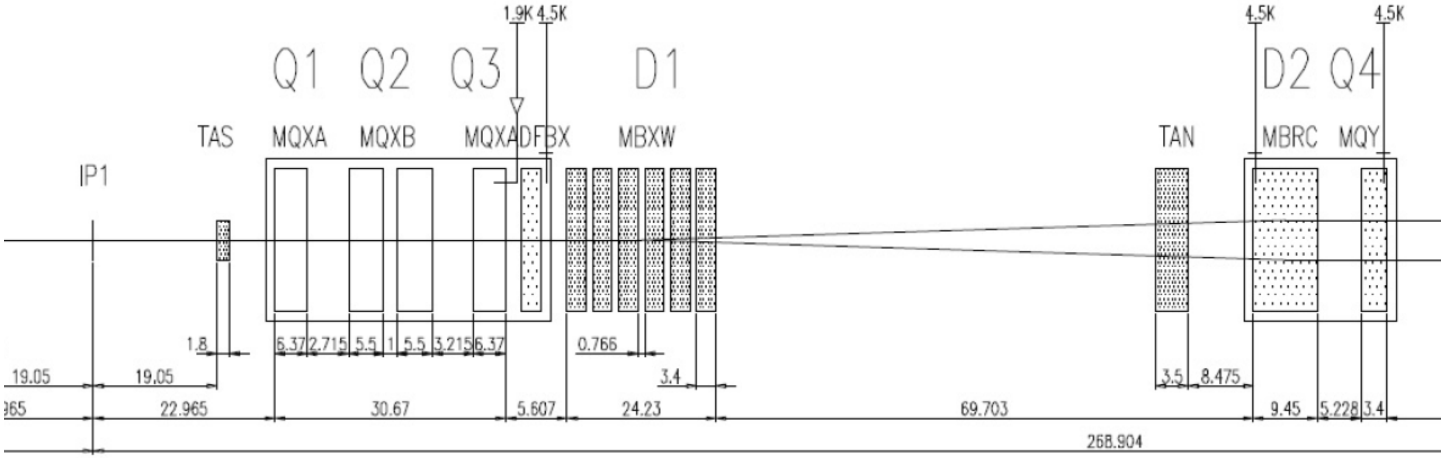
ENERGY DEPOSITION
IN THE LHC HIGH LUMINOSITY INSERTIONS



F. Borgnolutti, F. Broggi, F. Cerutti, A. Ferrari,

M. Mauri, A. Mereghetti, E. Todesco, E. Wildner

INFN, Milan *CERN, Geneva*

OUTLINE

- characterization of the collision debris
- magnetic field effect
- parametric study (magnet length - coil aperture - triplet gradient)
- shielding solutions
- crossing scheme effect
- use of increasing apertures (shadowing)
- damage to the coils
- radiation to electronics equipment (SEE)

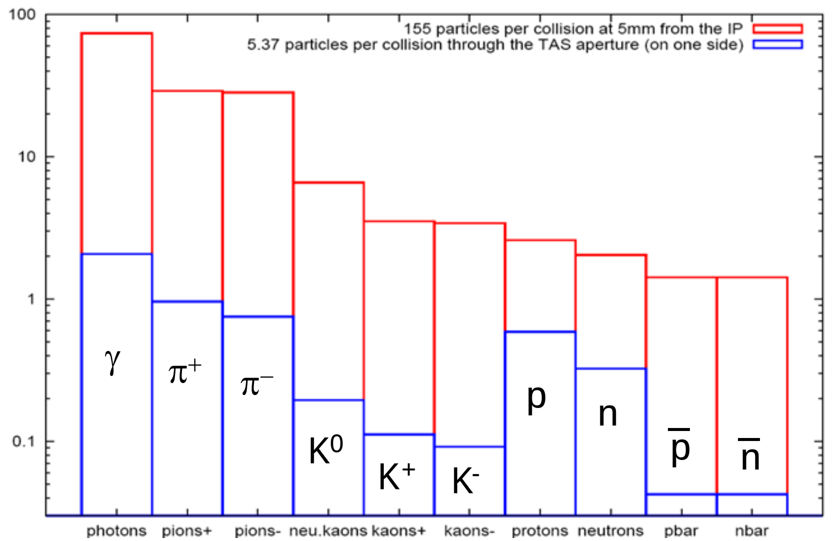
calculations carried out with FLUKA (using DPMJET as event generator for p+p collisions)

evaluation of peak power in Nb-Ti cable relevant to *quench*
made over a minimum volume of thermal equilibrium
(corresponding to cable transverse dimensions and twist pitch)

RADIATION FIELD FROM LHC COLLISIONS

7 TeV p + 7 TeV p

(with 225urad half crossing angle)



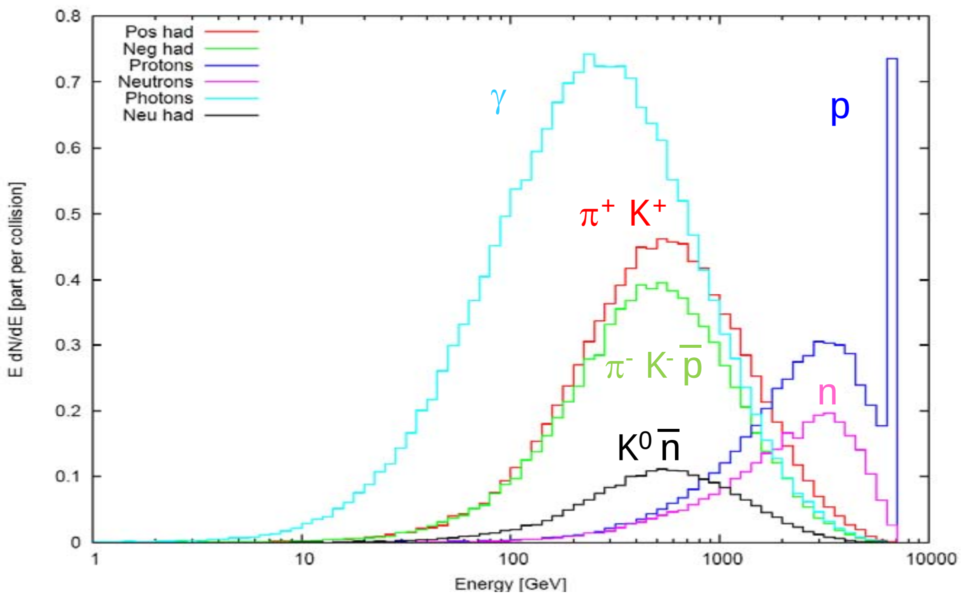
spectra of particles

through the TAS aperture

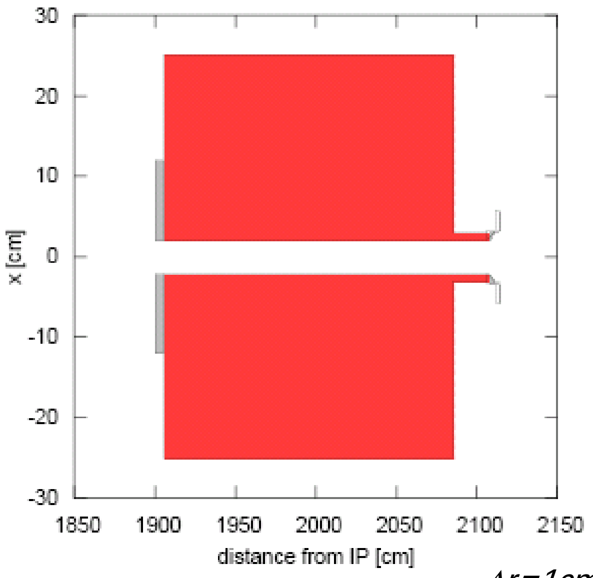
mainly

photons pions

high energy protons and neutrons



TAS



Phase I Upgrade

($L=2.5L_0$)

55mm TAS aperture -> 130mm triplet coil aperture

peak power 114 mW/cm³

total power 325 W (out of 2240 W)

45mm TAS aperture -> 110mm triplet coil aperture

peak power 180 mW/cm³

total power 385 W (out of 2240 W)

Δr=1cm x $\Delta\varphi$=2° x Δz=2cm scoring grid

present LHC ($L=L_0=10^{34}cm^{-2}s^{-1}$)	34mm TAS aperture peak power 110 mW/cm³ total power 184 W (out of 896 W)	*N.V. Mokhov et al., LHC Project Report 633*

significant protection for Q1 only *(and reducing backscattering to the experiments)*

