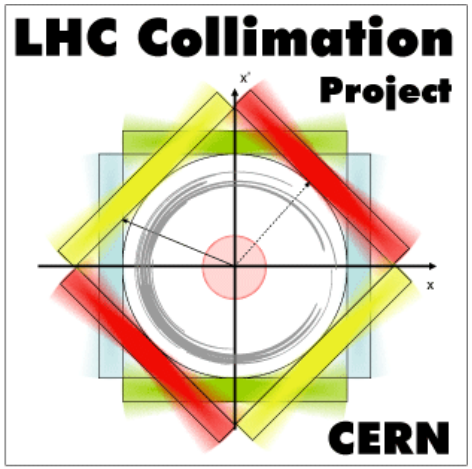
ENERGY DEPOSITION STUDIES FOR THE LHC PHASE II COLLIMATION



F. Cerutti for the FLUKA team (EN-STI)

OUTLINE

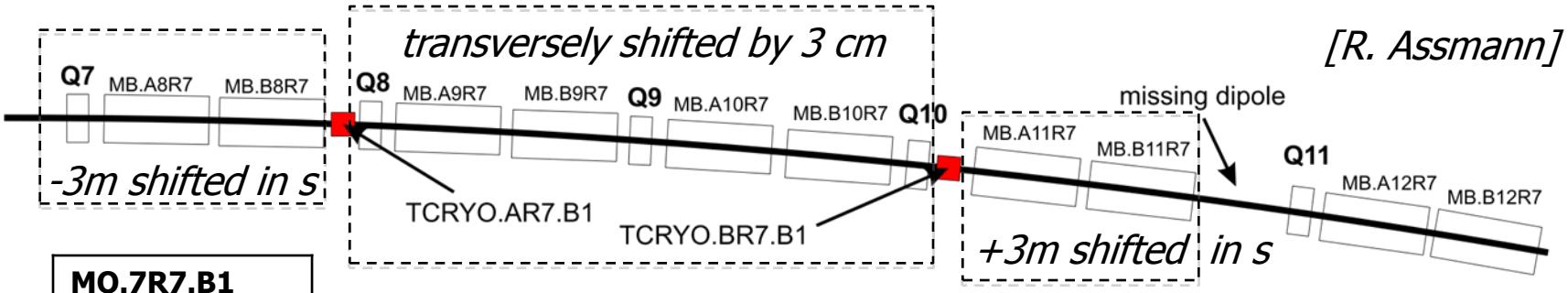
• effect of cryo-collimators on the LHC beam halo power deposition in the IR7 dispersion suppressor

- for the proton beam
- for the lead beam

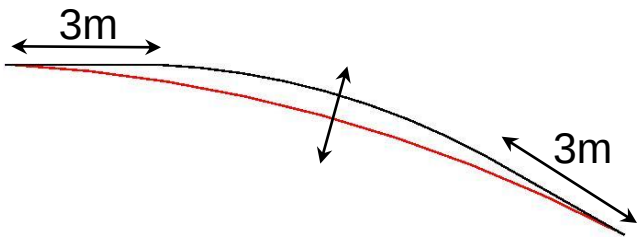
• effect of metallic collimators on the dose to delicate elements in the IR7 straight section

• considerations on LHC beam scraping from the point of view of material robustness

THE STUDIED LAYOUT

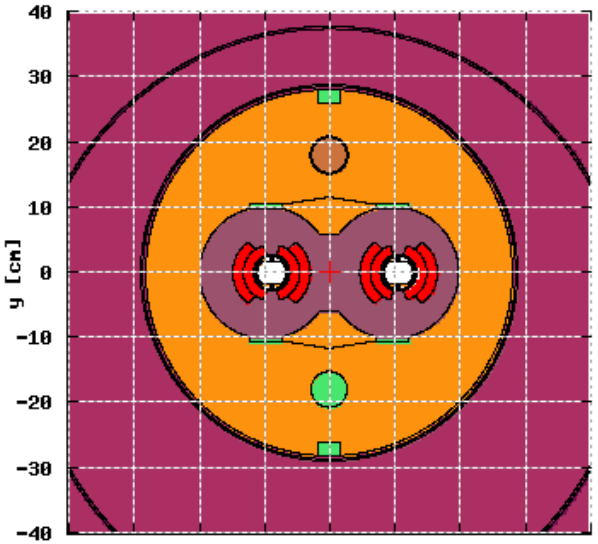


MQ.7R7.B1
MQTLI.7R7.B1
MCBCH.7R7.B1
MCDO.8R7.B1
MB.A8R7.B1
MCS.A8R7.B1
MB.B8R7.B1
MCS.B8R7.B1

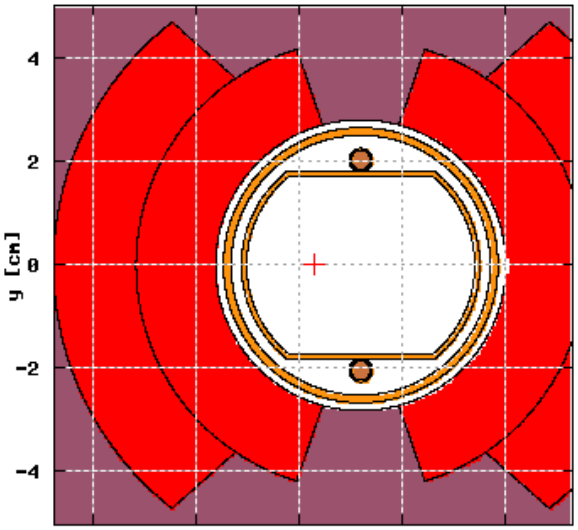


MCDO.11R7.B1
MB.A11R7.B1
MCS.A11R7.B1
MB.B11R7.B1
MCS.B11R7.B1

THE FLUKA MODEL [I]



