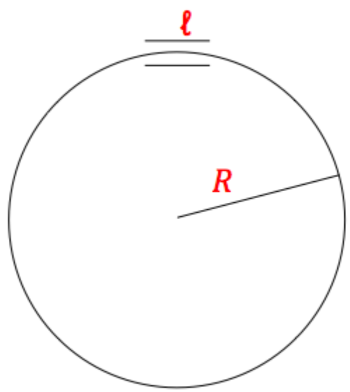
- E_{e-} =175 GeV → 80km machine;
- Radius at the dipole = 9.8 km → 81% Bending Magnets;
- E_{crit}= 1.21 MeV;
- ΔE= 9 GeV/turn,
  - dE/ds=1.39 keV/cm in the dipoles
- P = 9 x I[mA] MW = 9 x 10mA = 90 MW in the whole accelerator;
  - dP/ds= 1.39 x I[mA] W/cm in the dipoles
- SR photons generated and tracked above 100 eV (99.999% of the total power), average energy of the photons <E>=400 keV (E>100 eV) ;

The starting idea

Presented by A. Ferrari at the 4th TLEP workshop (April 2013)

EN Engineering Department

Synchrotron Radiation Interception



R accelerator bending radius

ℓ dipole length r vacuum chamber radius

SR hitting inside the same dipole only if $\ell > \sqrt{2\, r\, R}$

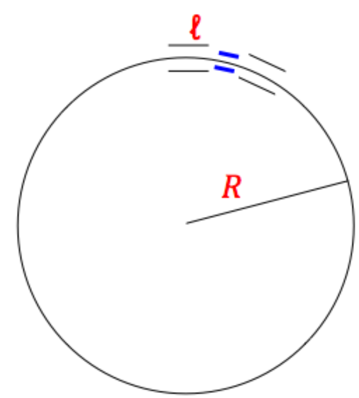
for R= 9 km and r= 4.5 cm ℓ > 28.5 m

for R= 3.1 km and r= 6.5 cm (LEP2) ℓ > 20 m

totally escaping (→ hitting downstream elements) for shorter dipoles

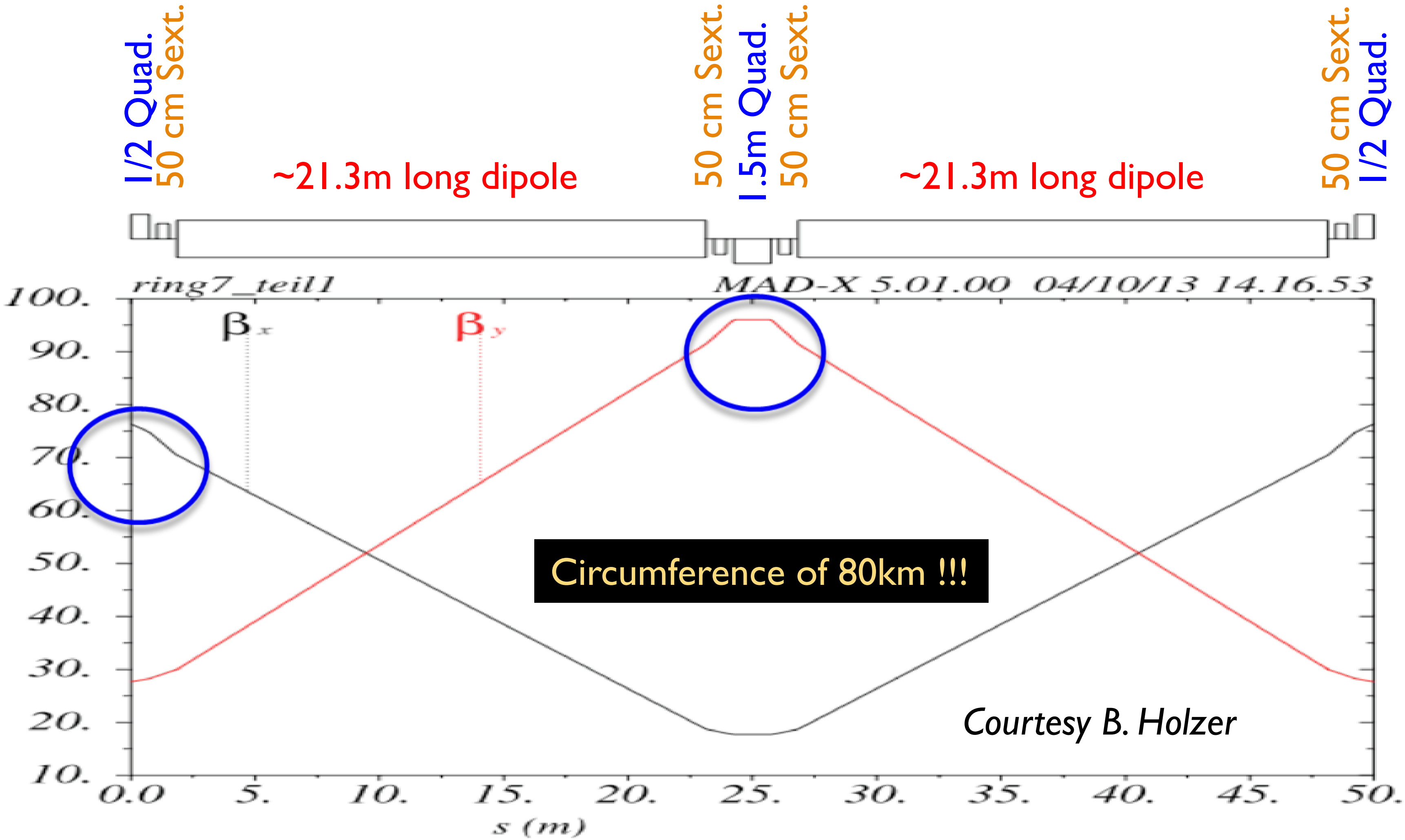
Pb shielding in the interconnects ?