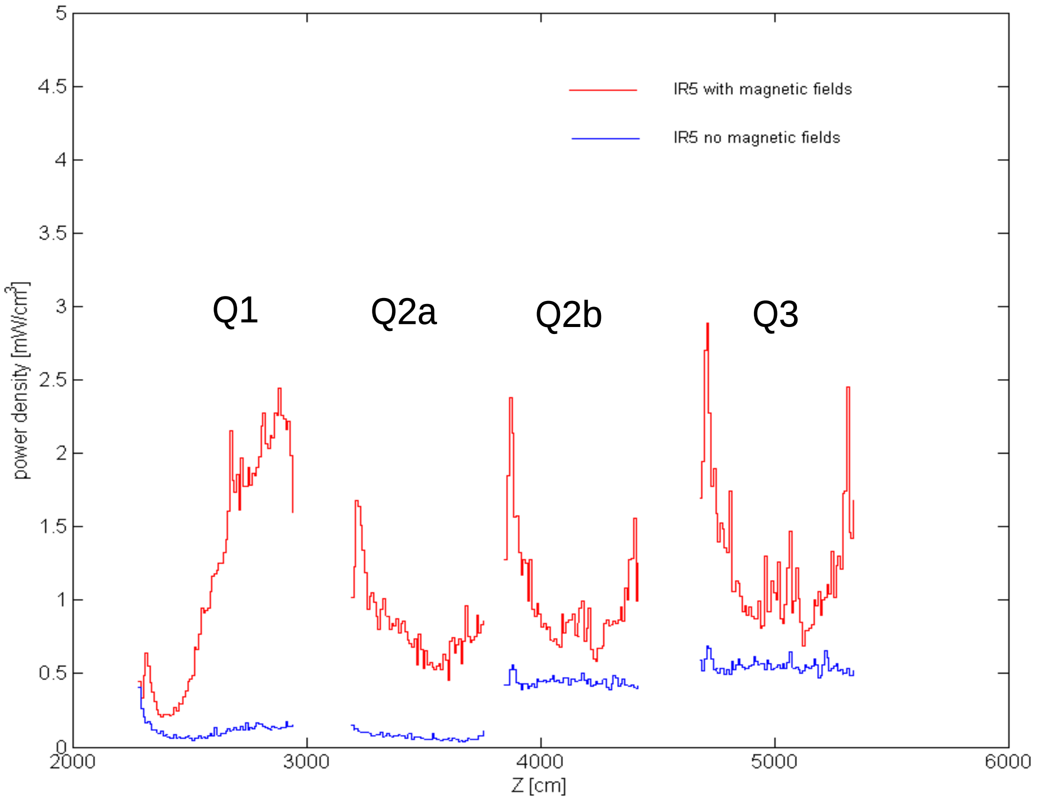
EFFECT OF THE TRIPLET MAGNETIC FIELD

present
LHC
(L=L_0)

34mm TAS aperture

triplet gradient

204 T/m



142.5 urad half crossing angle

C. Hoa et al.,

LHC Project Report to be published

striking effectiveness in capturing debris!

PARAMETRIC STUDY

Aperture (mm)	Gradient (T/m)	L(Q1,Q3) (m)	L(Q2a,b) (m)	Total length (m)
90	156	8.69	7.46	36.2
115	125	9.98	8.42	40.7
130	112	10.81	9.04	43.6
140	104	11.41	9.49	45.7

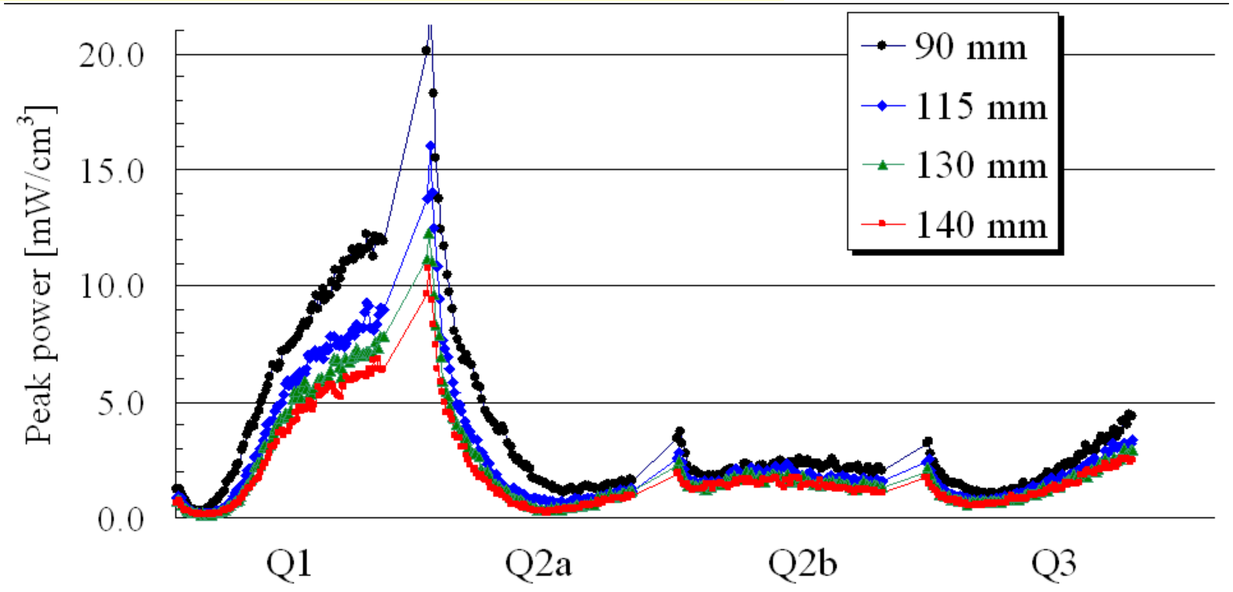
Phase I Upgrade

($L=2.5L_0$)

225 urad half crossing angle

vertical crossing

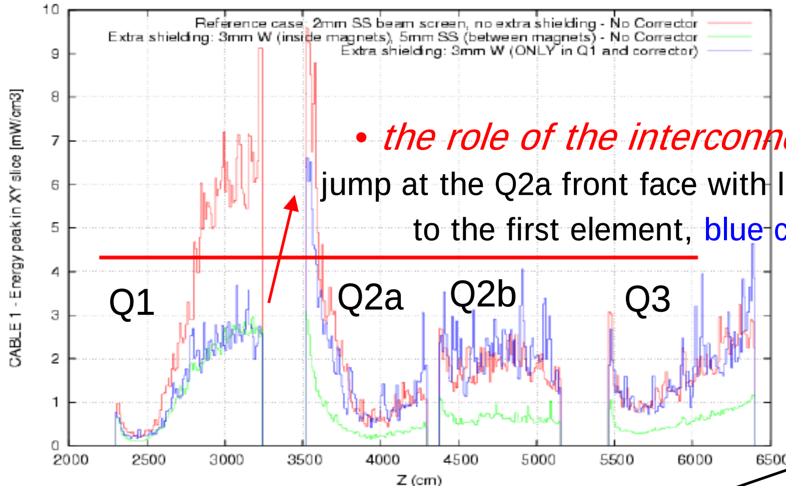
55mm TAS aperture



the longer, the better

SHIELDING OPTIONS

- *ideally* a continuous liner (here 3mm tungsten, green curve) is quite effective