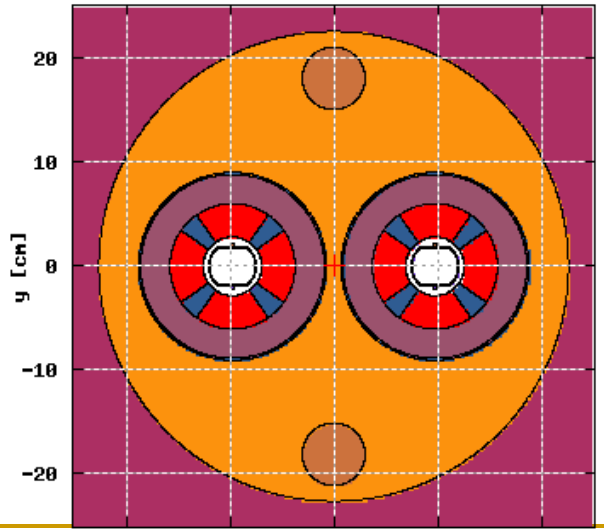
MB



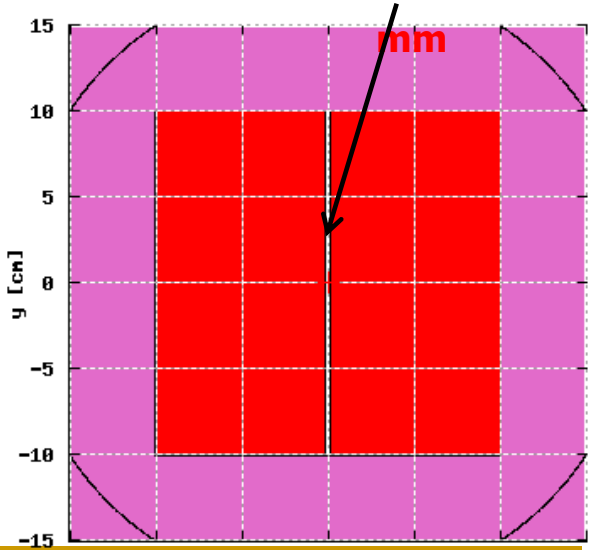
half-gap

15 sigma = 1.6 mm

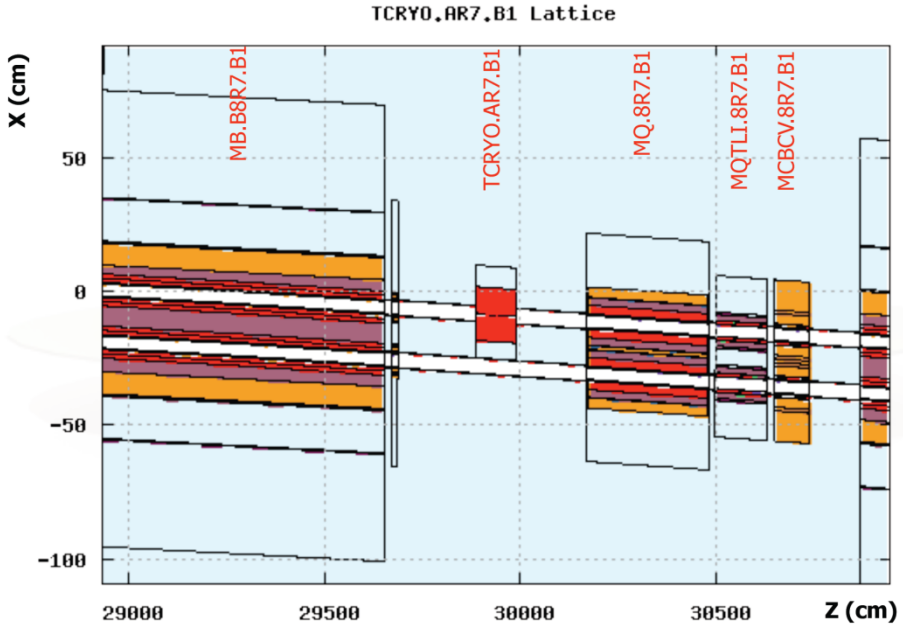
MQ

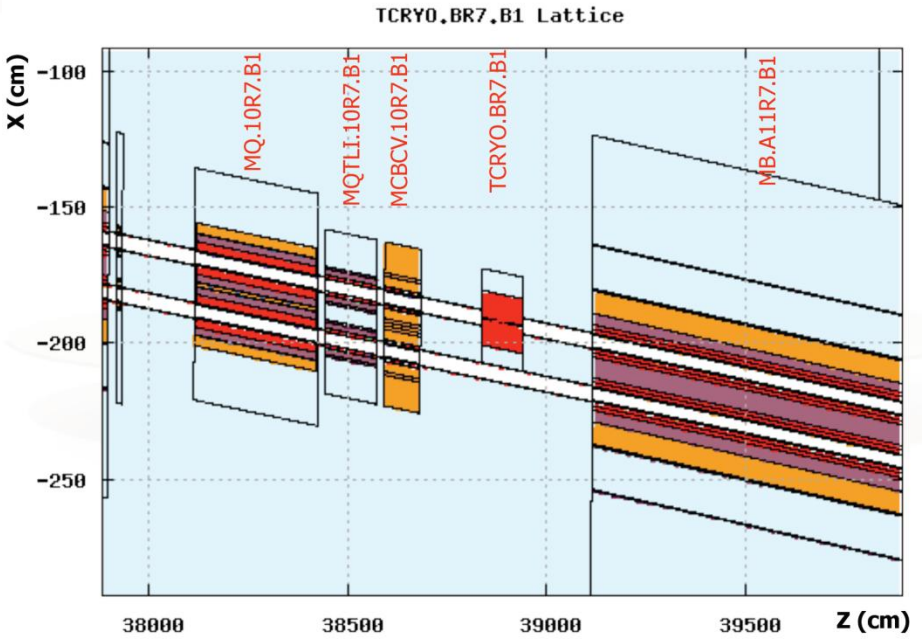


TCRYO



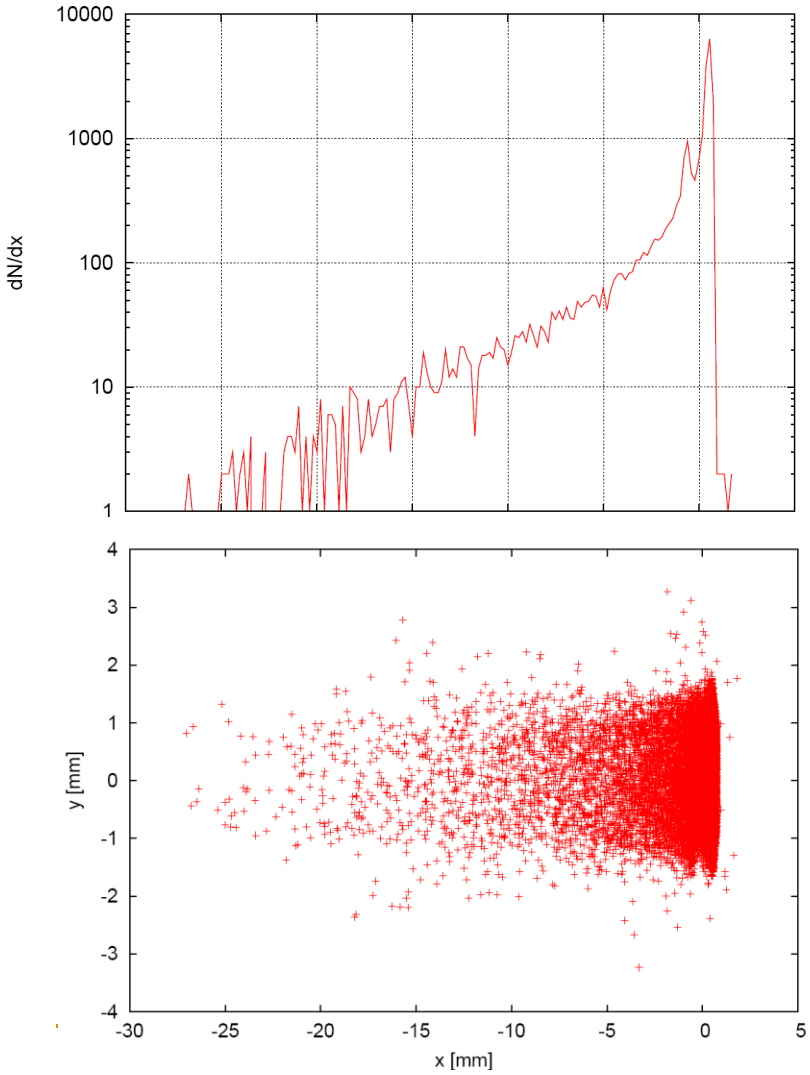
THE FLUKA MODEL [II]

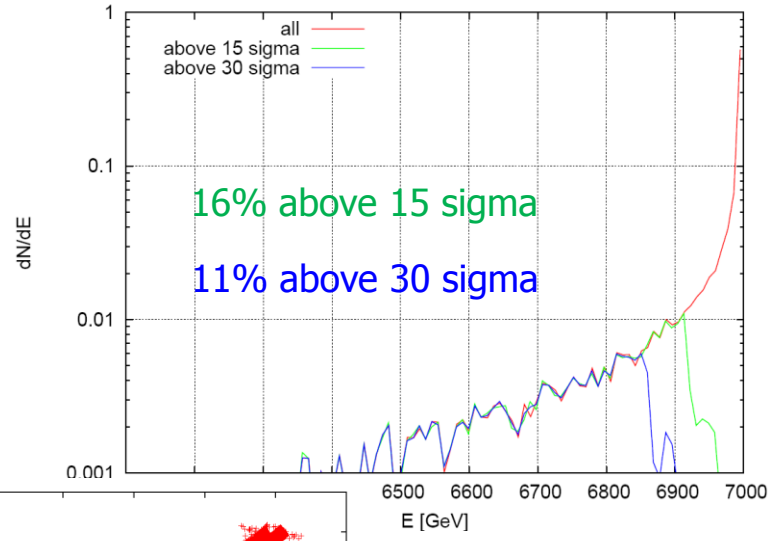


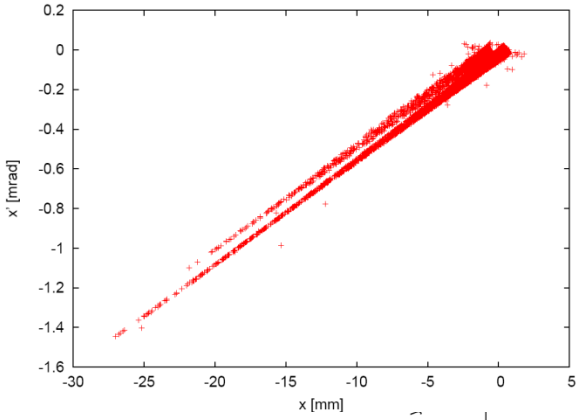


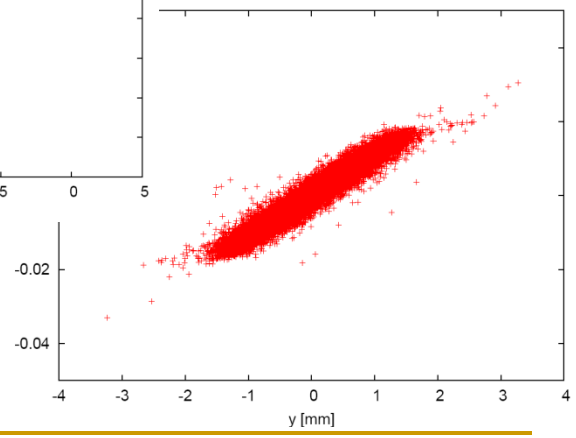
THE SINGLE DIFFRACTIVE BEAM HALO

at the entrance of TCRYO.AR7.B1









[T. Weiler]

EFFECT OF THE TCRYO OPENING

1m copper with 15, 20, 30, 45 sigma half-gap

(100 sigma half-gap means no TCRYO)

power values for 0.2h beam lifetime

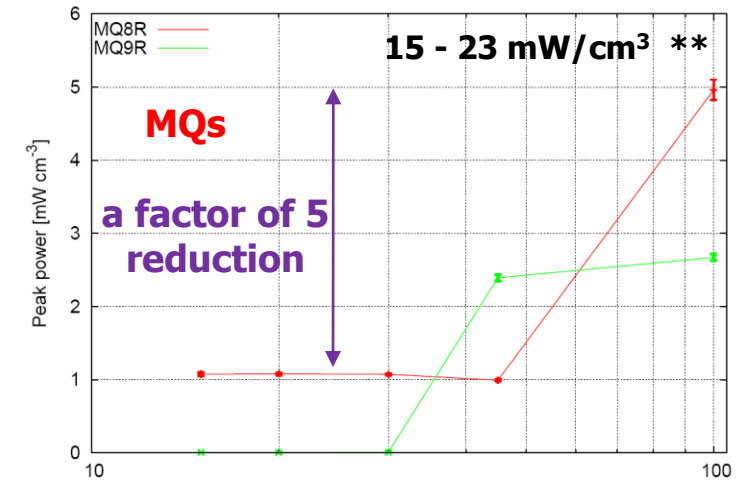
peak power in the coils

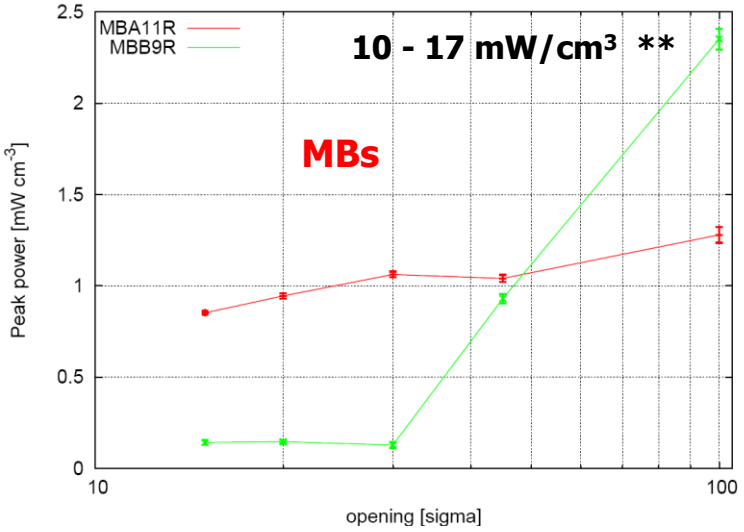
past estimations

no TCRYO, DS untouched

5.0 (2.64) MQ11R

1.0 (3.05) MBB9R





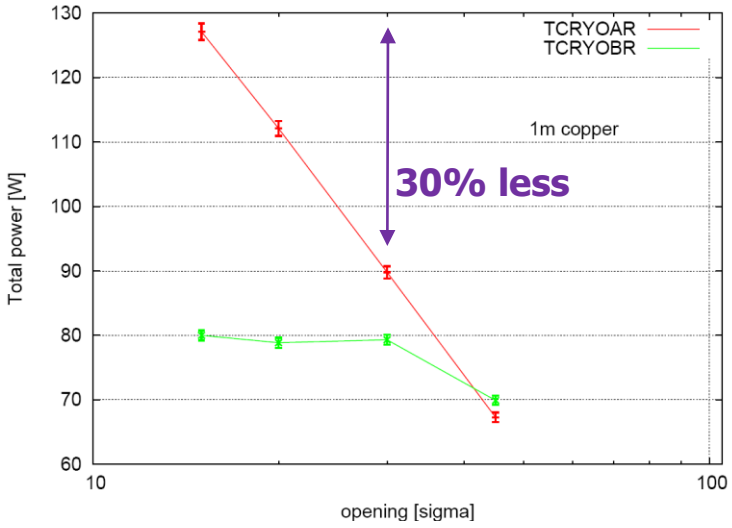
MQTLIs

~1mW/cm³ (MQTLI8R) for 15, 20, 30 sigma

** **quench limits**

[D. Bocian]