For the time being: impact angle as for "curved" geometry (eg, very short magnets, or very long curved ones)

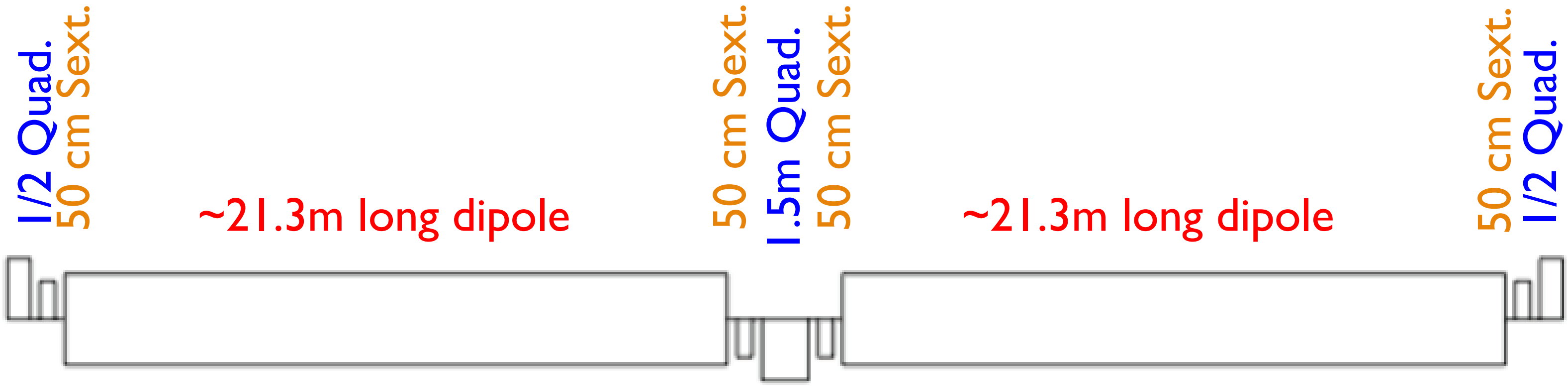


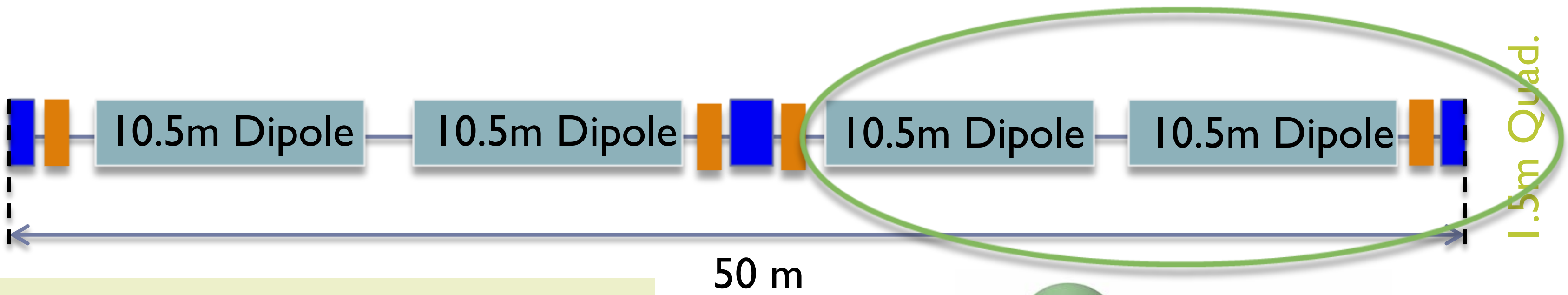
Alfredo Ferrari, Tlep workshop 8 4/4/2013