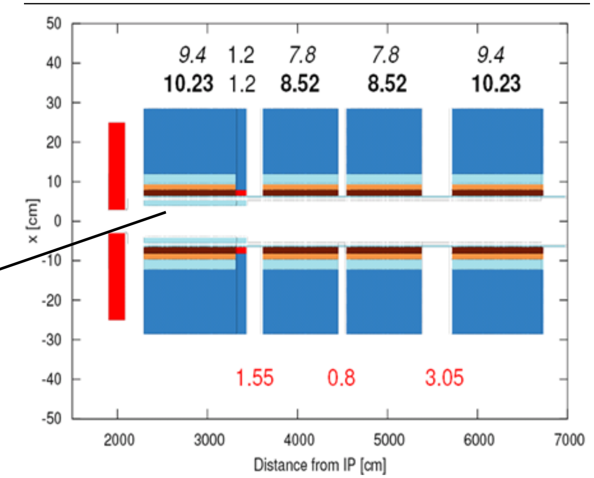


- *the role of the interconnections!*

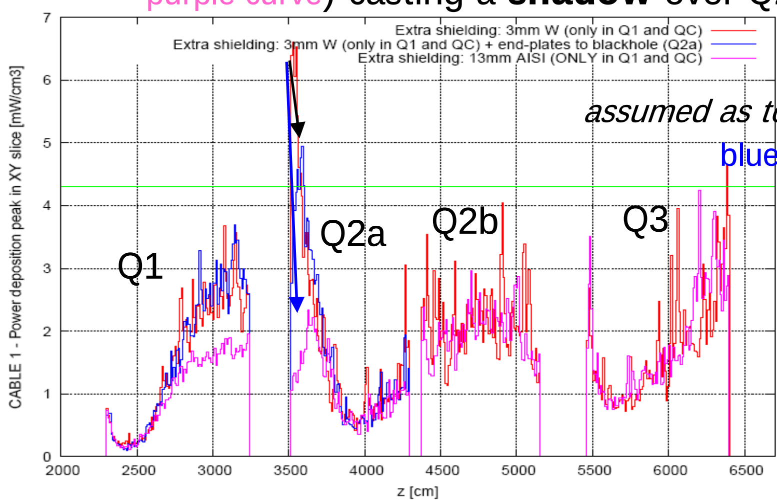
jump at the Q2a front face with liner limited to the first element, blue curve

$L=2.5L_0$

130mm coil aperture

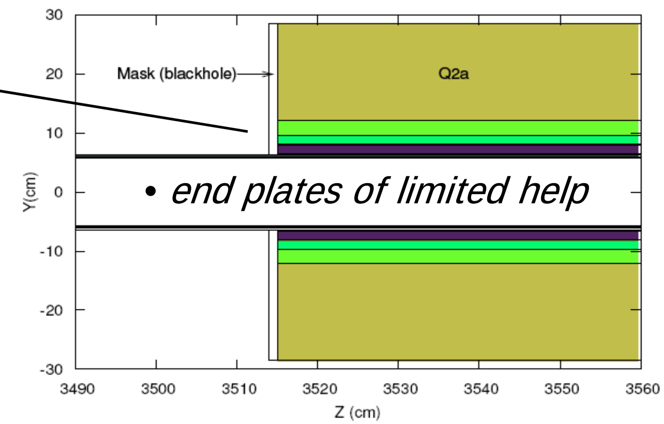


- as an alternative, a thick liner in Q1 (here 13mm stainless steel, purple curve) casting a **shadow** over Q2a



assumed as totally absorbing!