total power in the **TCRYOs**



UNCERTAINTIES

only *statistical* errors are accurately known and shown

On top of them there are the systematic ones:

factor for **point** quantities	**factor** for **integral** quantities	**origin**	**reason**
2	2	single diffractive	almost no data for p-A collisions
1.5	1.5	grazing impact	jaw roughness dependence on the angular distribution at zero degrees
2	1.2	FLUKA / physics	interaction extrapolation at 7TeV
1.5	1.1	FLUKA / machine model	description of a large sector (including material implementation)
1.3	1.3	SixTrack / beam model	beam halo description
?	?	imperfections	collimator tilting, magnet displacement, field accuracy…

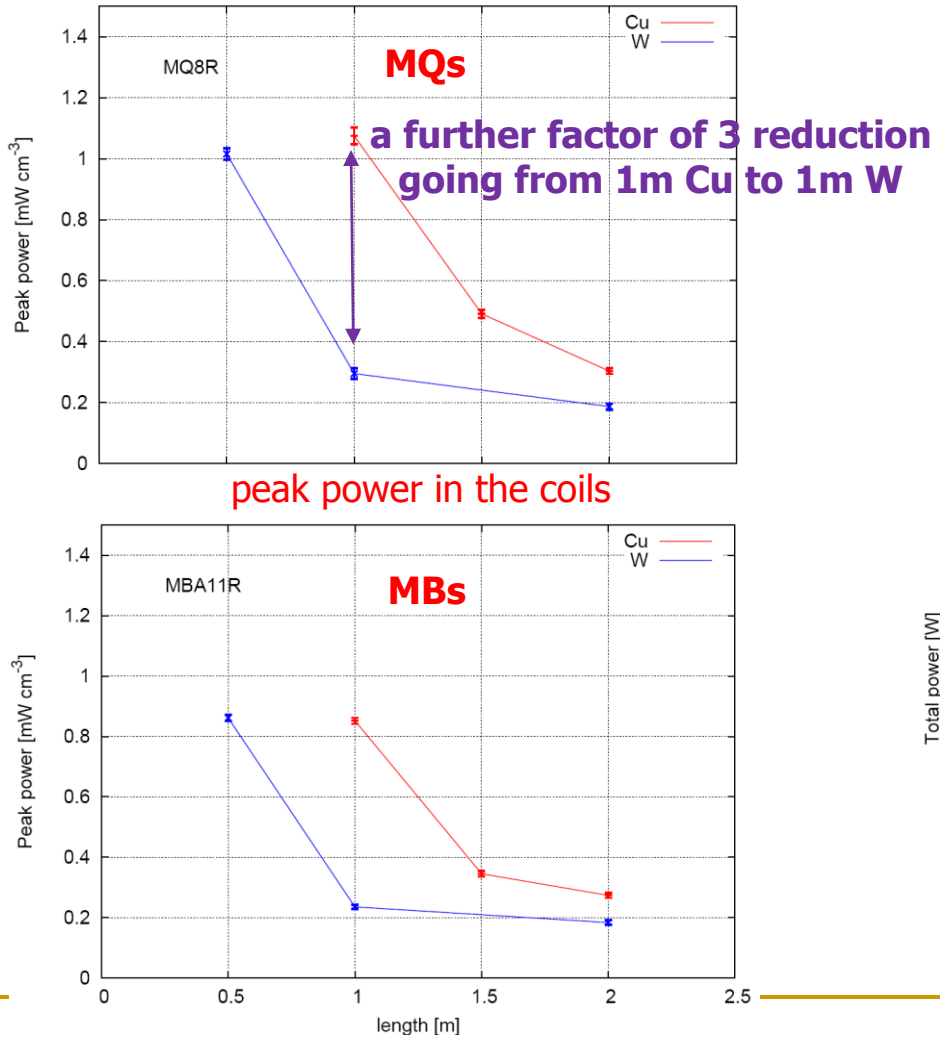
…plus those in the estimation of the quench limits

Ratios (i.e. comparison between different cases) are much more reliable than absolute values