Preliminary layout of 1 FODO cell for TLEP



Preliminary layout of 1 FODO cell for TLEP

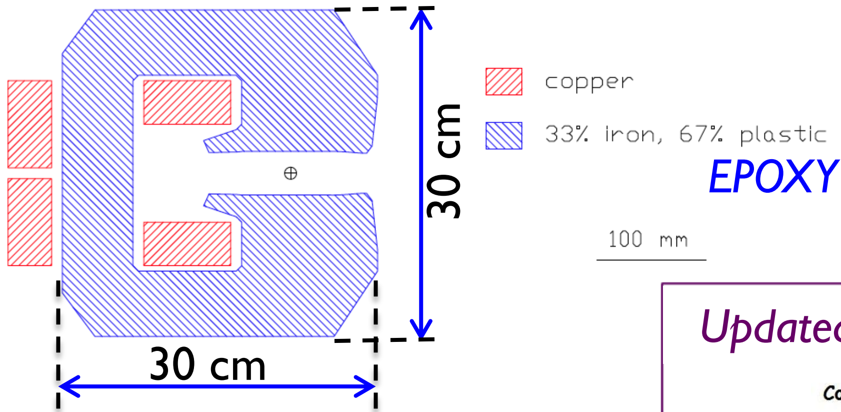




Note that Sextupoles were not yet considered in the actual Fluka model

50m -4*10.5m -2*1.5m -4*0.5m= 3 m → 3/10 =0.3m each interconnect

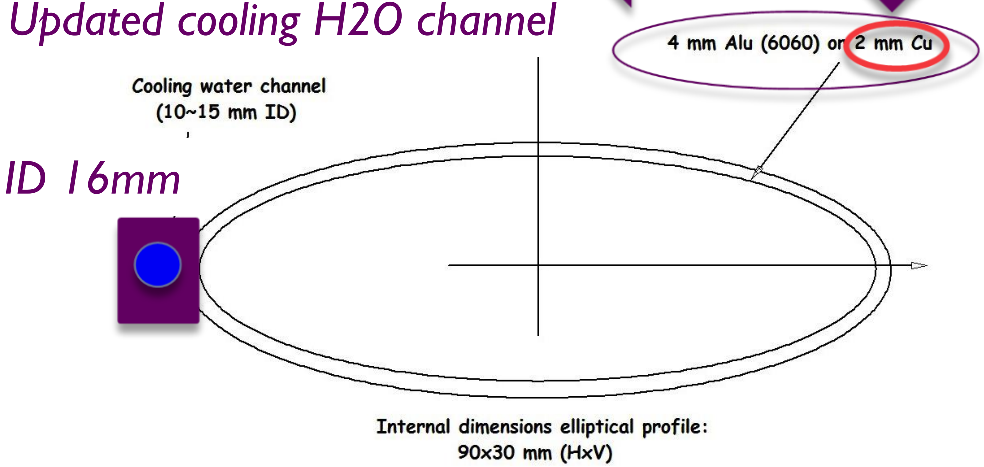
Preliminary layout



Courtesy A. Milanese