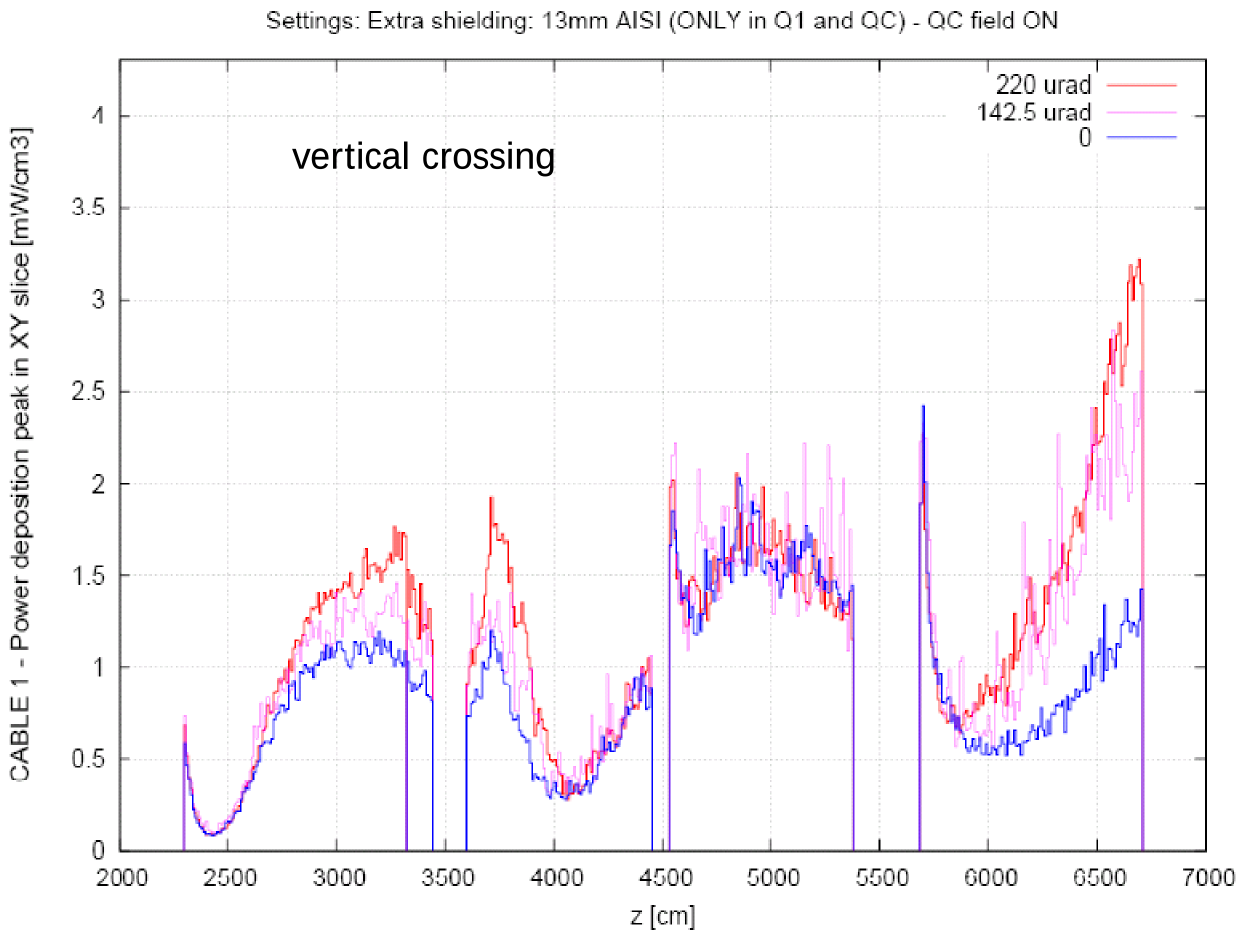
blue curve



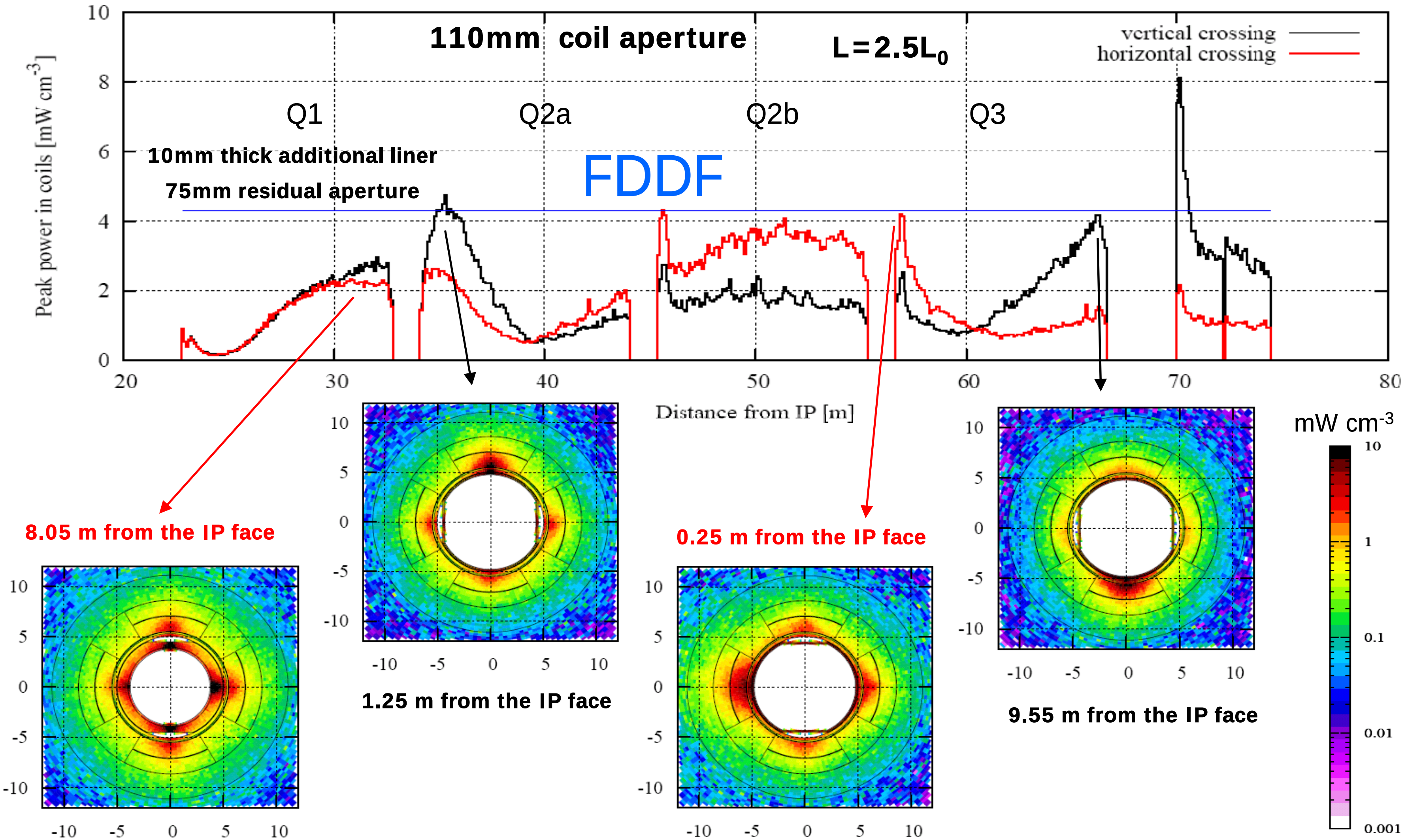
- *end plates of limited help*

CROSSING ANGLE

$L=2.5L_0$



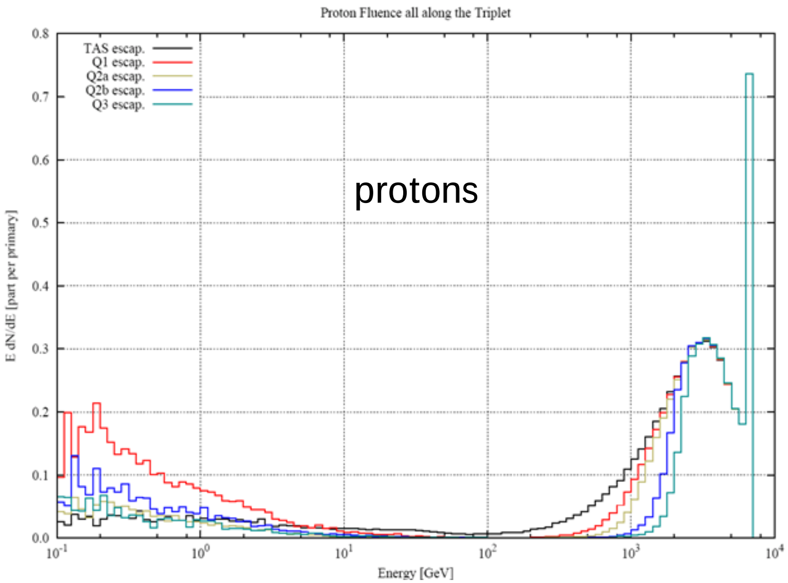
CROSSING SCHEME & TRIPLET CONFIGURATION

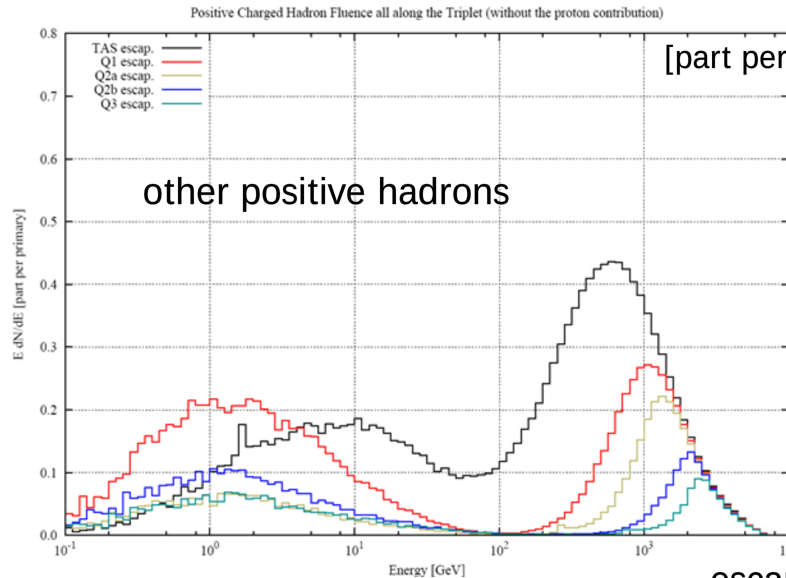


COLLISION DEBRIS EVOLUTION

E dN/dE

[part per collision]