EFFECT OF THE TCRYO LENGTH/MATERIAL

0.5, 1, 1.5, 2 m copper/tungsten with 15 sigma half-gap

power values for 0.2h beam lifetime



peak power in the coils

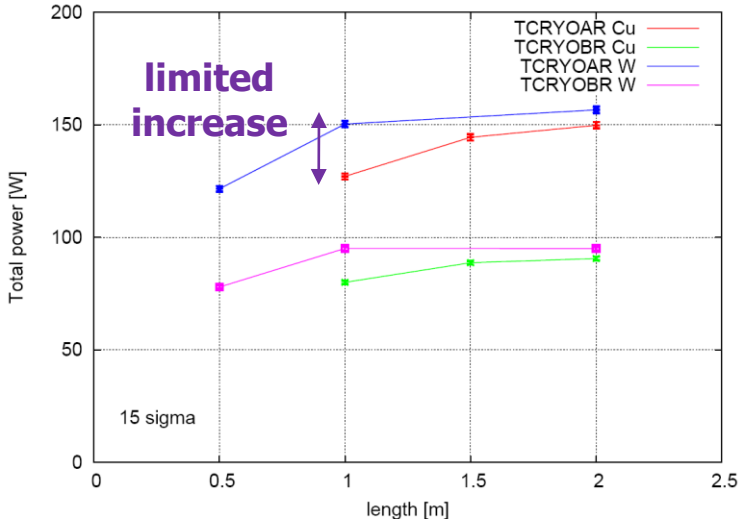
peak power in the **TCRYOs**

1.1 W/cm^3 in the Cu jaw

2.6 W/cm^3 in the W jaw

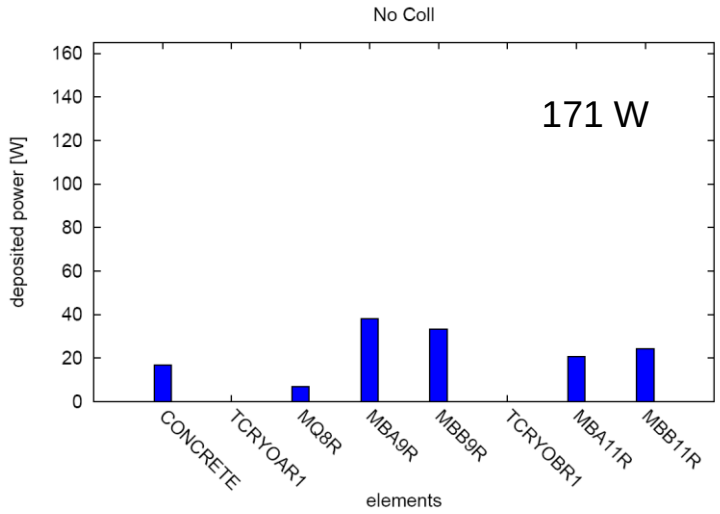
on a 4mm x 4mm x 1cm volume

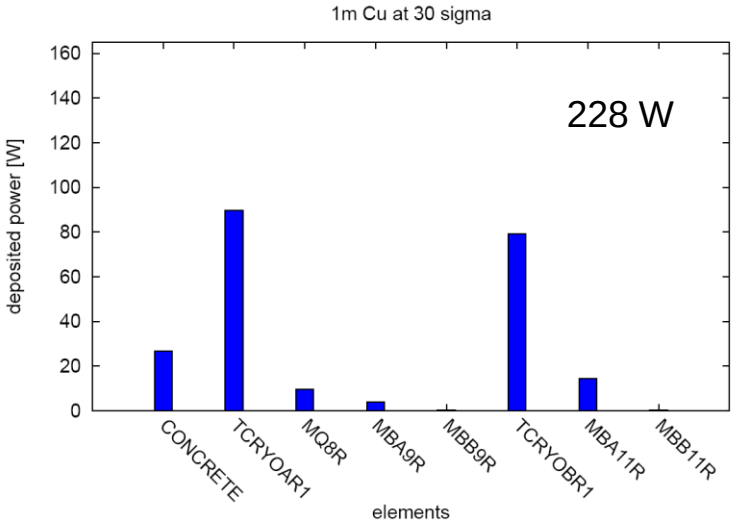
total power in the **TCRYOs**

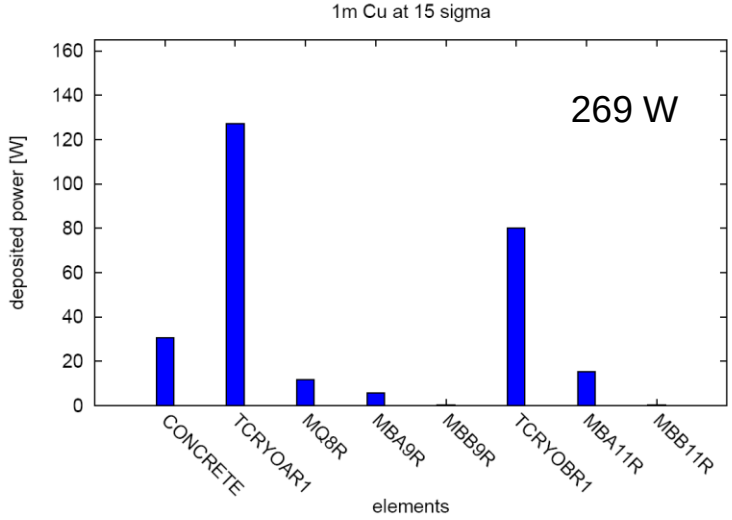


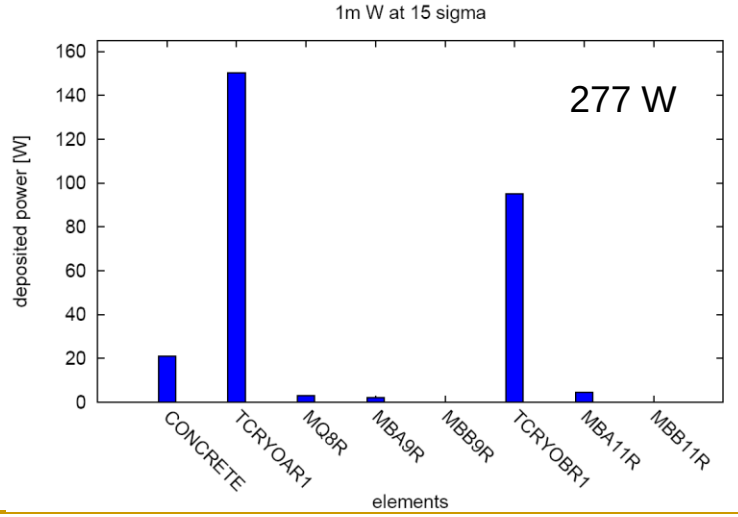
POWER IMPACTING THE DS

power values for 0.2h beam lifetime



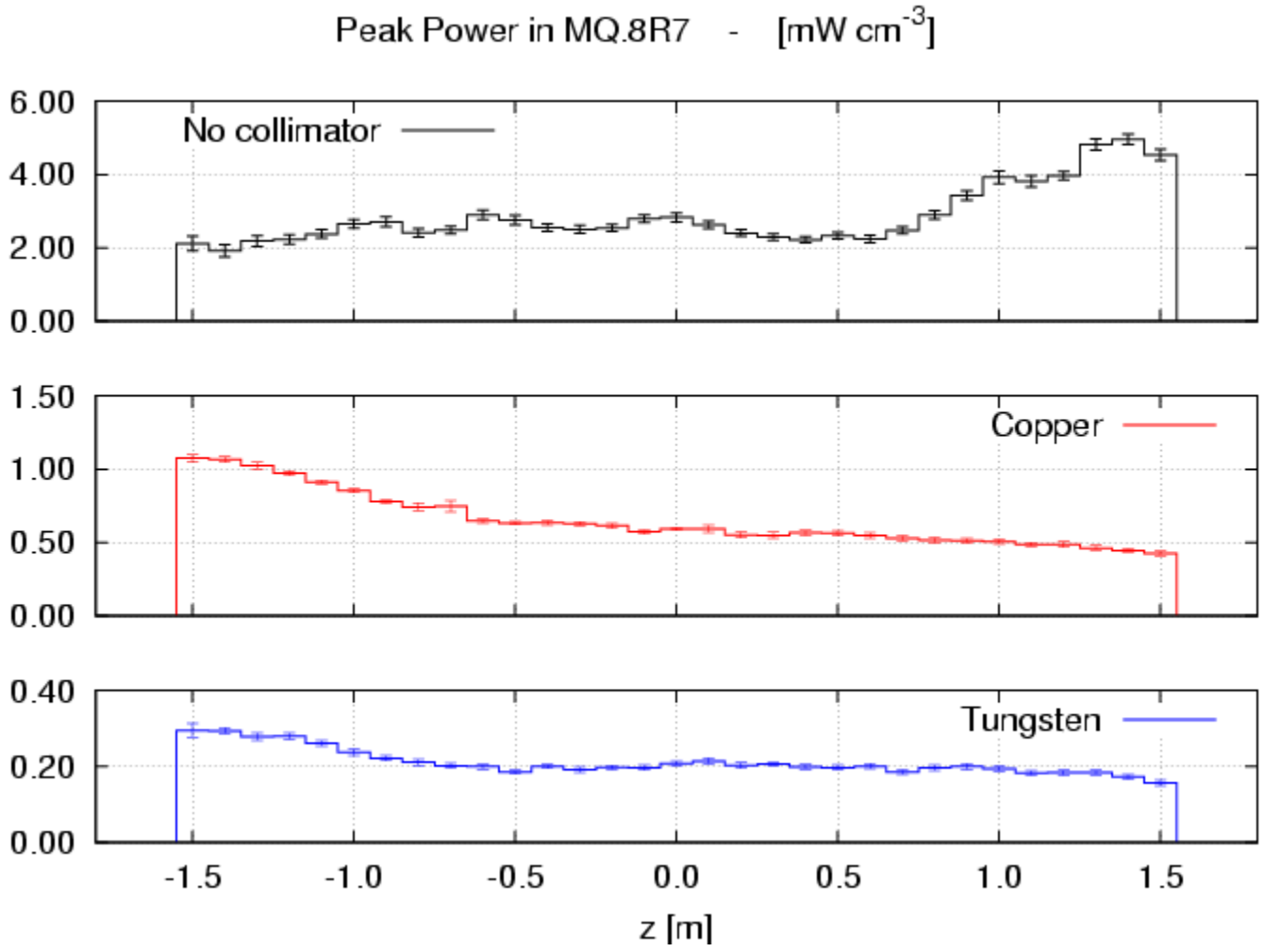






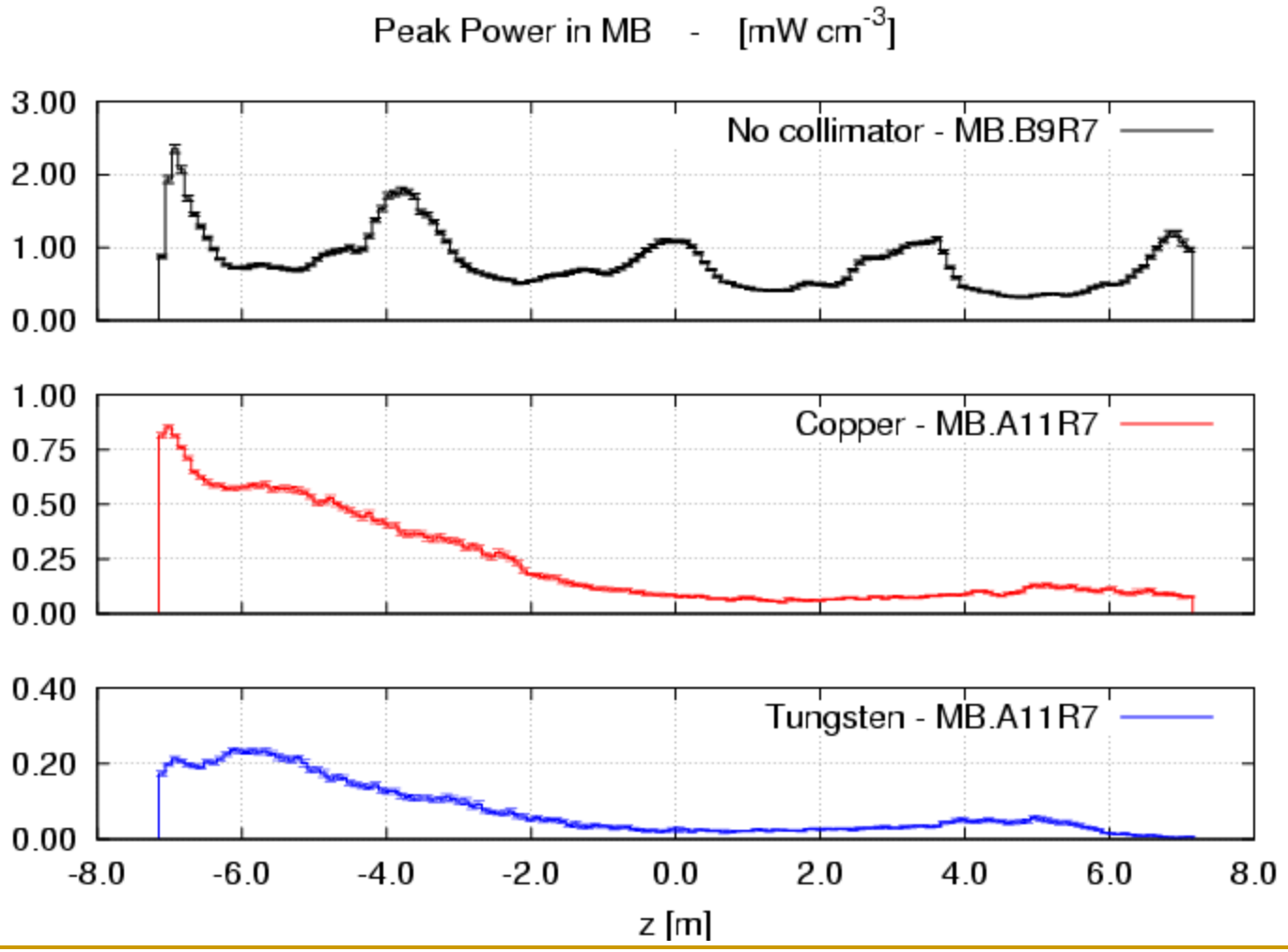
LONGITUDINAL PEAK PROFILES [MQ]