2 proposed materials for the beam pipe

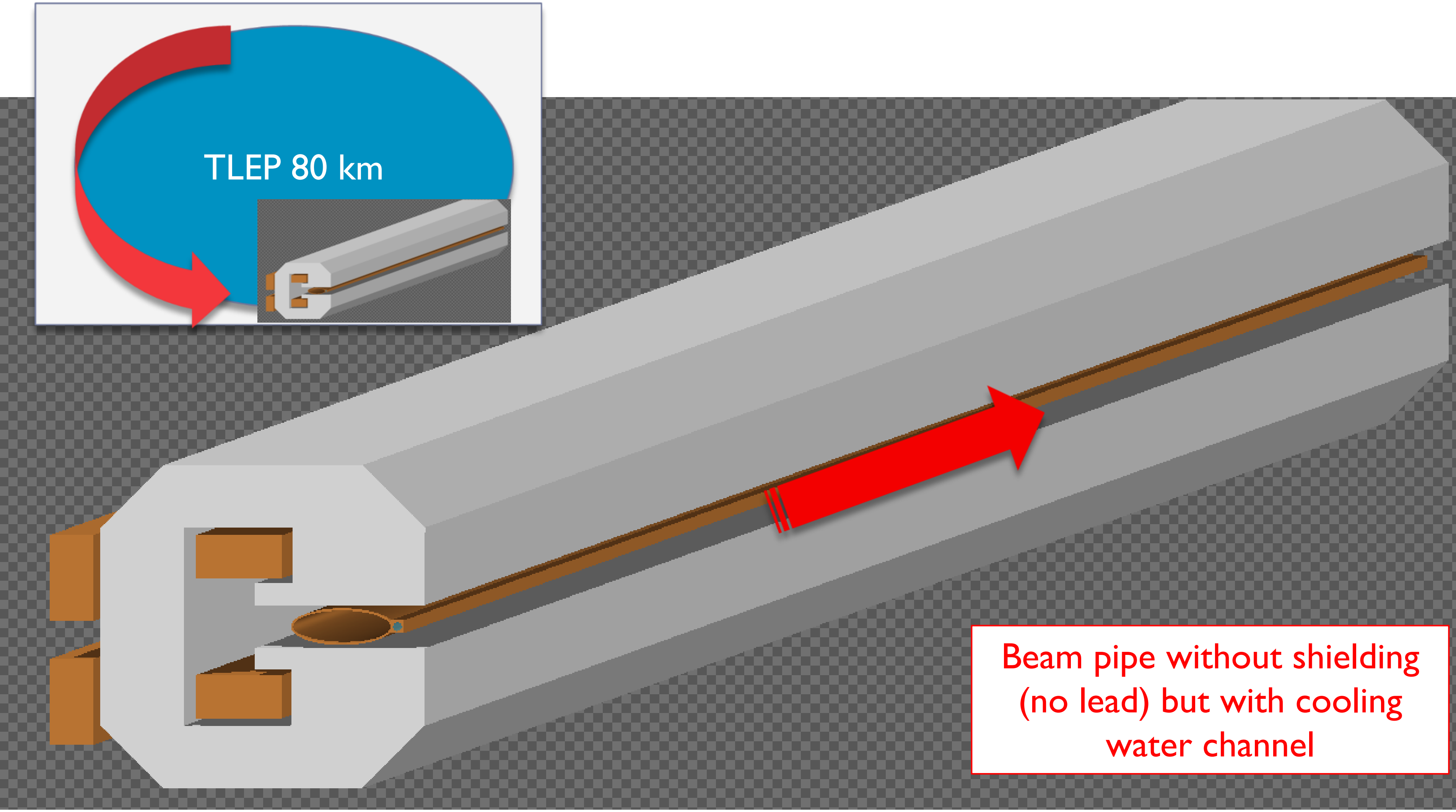
Updated cooling H2O channel



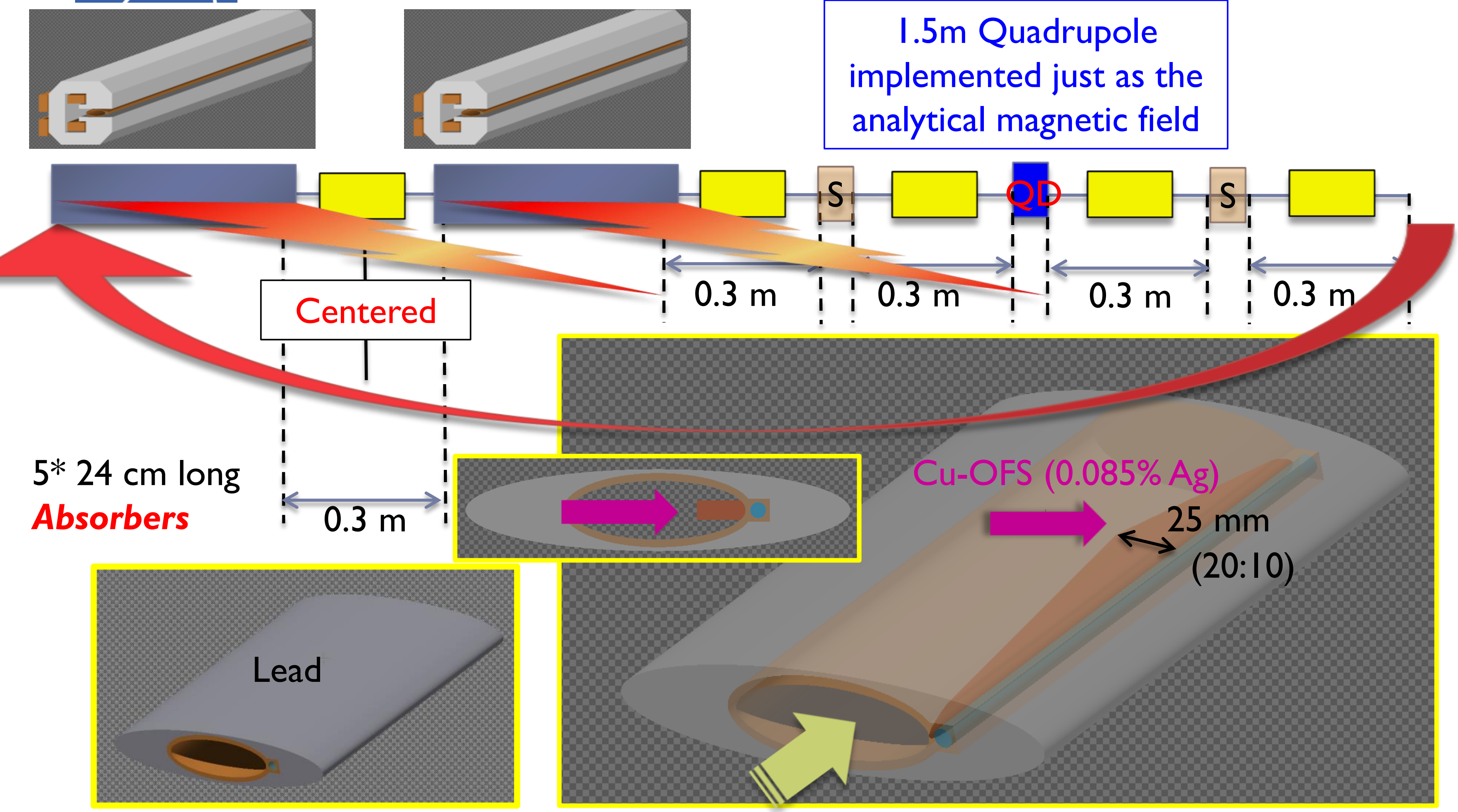
Courtesy R. Kersevan

Not yet an available quad. design → but the B yes!
Courtesy B. Holzer

10.5 m long dipole for 1 Beam line

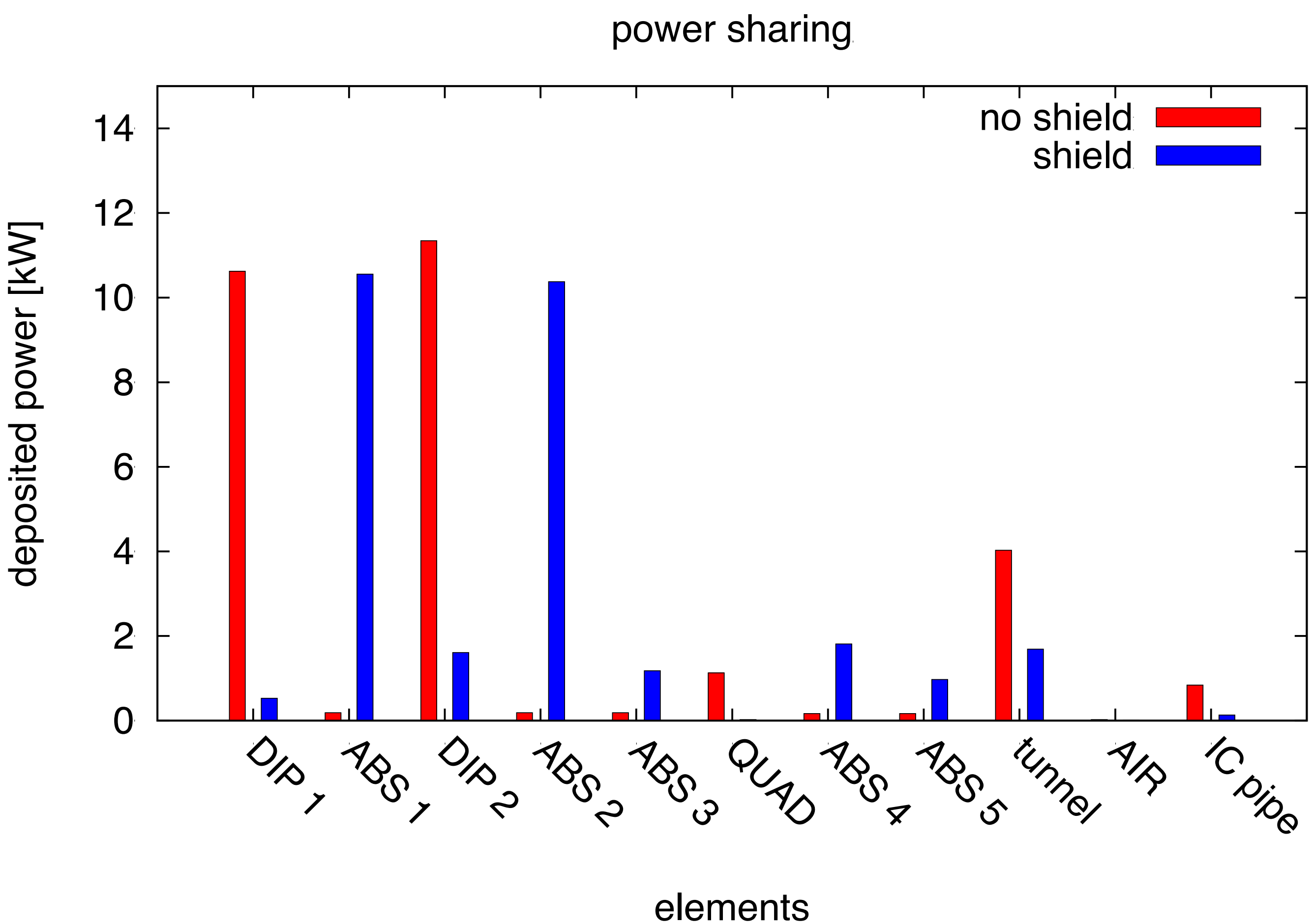


FLUKA model: summarizing