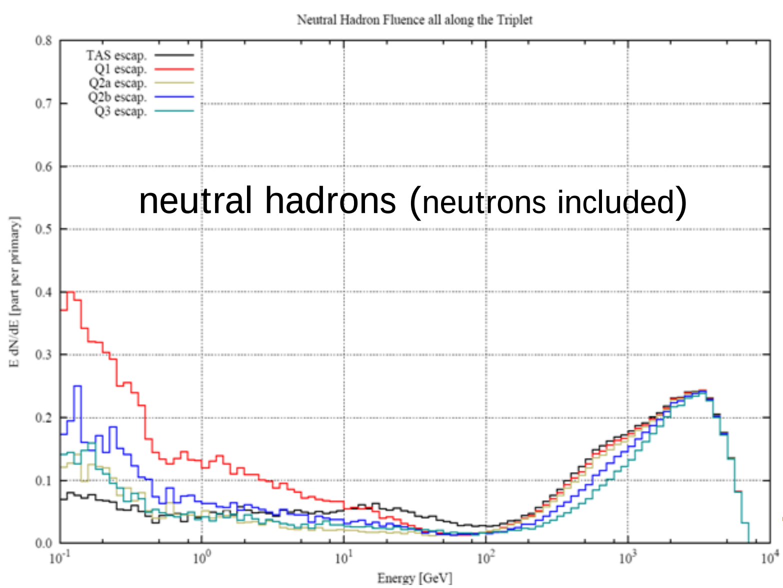
TAS

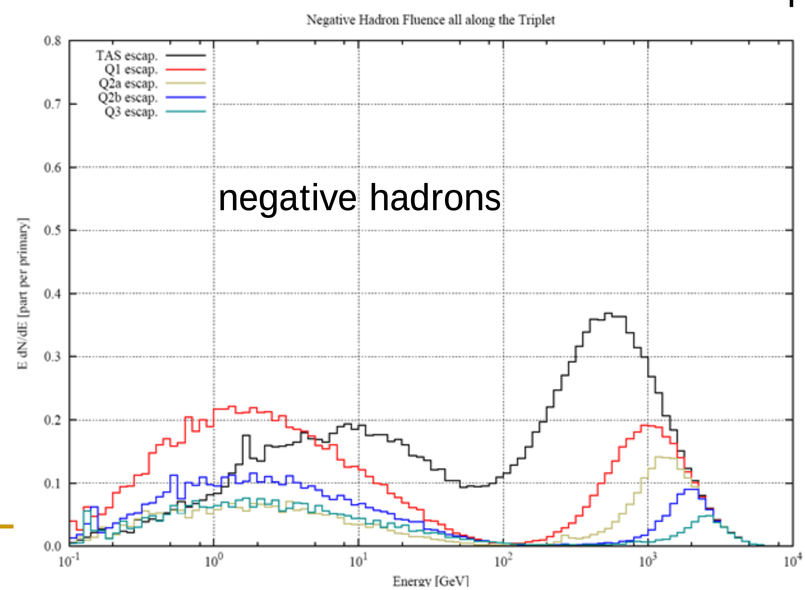
Q1

escaping Q2a

Q2b

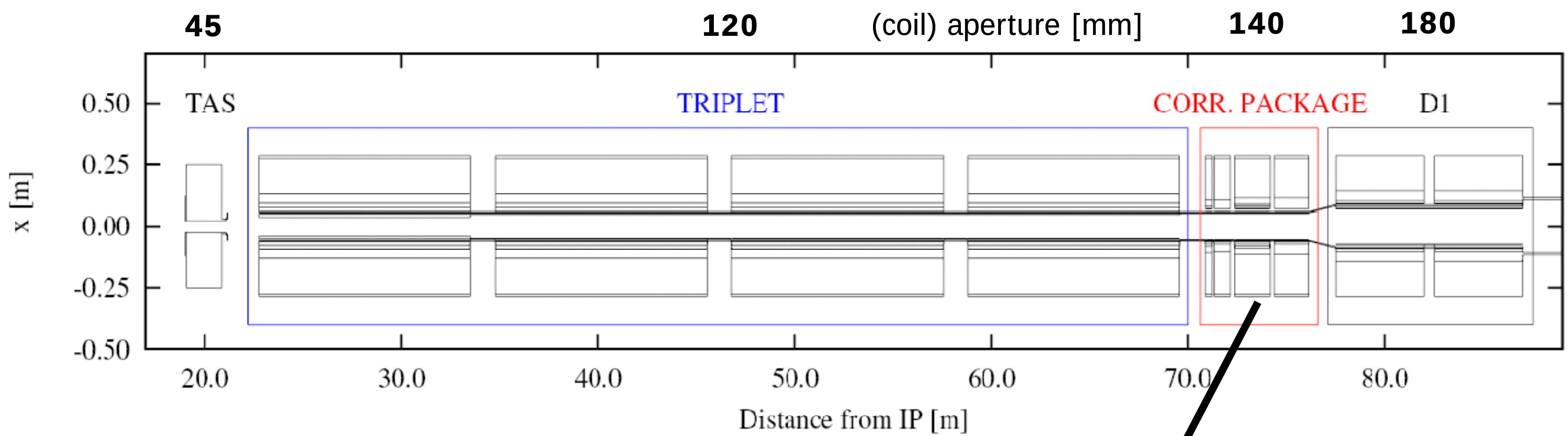
Q3

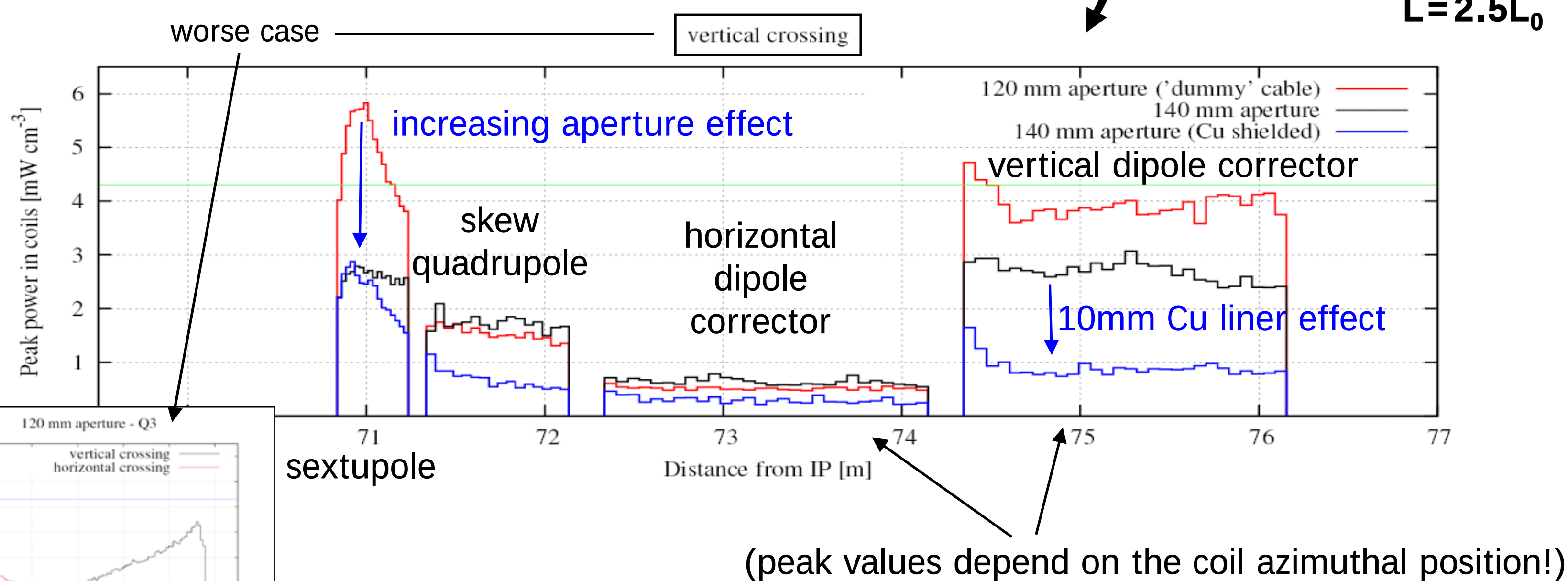


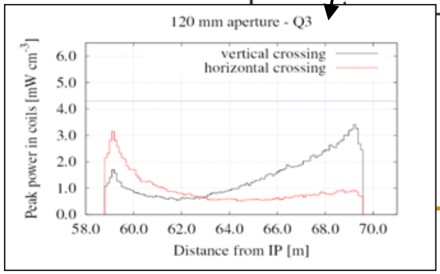


E [GeV]

USE OF INCREASING APERTURES



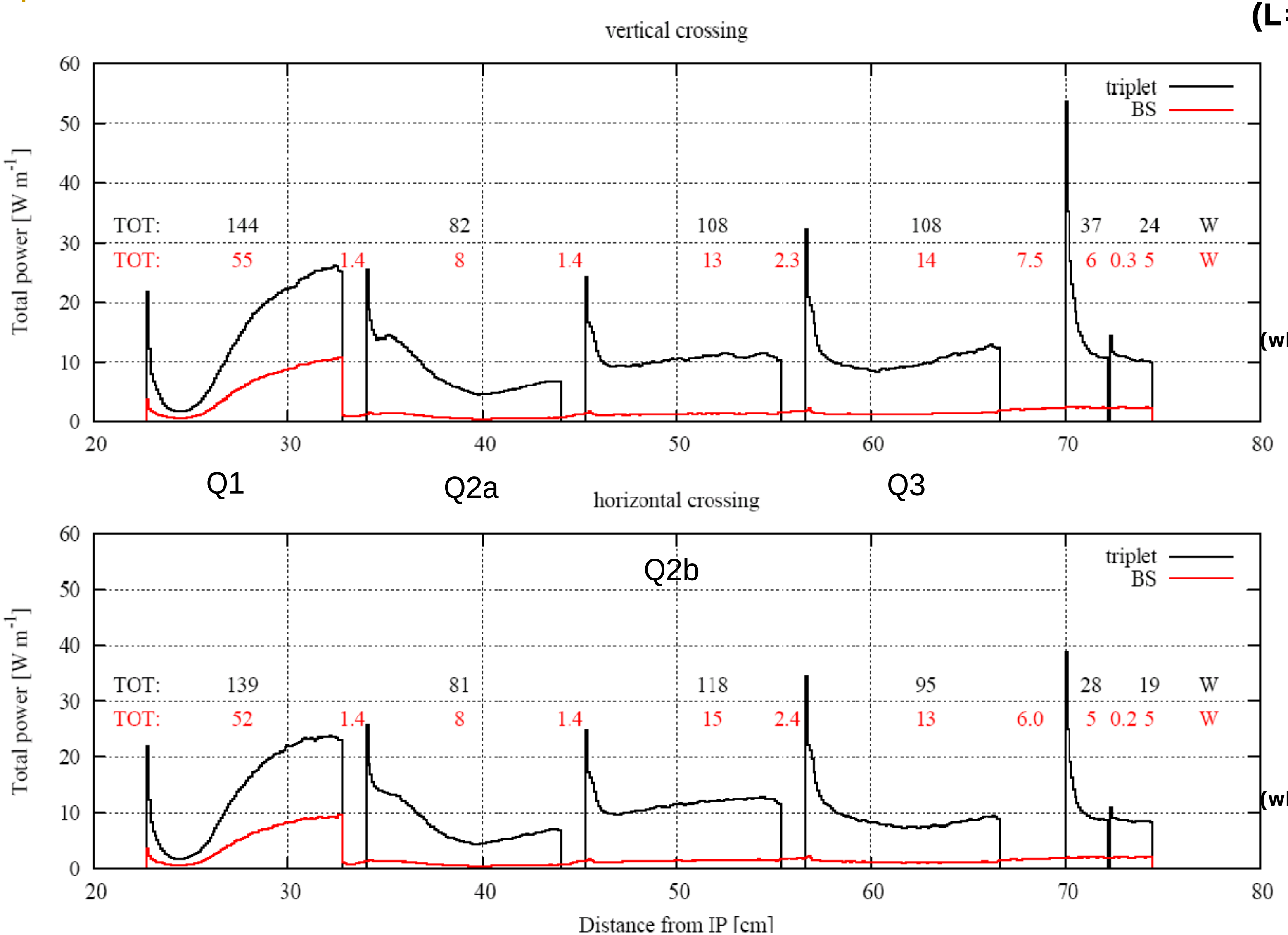




TOTAL POWER LOAD

Phase I Upgrade

($L=2.5L_0$)