power values for 0.2h beam lifetime



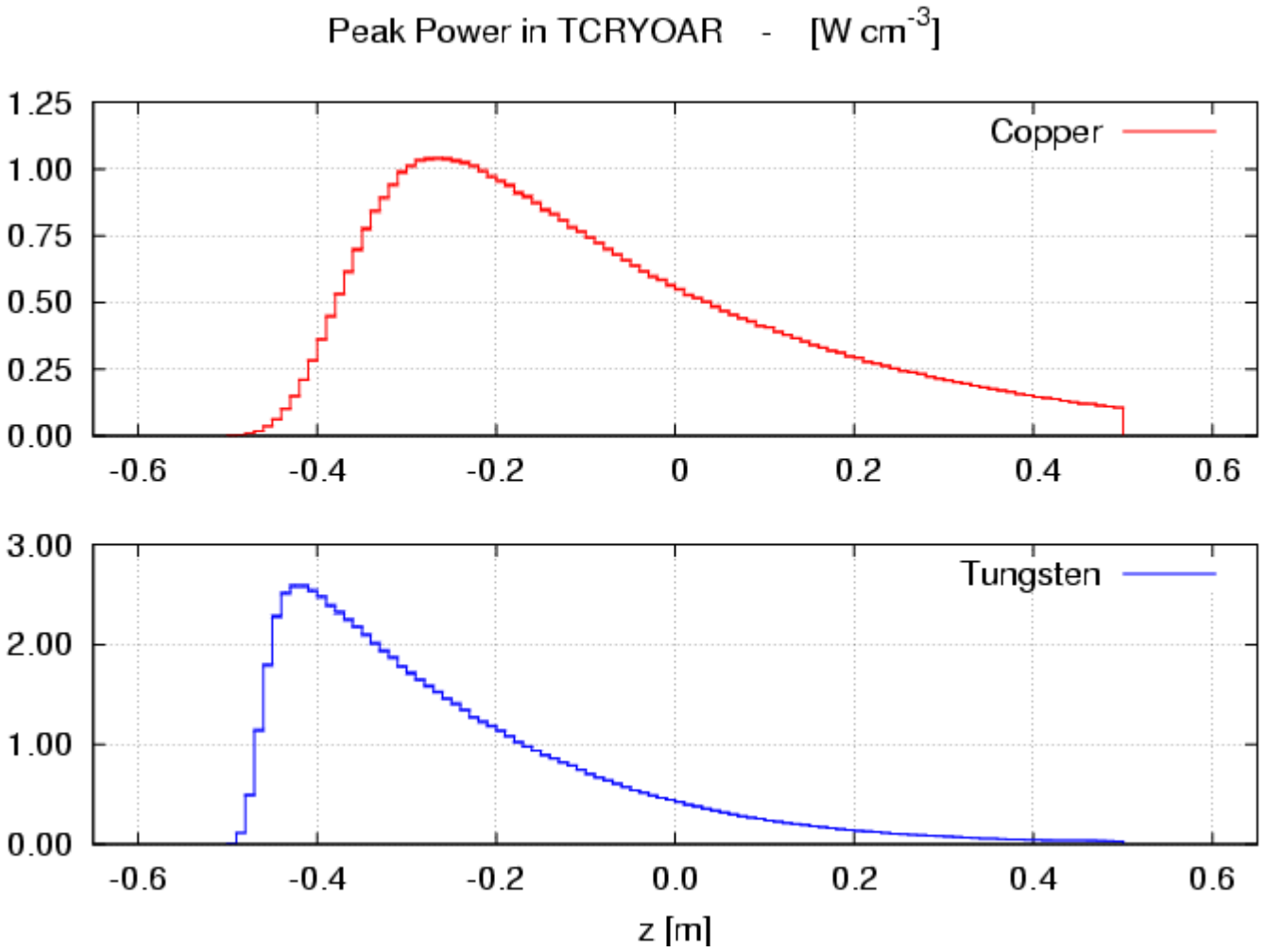
LONGITUDINAL PEAK PROFILES [MB]

power values for 0.2h beam lifetime



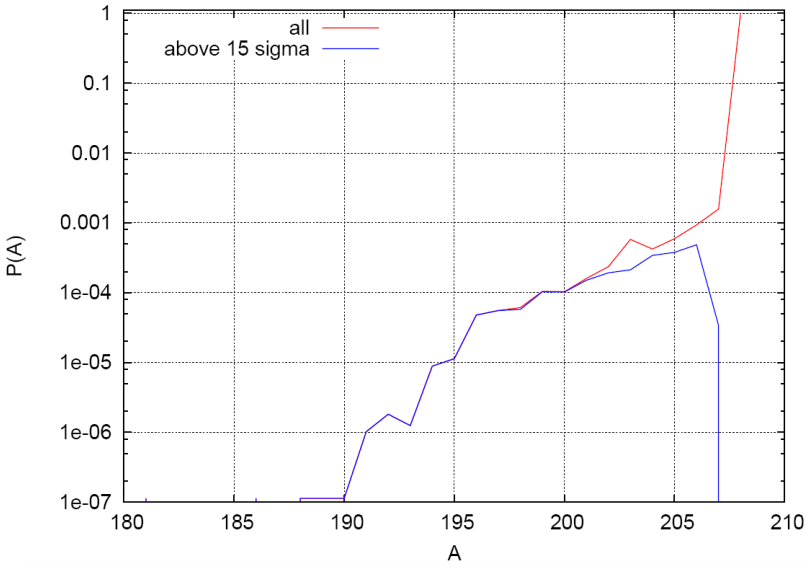
LONGITUDINAL PEAK PROFILES [TCRYO]

power values for 0.2h beam lifetime



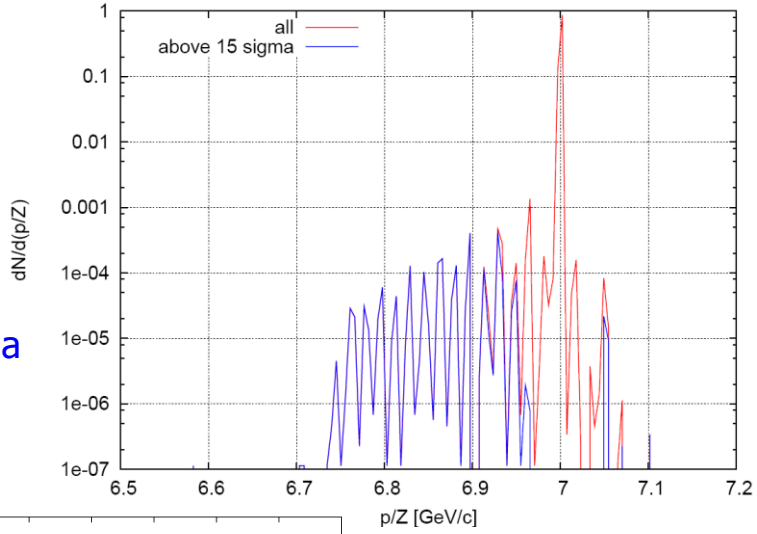
THE LEAD BEAM HALO

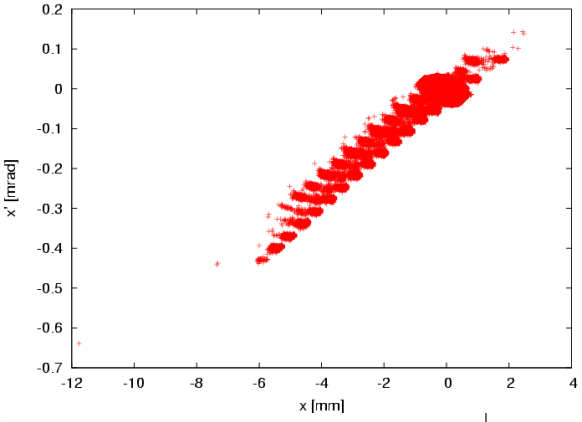
at the entrance of TCRYO.AR7.B1

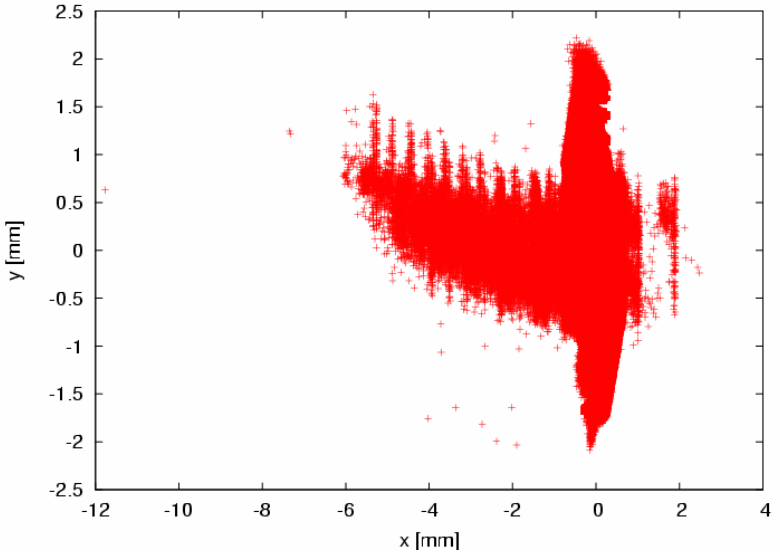


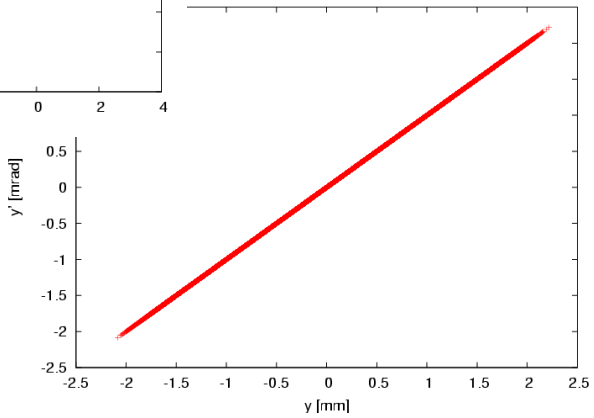
0.22%

above 15 sigma









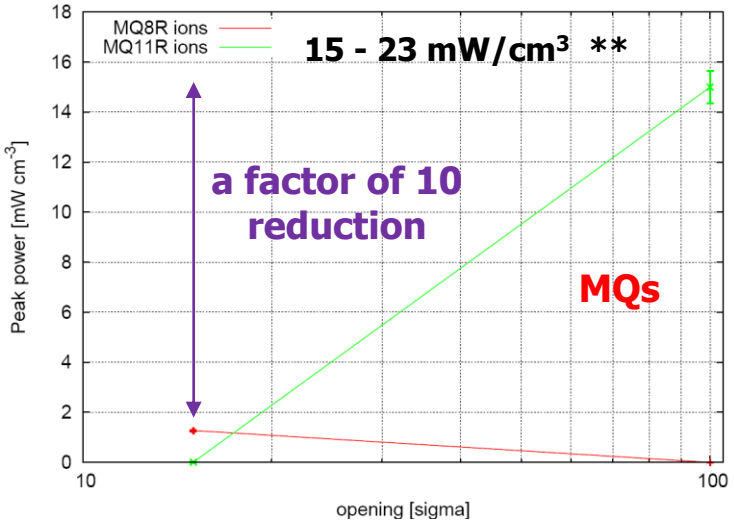
[G. Bellodi]