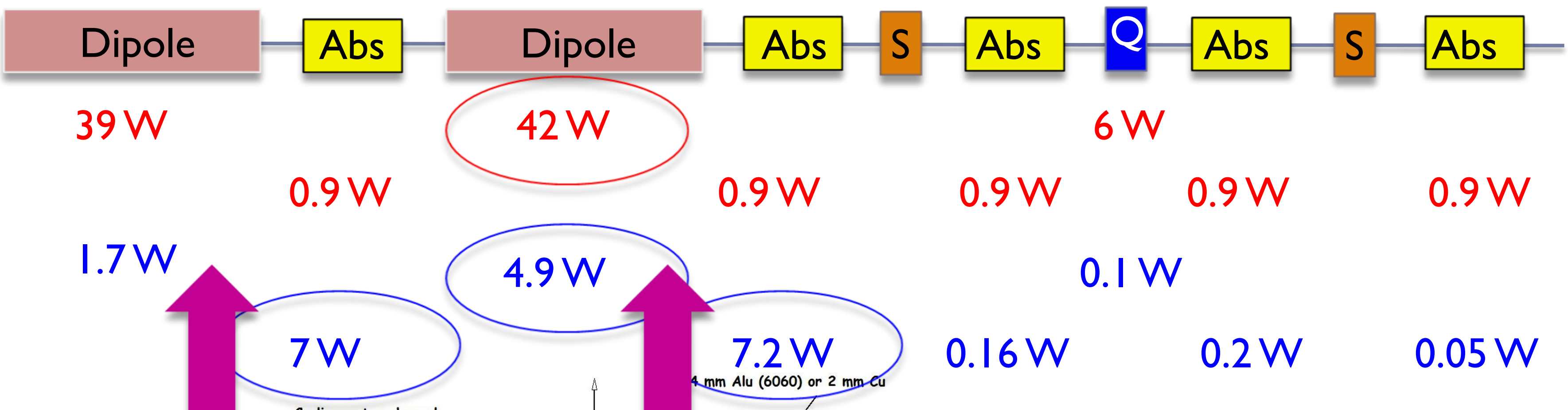
Total power

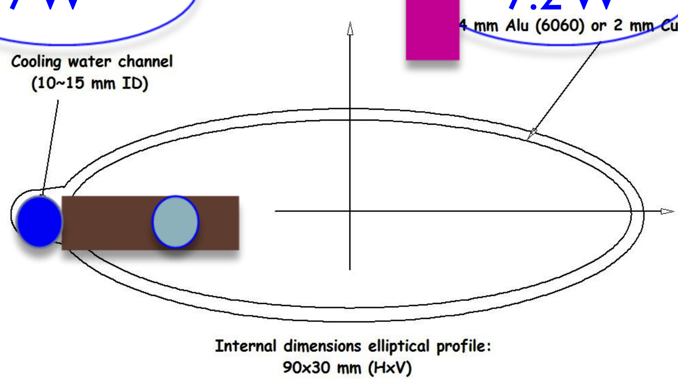
All results take into account a Beam current = 10 [mA]



H2O channel

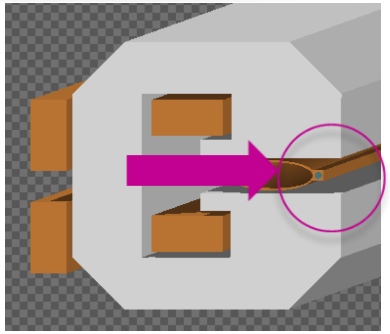
- Power in the H20 for all the ABSORBERS: 14.7 W (shield) and 4.5 W (no shield)
- Power in the H20 for all the MAGNETS: 6.7 W (shield) and 87 W (no shield)