BS included
BS only

BS included
BS only 101 W
+12.9 W in the interconnections (where BS is supposed to continue)

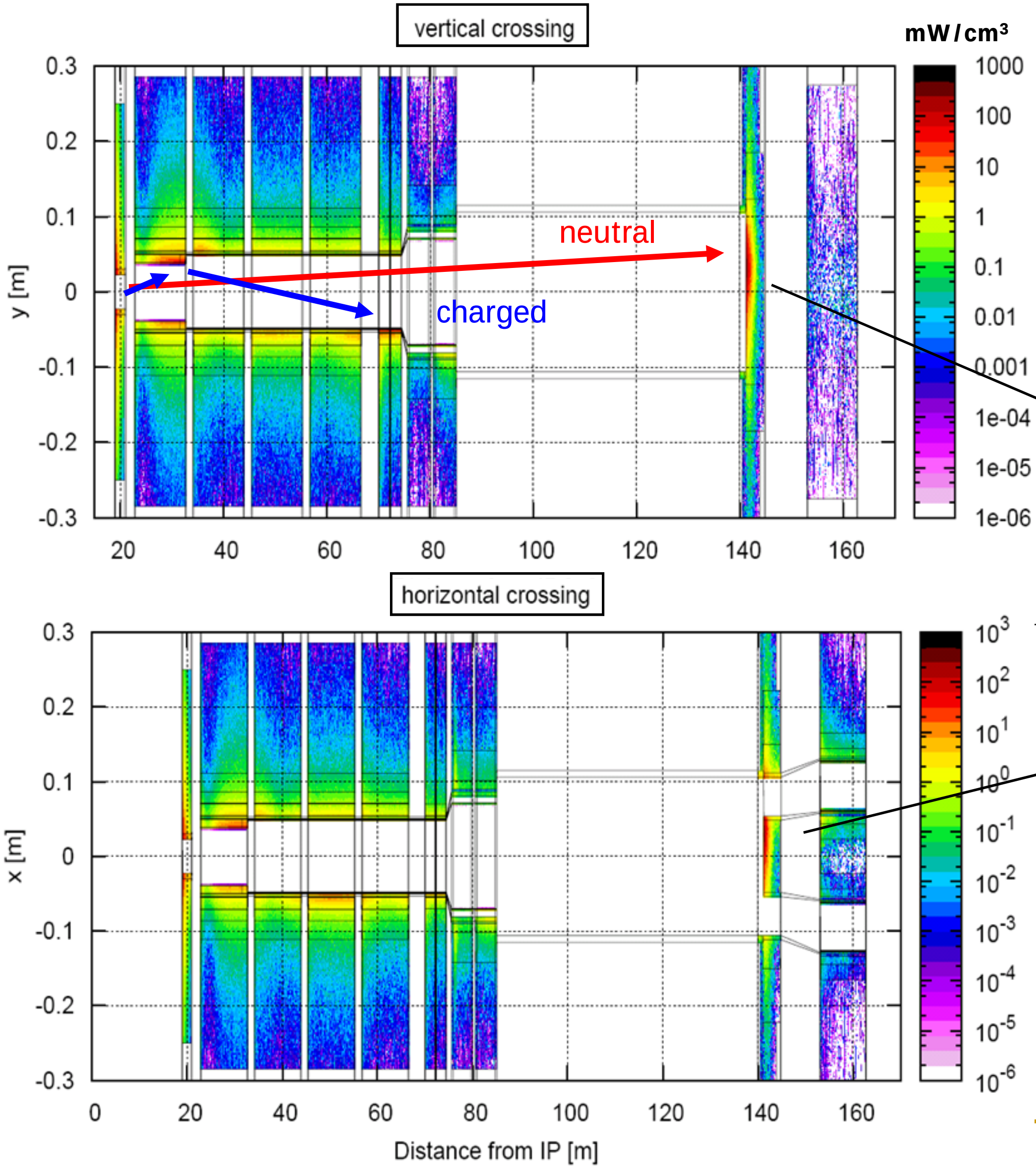
in the rest
402 W @ 1.9 K

BS included
BS only

BS included
BS only 98 W
+11.4 W in the interconnections (where BS is supposed to continue)

in the rest
382 W @ 1.9 K

GLOBAL VIEW ON THE TAS-D2 REGION



vertical plane

L=2.5L$_0$

TAN 560W

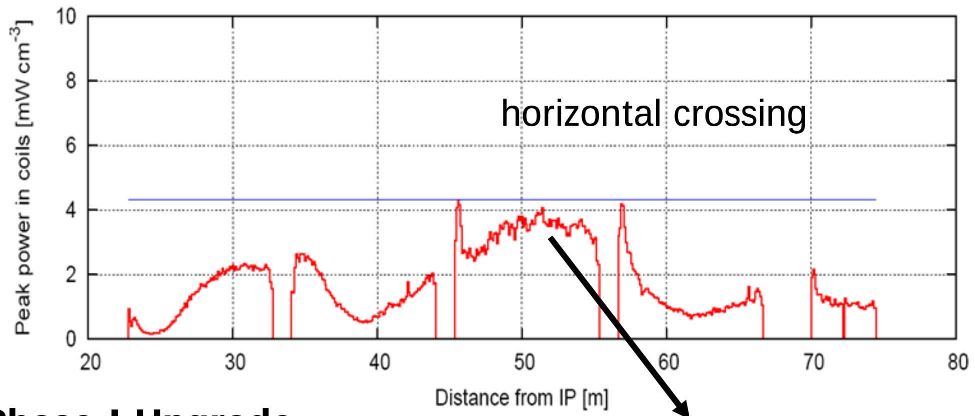
peak of 420 mW/cm^3 (190 MGy/100fb^{-1})