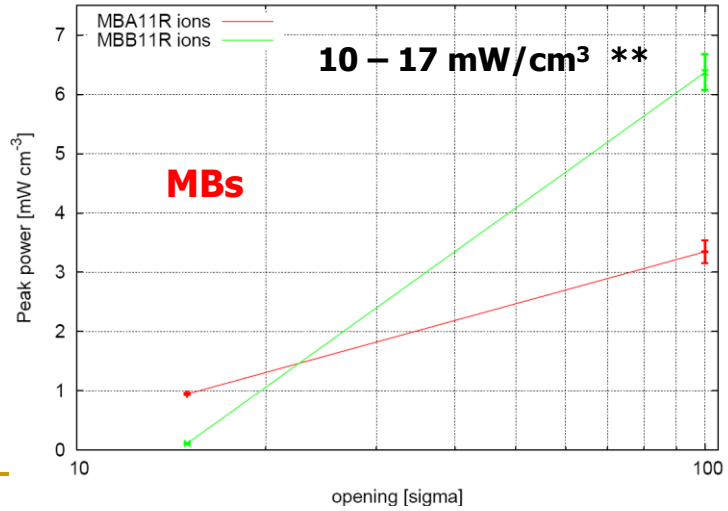
EFFECT OF THE TCRYO (LEAD BEAM)

1m copper with 15 sigma half-gap

(100 sigma half-gap means no TCRYO)

power values for 0.2h beam lifetime





peak power in the coils

MQTLIs

~1mW/cm^3 (MQTLI8R)

**** quench limits**

[D. Bocian]

peak power in the **TCRYOs**

1.75 W/cm^3 in the Cu jaw

on a 4mm x 4mm x 1cm volume

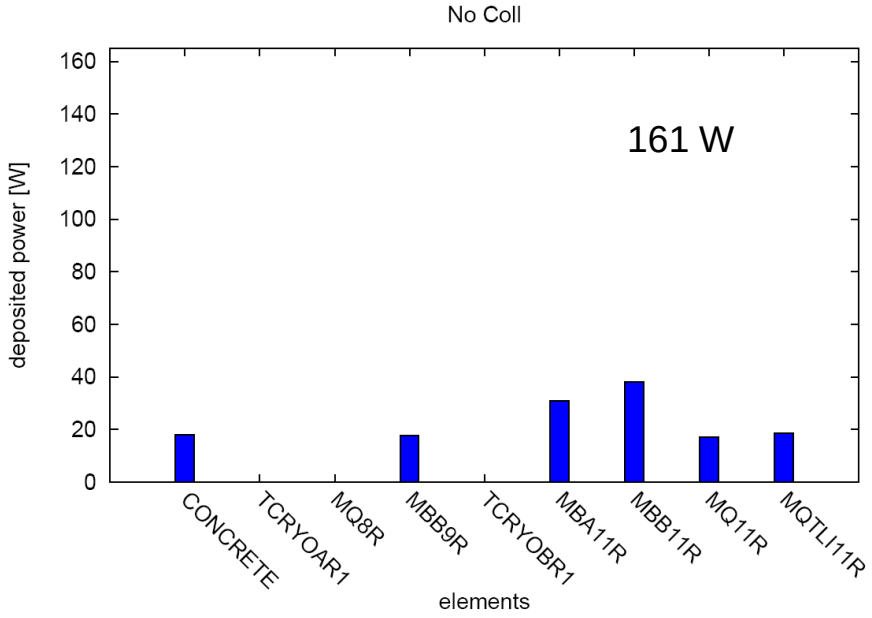
total power in the **TCRYOs**

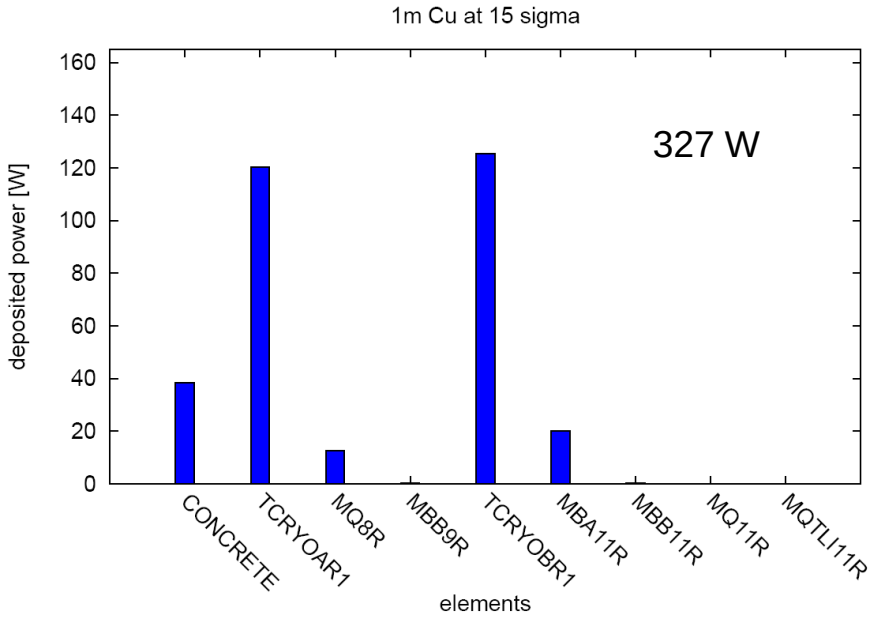
120 W in the TCRYOAR

125 W in the TCRYOBR

POWER IMPACTING THE DS (LEAD BEAM)