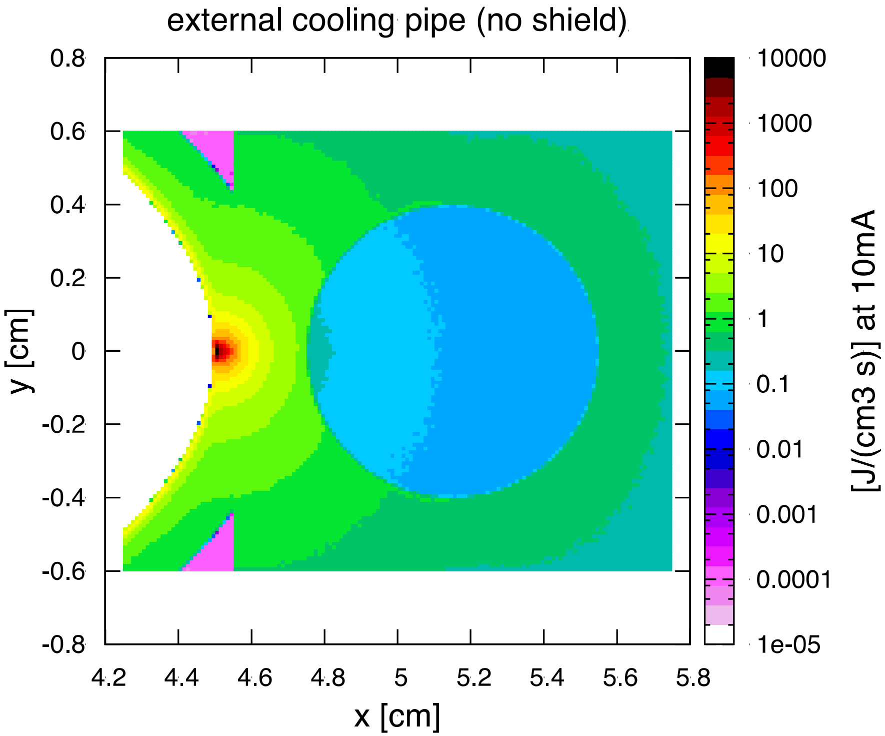


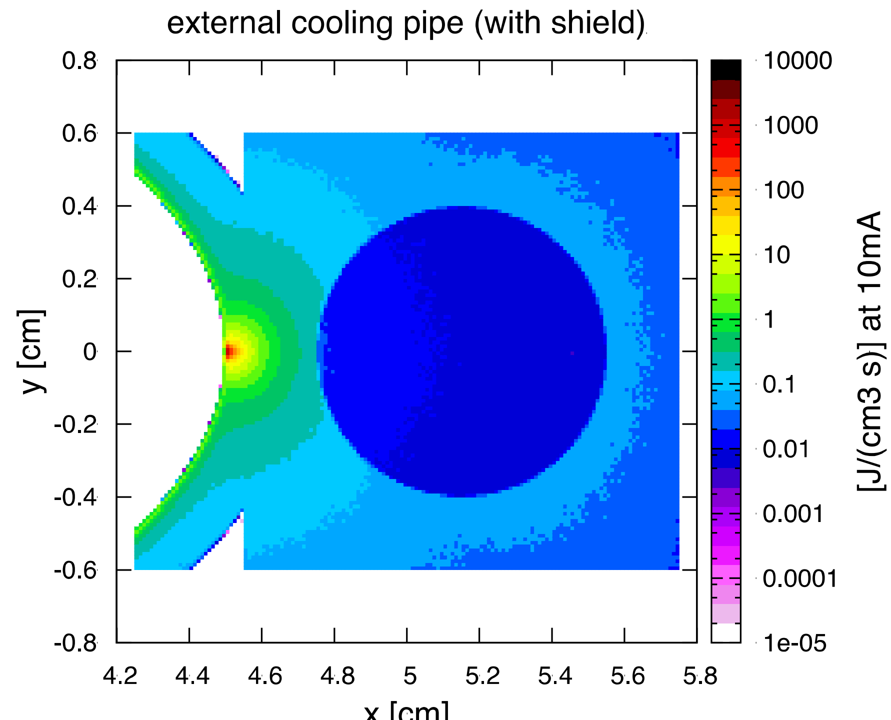
Heating of the in-pipe shield: need to move the H2O channel further in ?