Δx=2.5mm x Δy=2.5mm x Δz=5cm scoring grid

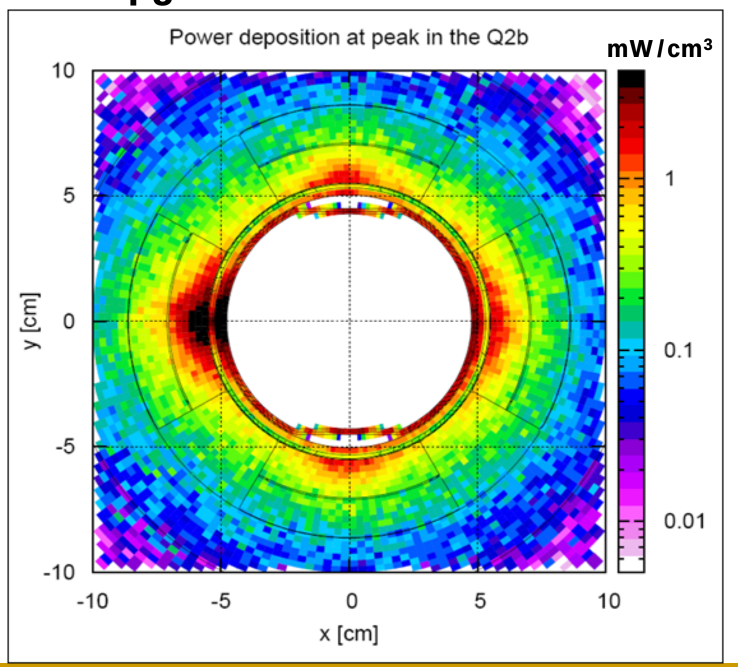
520W

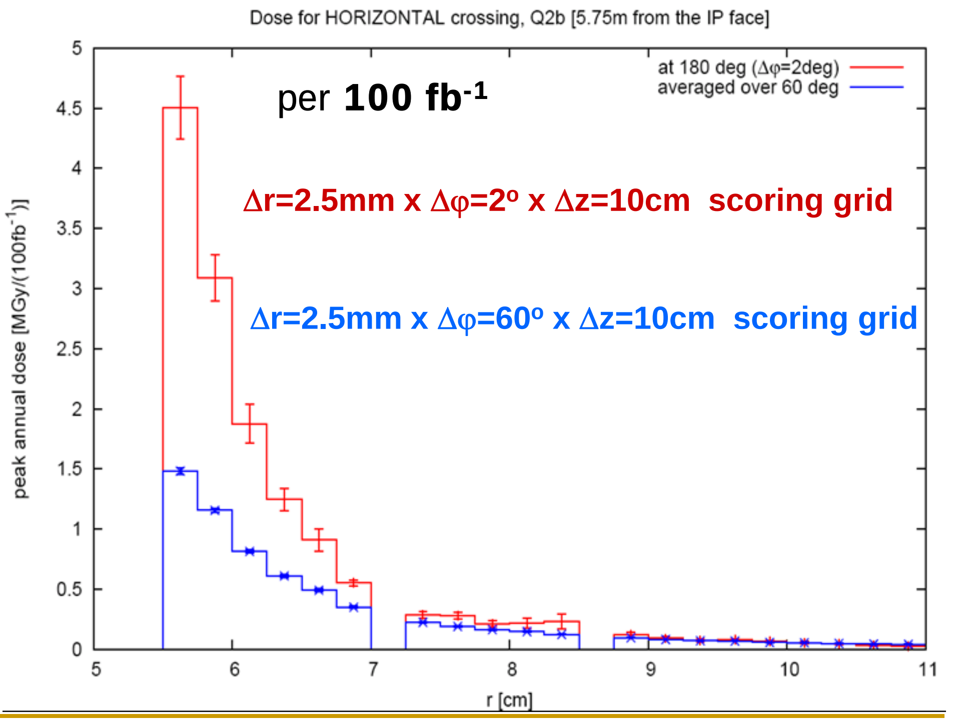
horizontal plane

DOSE TO THE COIL INSULATOR



Phase I Upgrade

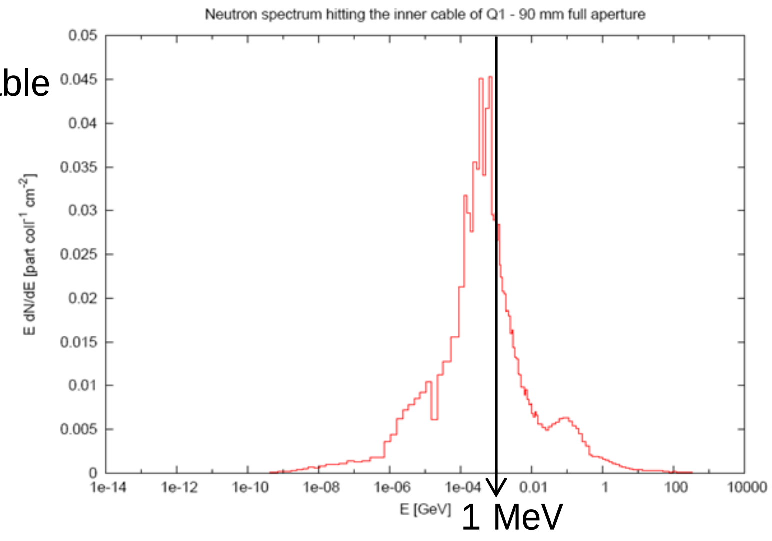




PARTICLE FLUENCE IN THE COILS

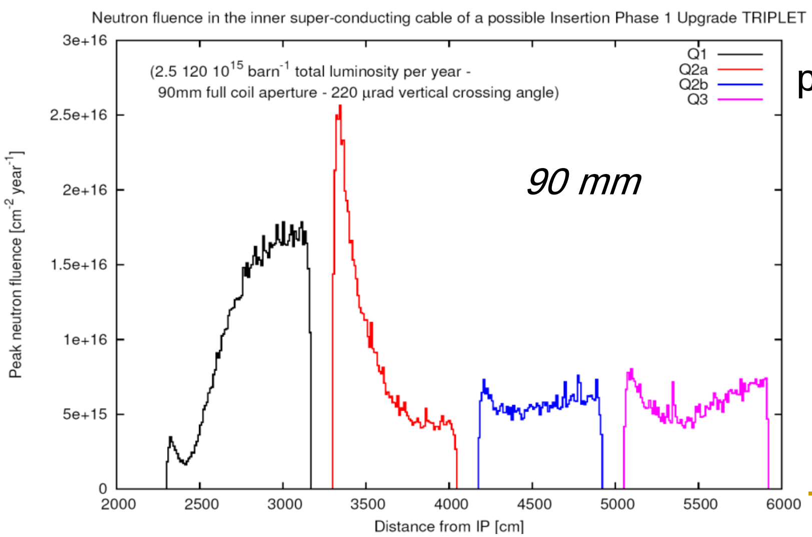
coil aperture [mm]	*90*	*140*
tracklength fraction [%]		
photons	87.0	86.0
neutrons	6.0	7.8
electrons	3.5	3.3
positrons	2.5	2.3
pions	0.4	0.4
protons	0.15	0.15