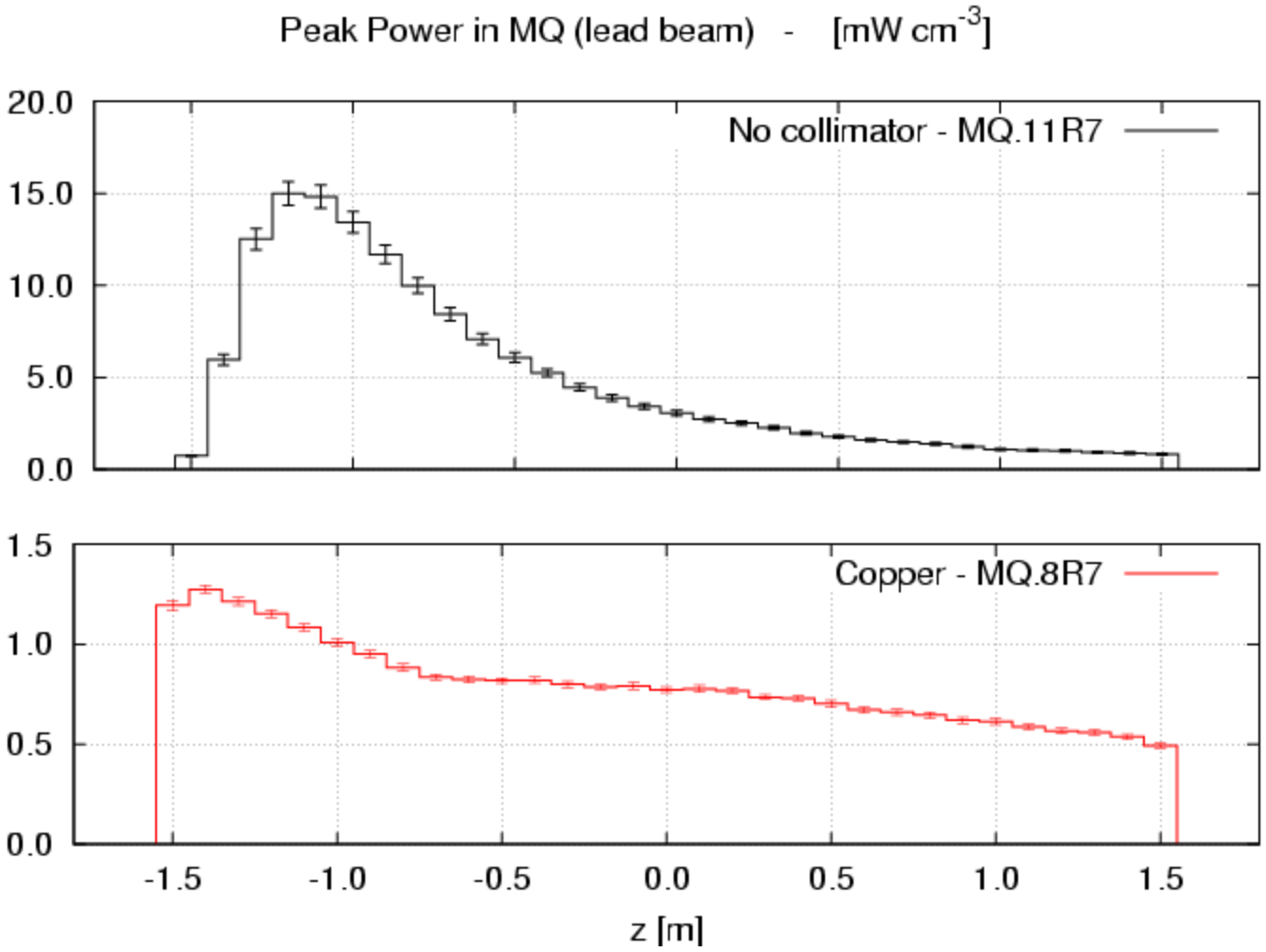
power values for 0.2h beam lifetime





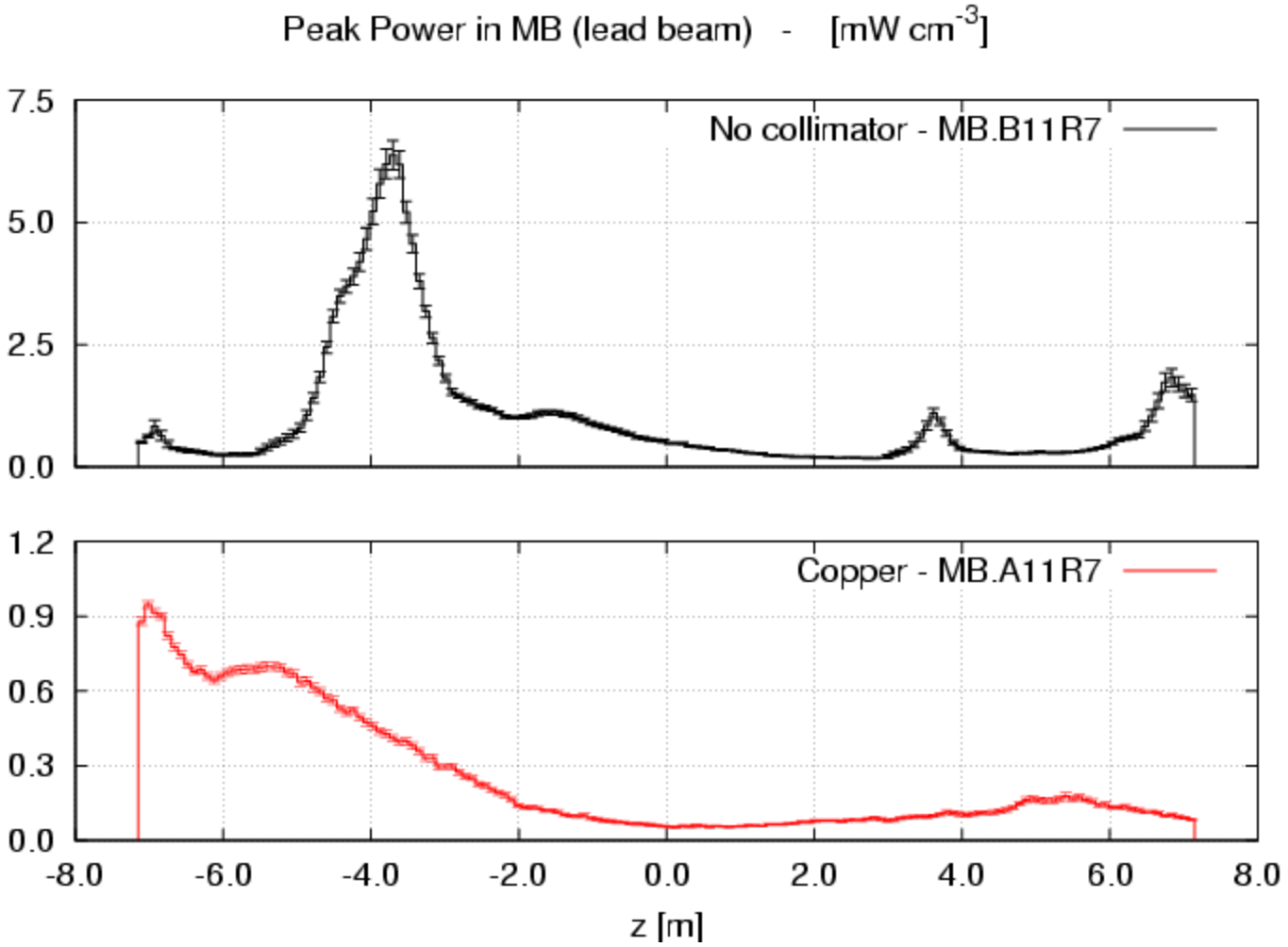
LONGITUDINAL PEAK PROFILES (LEAD BEAM) [MQ]

power values for 0.2h beam lifetime



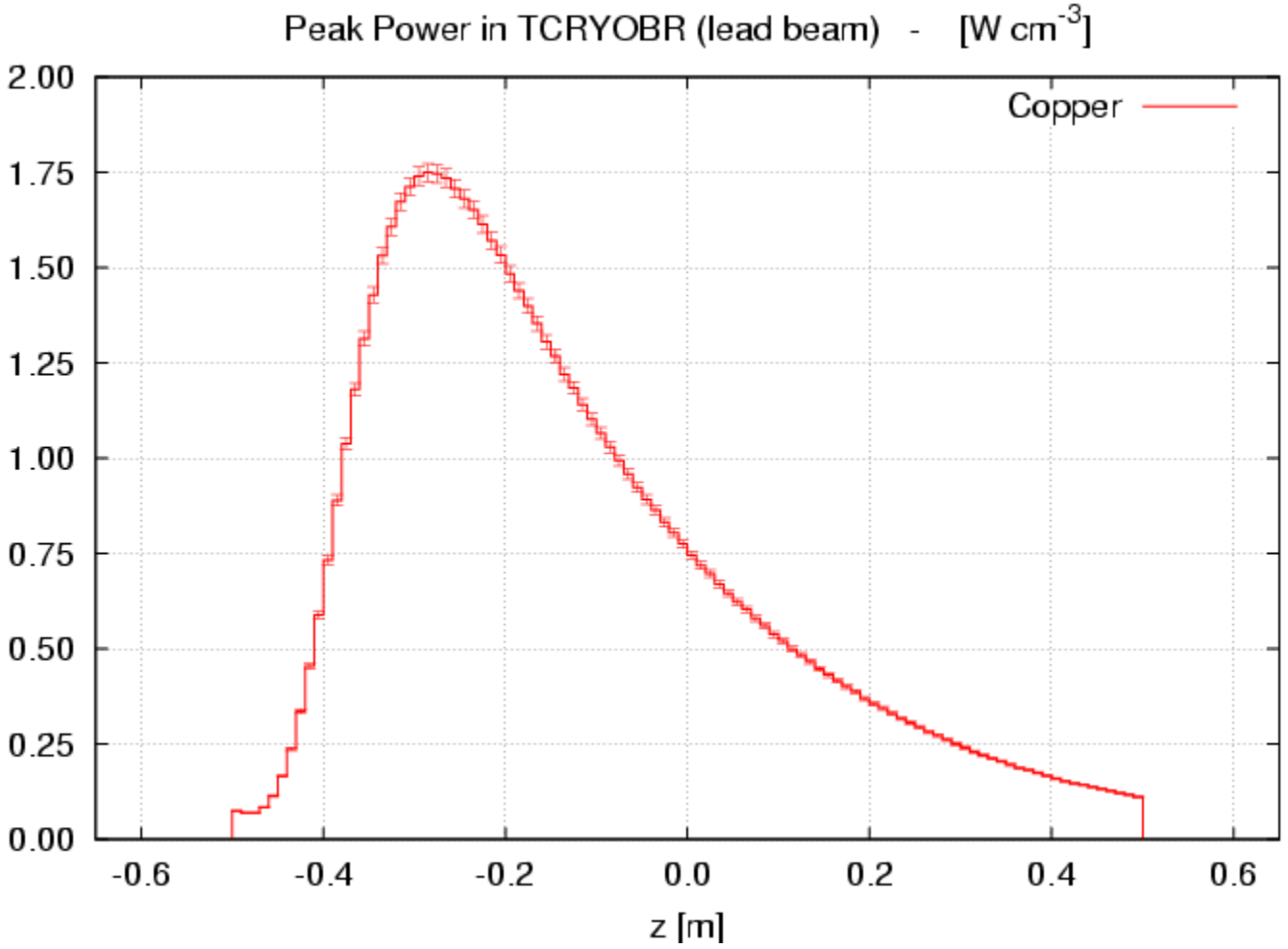
LONGITUDINAL PEAK PROFILES (LEAD BEAM) [MB]

power values for 0.2h beam lifetime

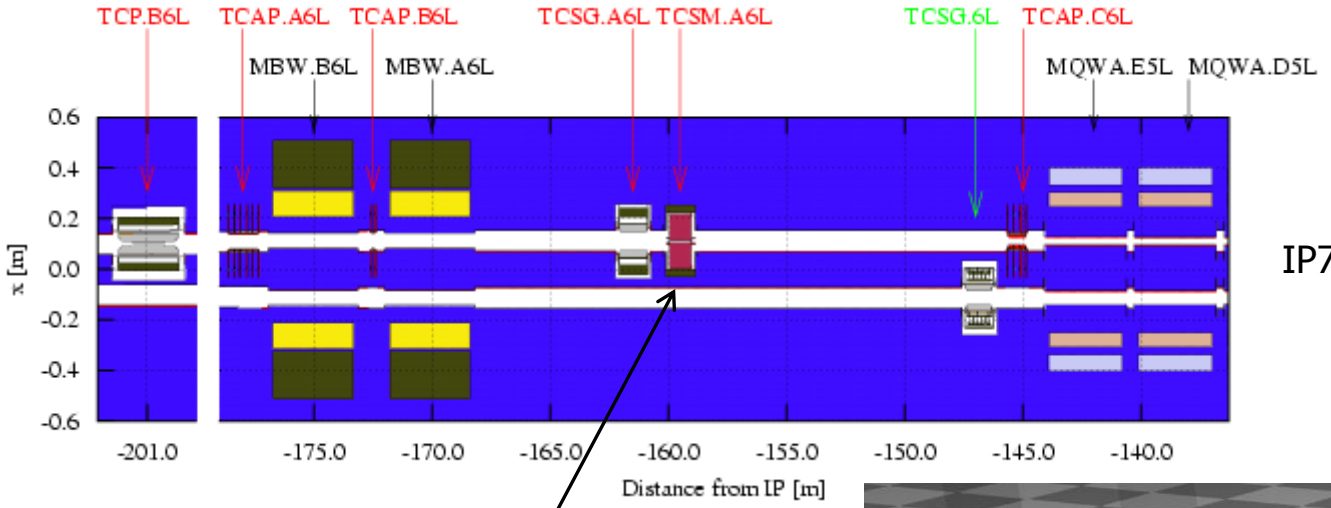


LONGITUDINAL PEAK PROFILES (LEAD BEAM) [TCRYO]

power values for 0.2h beam lifetime



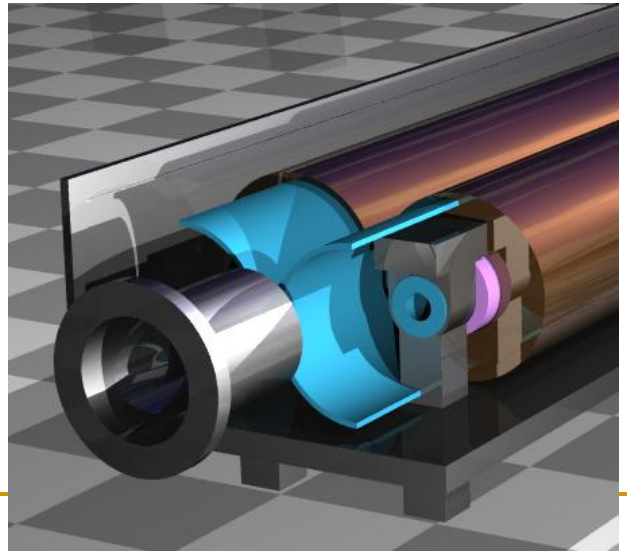
USING METALLIC COLLIMATORS IN THE WARM SECTION