Power density in the dipole beam-pipe

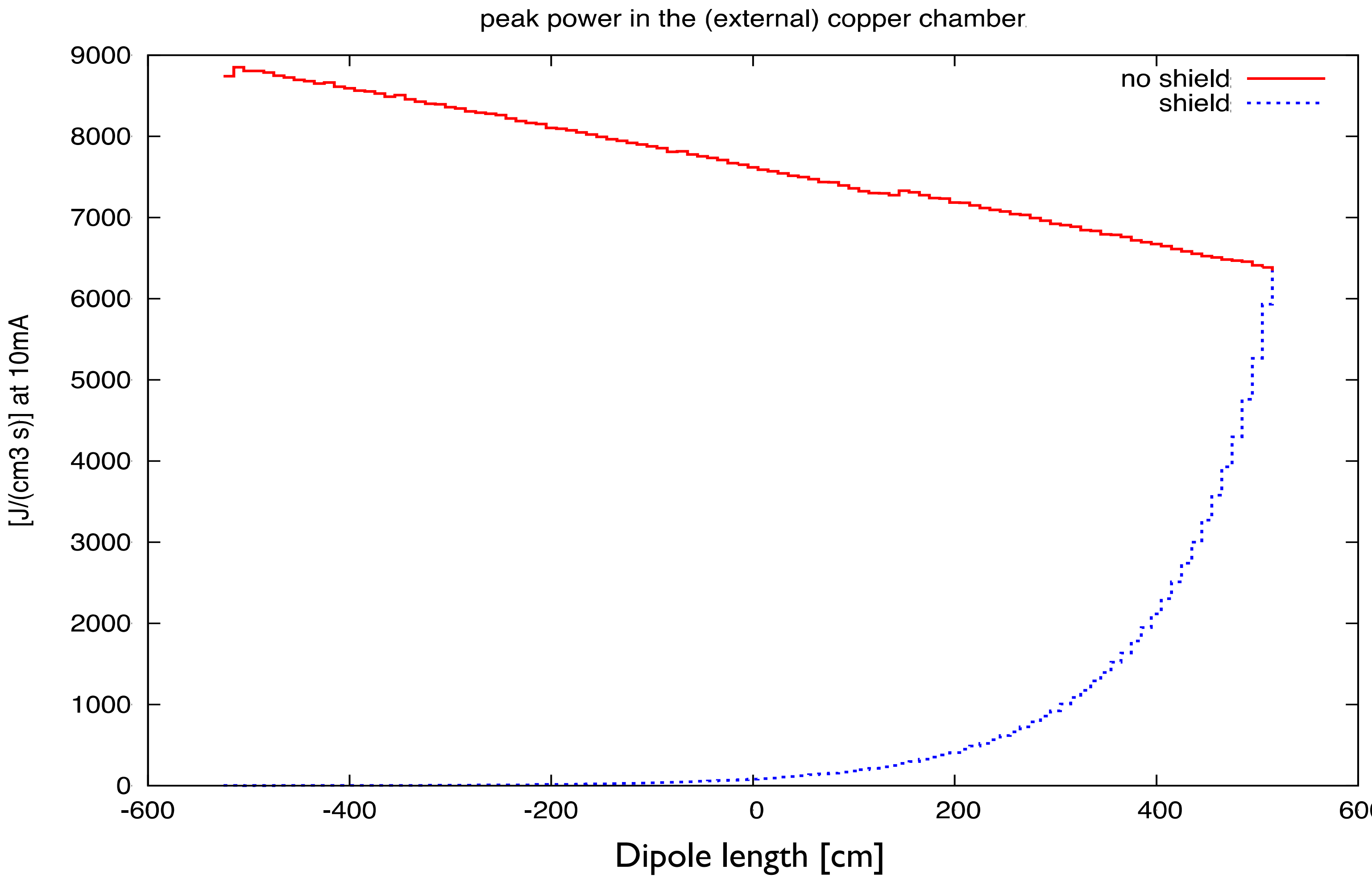


Averaged along the Dipole length

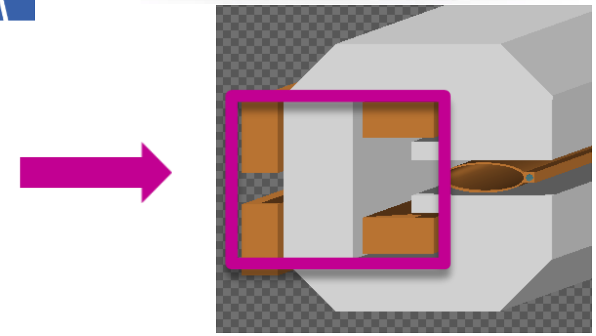




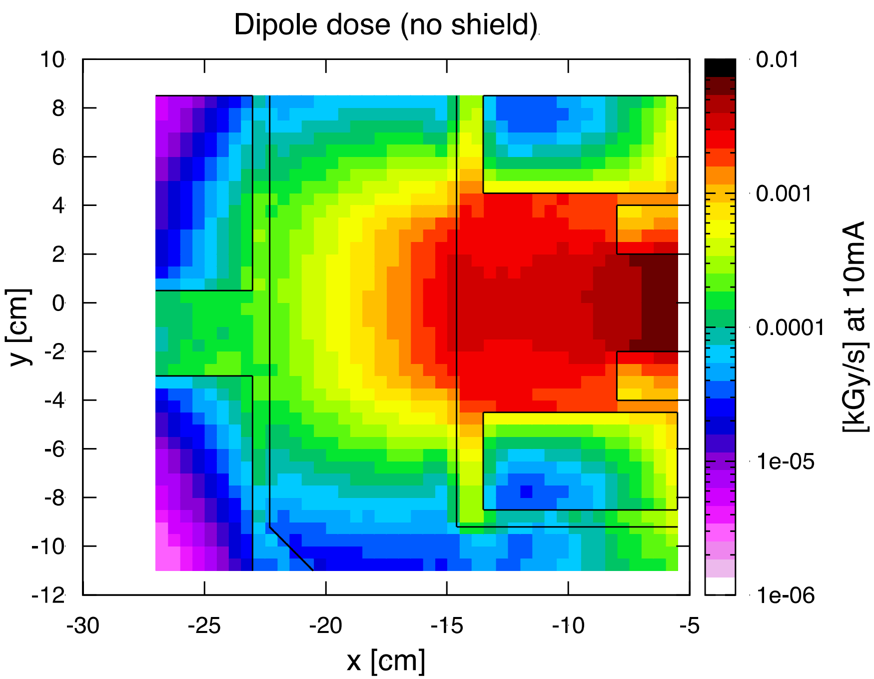
Peak power density in the dipole beam-pipe