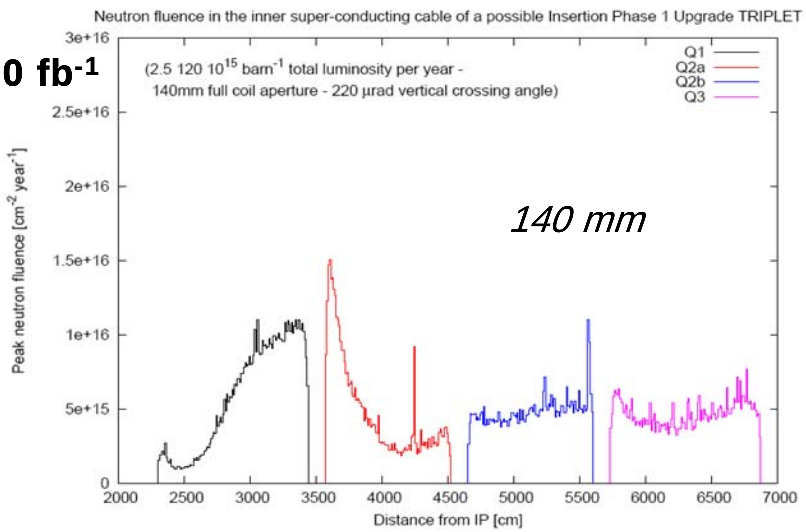
over the inner cable



peak neutron fluence

per **300 fb^-1**

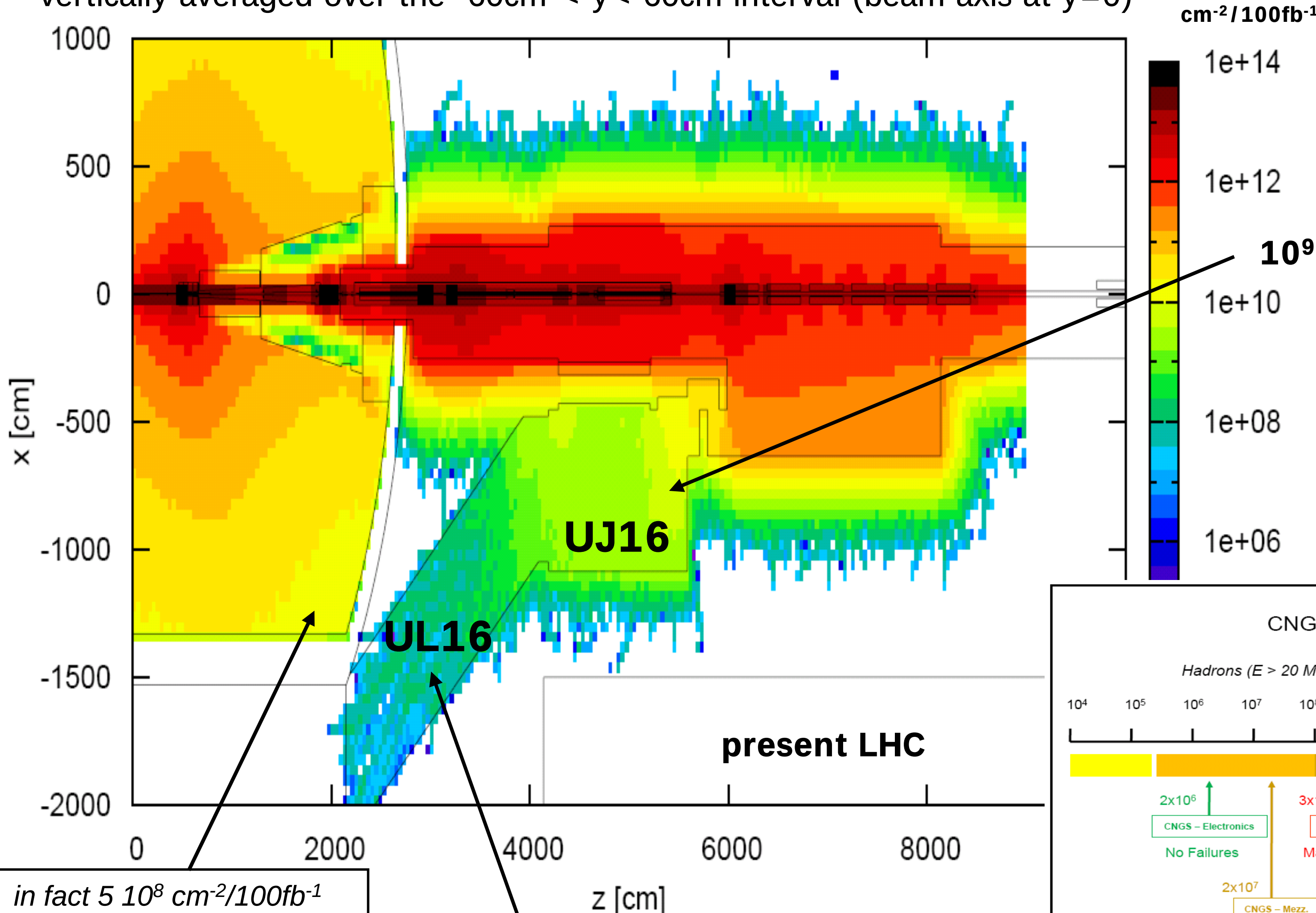




>20 MeV HADRON FLUENCE IN THE TUNNEL (I)

relevant to Single Event Errors

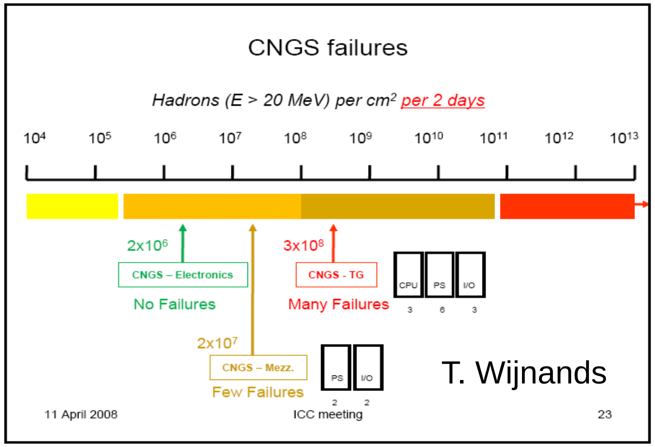
vertically averaged over the -60cm < y< 60cm interval (beam axis at y=0)



10^9-10^{10} $cm^{-2}/100fb^{-1}$

in fact 5 10^8 $cm^{-2}/100fb^{-1}$
due to the ATLAS detector

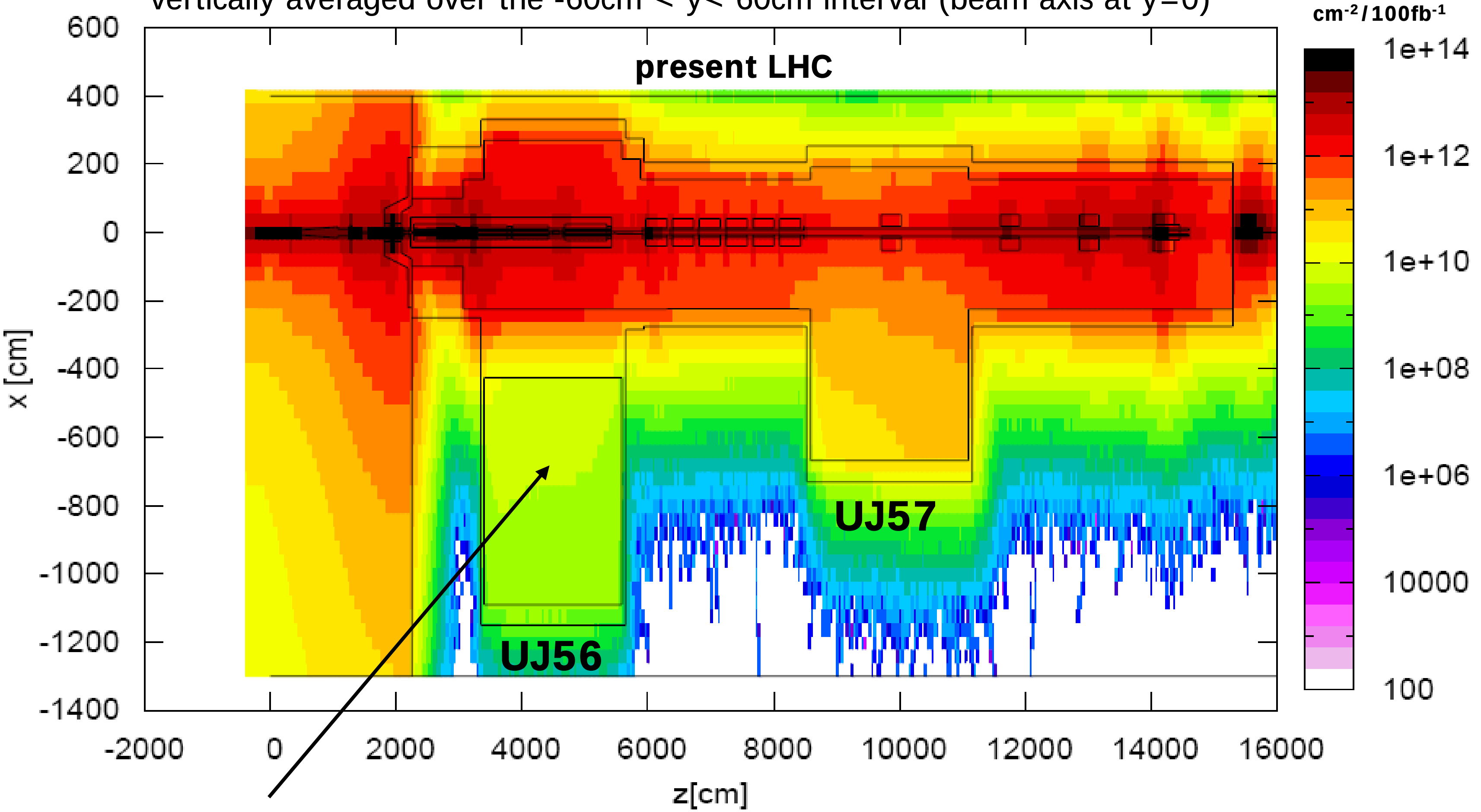
5 10^7 – 5 10^8 $cm^{-2}/100fb^{-1}$



>20 MeV HADRON FLUENCE IN THE TUNNEL (II)

relevant to Single Event Errors

vertically averaged over the -60cm < y< 60cm interval (beam axis at y=0)



in UJ56, after a 2m concrete shielding, high energy hadron fluence at beam level ranging **from 1.3 10^9 up to 1.3 10^{10} cm^{-2} / $100fb^{-1}$**

CONCLUSIONS

• the TAS is effective in reducing the load on Q1 (and for minimizing backscattering to the detector)

• hot spot expected at the end of Q1 and on the IP-side of Q2a

the longer the triplet, the lower the peak (and integrated) power density

peaks lie on the crossing plane and change their position (up->down, outer->inner) in the Q2a

• a continuous liner inside the aperture (along the interconnections too) provides the SC cables with a substantial shield

the effectiveness of a thick beam screen in Q1 is limited to the first half of the Q2a

• the larger the crossing angle, the higher the peak power density (a magnetic TAS can play a role closing the crossing angle)

the vertical crossing is more harmful for the downstream elements (the coil azimuthal position - wrt the crossing plane – is critical)

• effective shadowing can be obtained by the use of increasing apertures (large aperture SC D1 planned for the Upgrade Phase I)

• ~400 W the triplet toal load + ~100 W in the beam screen (about one half in the Q1 liner) for $L=2.5L_0$

• localized peak dose in the coils has to be considered wrt the insulator robustness

• radiation tolerance of electronics in the tunnel and shielded areas nearby must be assured

ACKNOWLEDGEMENTS

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