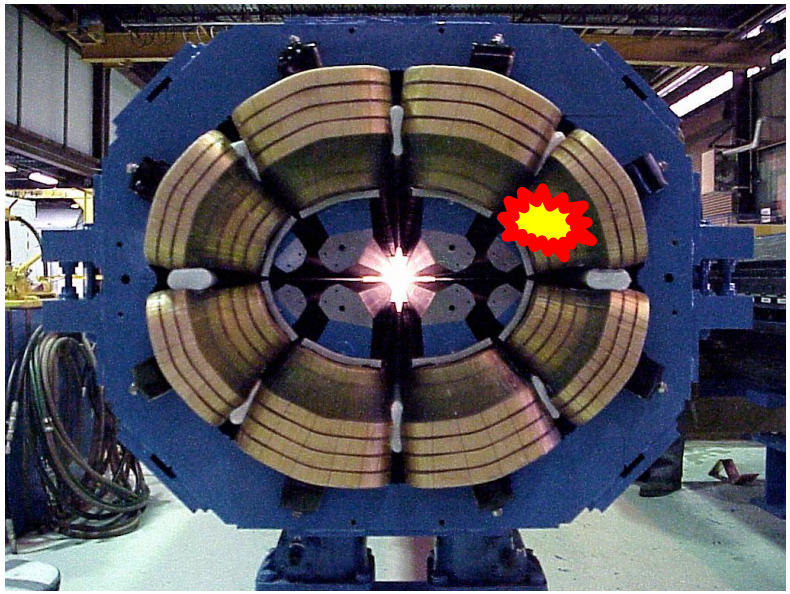
IP7

SLAC prototype

[L. Lari]



IMPACT ON THE WARM MAGNET LIFETIME



the dose to coil insulator is the critical quantity

the damage threshold is expected to lie

between 5 and 10 MGy

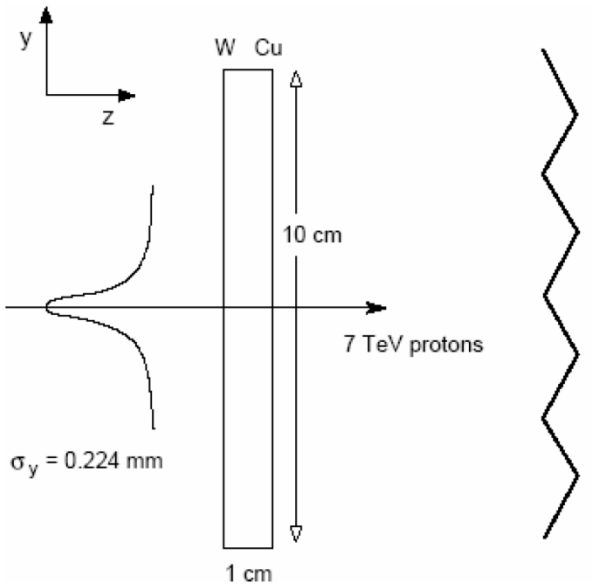
predicted dose values for 1.15 10^{16} p/y annual loss (protons)

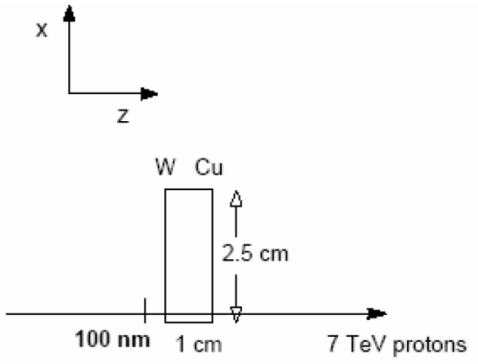
	actual layout		with metallic collimator	
element	peak [MGy/y]	stat. err. [%]	peak [MGy/y]	stat. err. [%]
MQWA.E5L7	0.92	7	0.29	21
MQWA.D5L7	0.46	11	0.09	14

considering the (limited) statistical quality, an improvement of a factor of 2

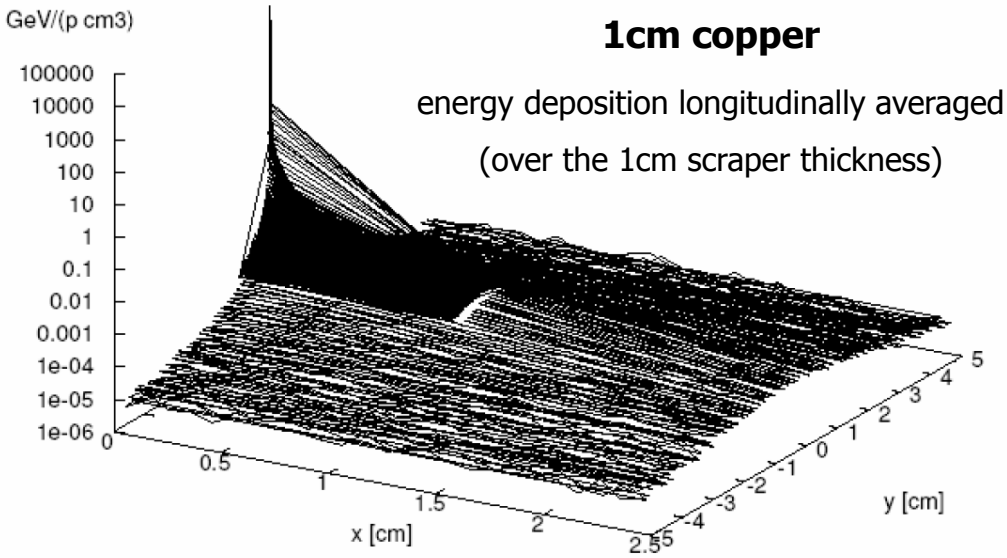
can be envisaged for the use of a metallic collimator

SCRAPING THE LHC BEAM AT TOP ENERGY





proton impact parameters between 0 and *100 nm*

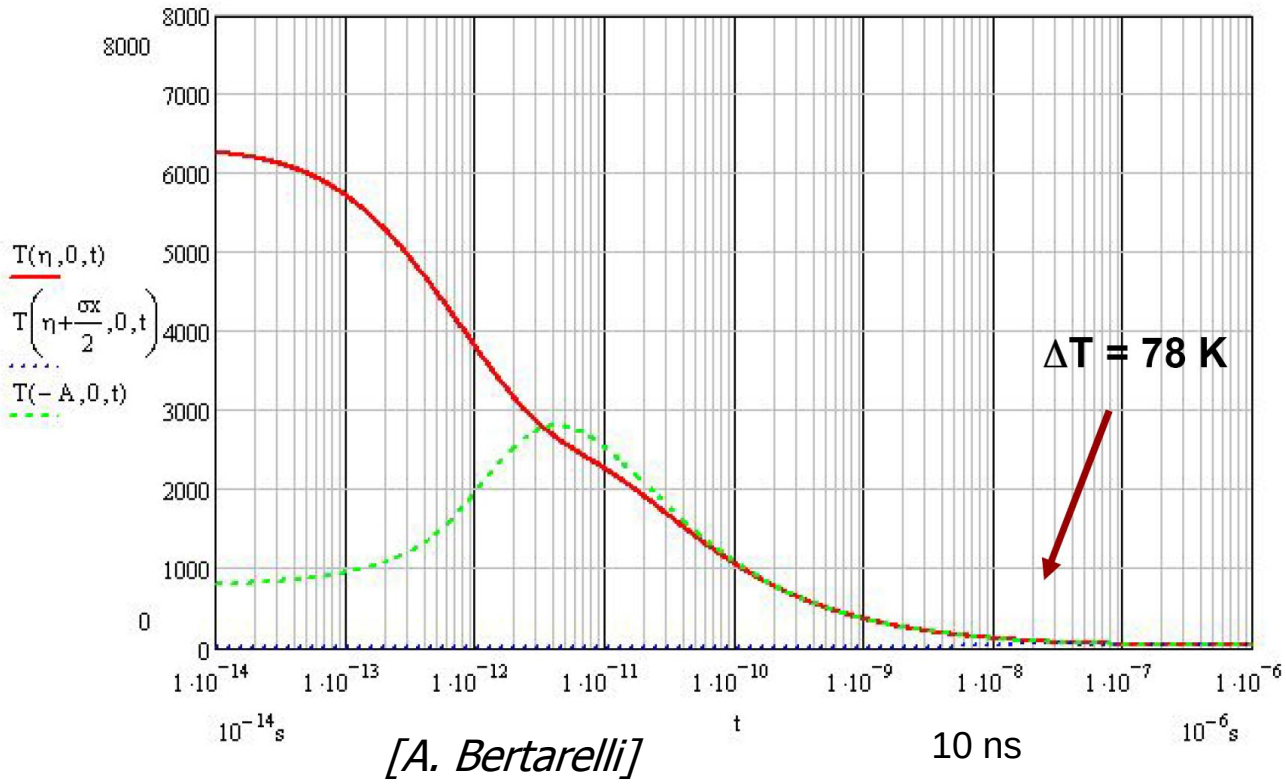


1cm copper

energy deposition longitudinally averaged

(over the 1cm scraper thickness)

HOW CLOSE CAN A SCRAPER GO?



[A. Bertarelli]

10 ns

78 K temperature rise after each proton bunch for scraping at 2 sigma

how reducing the heat load due to bunch piling up?

(how slow has the scraper to get into the beam?)

CONCLUSIONS

• for the LHC proton beam, the addition of the cryo-collimators is expected to decrease by a factor from 5 (with 1m Cu jaws) to 15 (with 1m W jaws) the predicted peak power in the DS magnet superconducting coils, which is critical for quench occurrence.
The total load on the cold magnets is decreased as well, becoming the cryo-collimators the DS hottest points.
The improvement is not strongly dependent on the cryo-collimator aperture, provided that it is not too large.

• the reduction is even more significant for the lead beam (a factor of 10 with 1m Cu jaws)

• metallic collimators have a beneficial effect on the straight section warm magnet lifetime (determined by the resin degradation induced by dose deposition)

• fast and deep scraping of the LHC beam requires other solutions than material blocks, unable to withstand even few percents of the nominal current (-> see J. Smith & V. Shiltsev's talk on hollow e-beam lens)