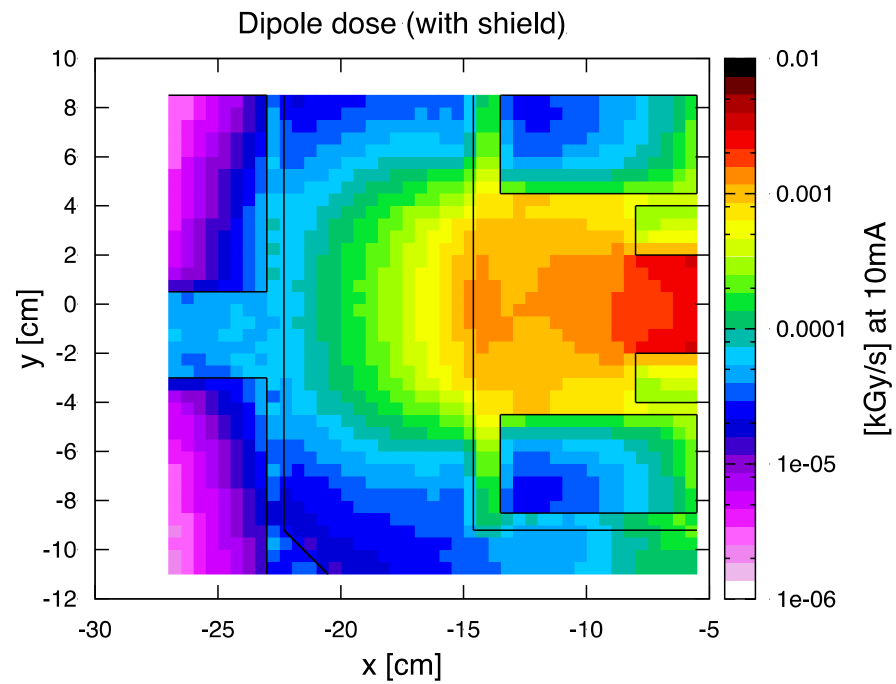


Dose in the coils

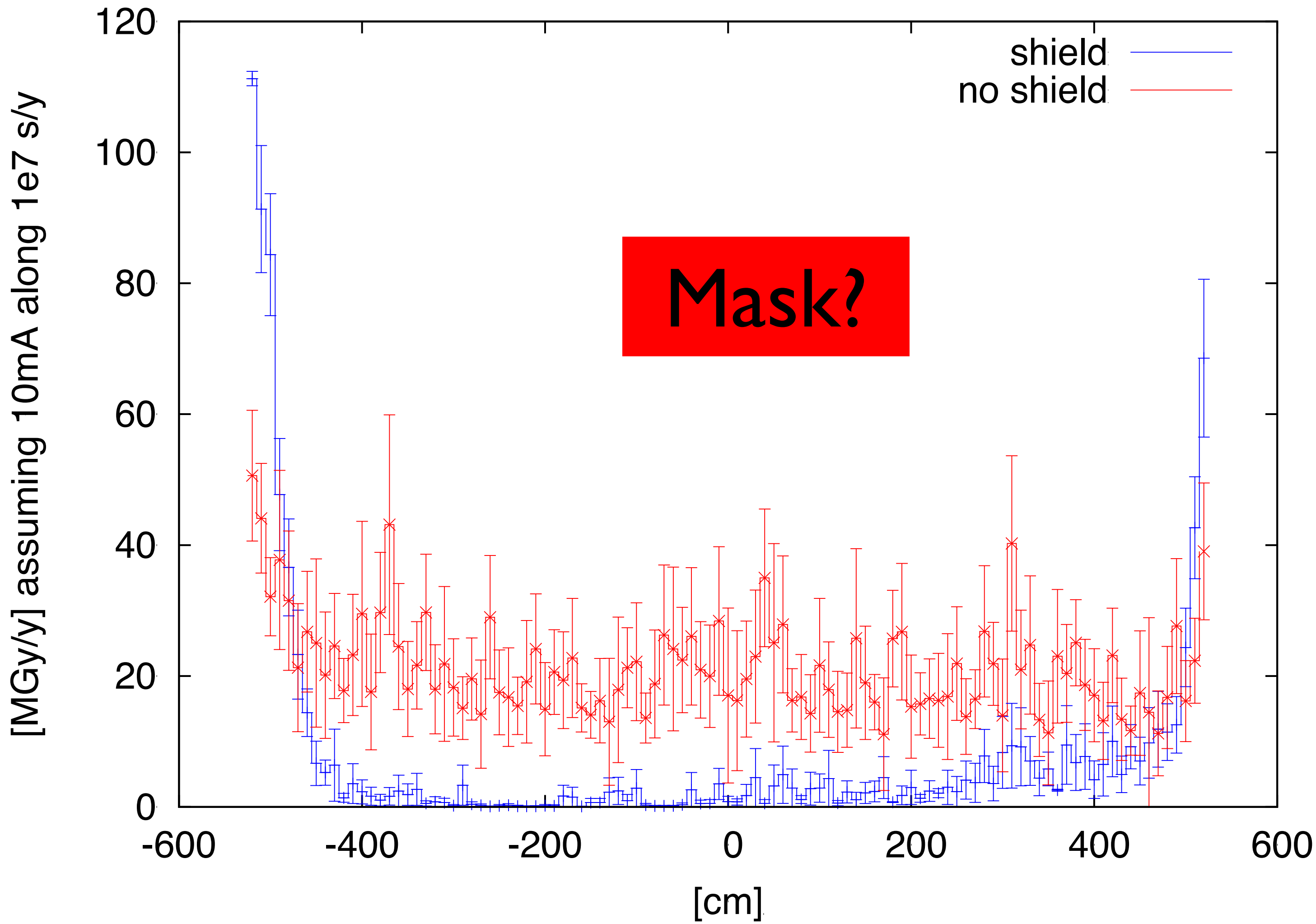


Averaged along the Dipole length





Peak Dose on the coils



Ozone production

Adapted from NCRP Report 51, under the assumption of no O_3 dissociation over the air renewal time τ_{vent} :

$$C_{O_3} = \frac{C_{O_2} G P_{eV} \tau_{vent}}{N_{Av}\left(\frac{\rho_{Air} V}{P_{Air}}\right)}\left(1-e^{-\frac{t}{\tau_{vent}}}\right)$$

$$C_{O_2} = 0.232 \quad G = 0.06\ [O_3/eV] \quad N_{Av}\frac{\rho_{Air}}{P_{Air}} @ NTP = 2.50\cdot10^{19}\,[\text{molecules/cm}^3]$$

$$P_{eV}\,[\text{eV/s}] = 6.24\cdot10^{18}\,P[\text{W}] \qquad \dot{r} = \frac{1}{\tau_{vent}}[\text{air renewal/s}]$$

$$C_{O_3}[\text{ppm}] = 3.47\cdot10^{3}\,\frac{P[\text{W}]\tau_{vent}[s]}{V[\text{cm}^3]}\left(1-e^{-\frac{t}{\tau_{vent}}}\right)$$

Corrosion of the materials?

For example, for P=10 W, $V\sim10^8$ cm^3, $\tau_{vent}\sim10$ h → at saturation $C_{O3}\sim12$ ppm

Conclusions

- For SR emission the effects of absorbers were shown for the 80km TLEP option.
  - A considerable reduction of the power deposited into the dipoles, in particular thanks to the absorbers immediately downstream of the dipoles.
  - Not a critical integrated energy into the water channels with and without absorbers.
  - A factor of 10 difference with and without absorbers for the power density in the dipole beam pipe and for the dose on the coils. Masks?
  - Ozone production has to be carefully considered for limiting the corrosion of the materials. Limits?

Future work

- Possible follow-up:
  - Other magnets design for dipoles, quadrupoles and sextupoles.

See also L. Rossi at the 3rd TLEP workshop (January 2013)

  - Following impedance considerations, an updated version of the in-pipe shielding with possible different integration of the water cooling channel into the absorbers.
  - Changing the orientation of the dipoles could be a gain for the ozone but not for the coils.