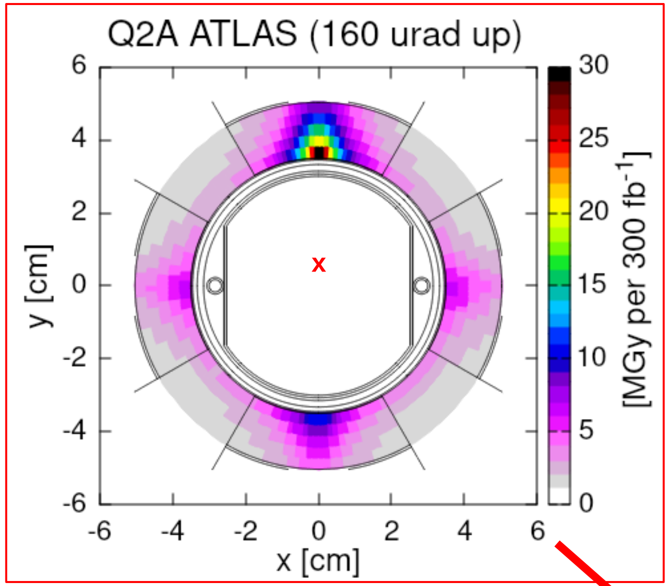
Radiation hardness requirements for organic materials in magnets and radiation environments in high-energy colliders

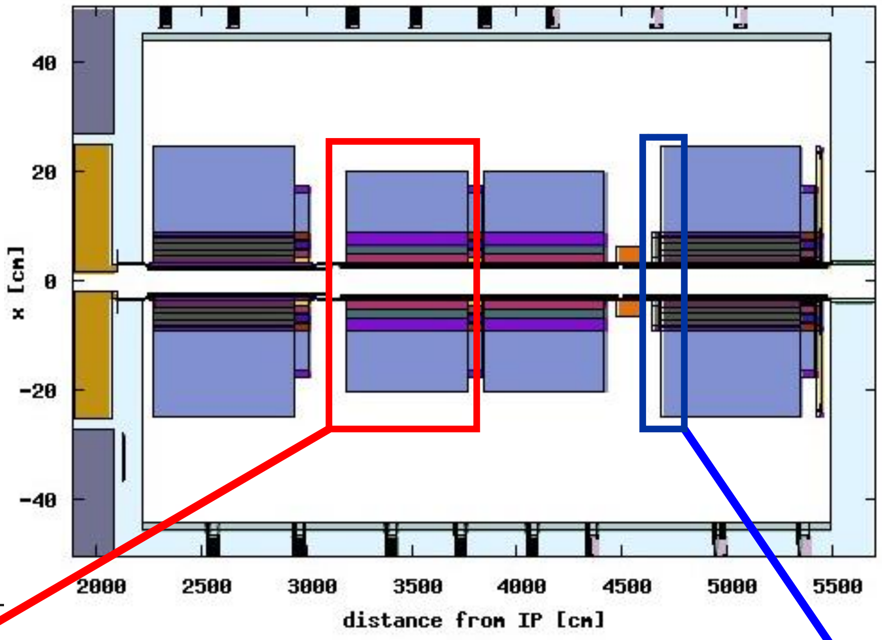
F. Cerutti on behalf of the CERN FLUKA team

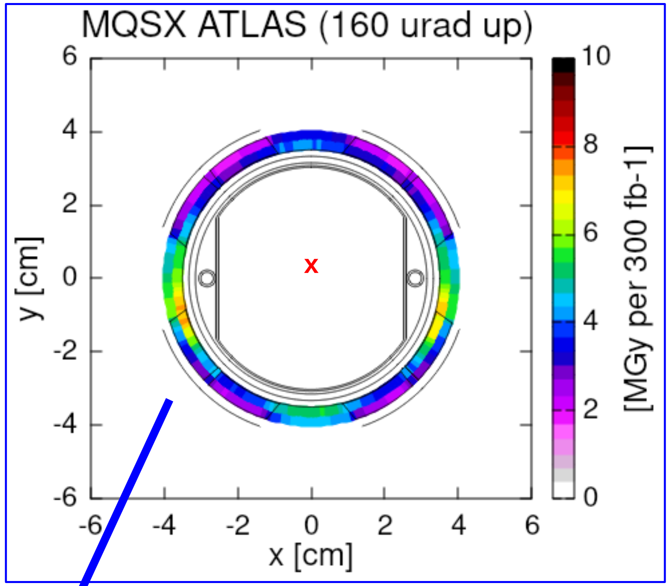
RADSUM 2025

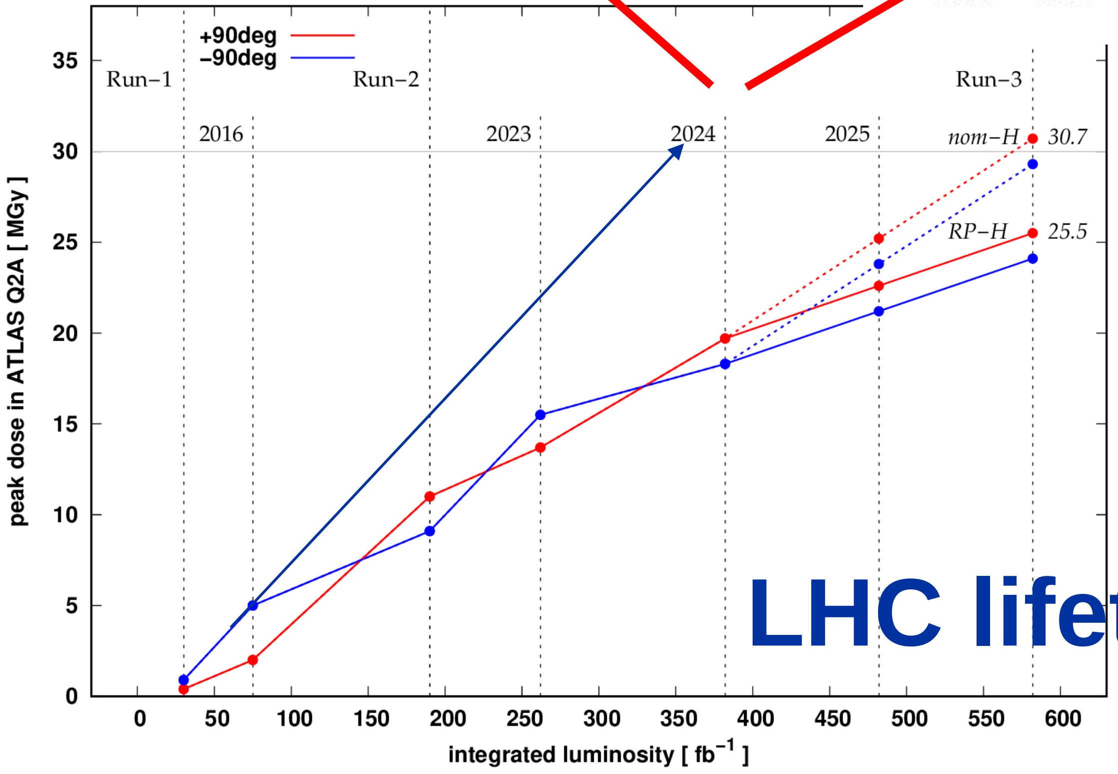
Outline

- **Approaching the limit of the LHC (first) life**
- **Without touching it**
- **From the radiation source to the radiation field**
- **Design dose values for various colliders**

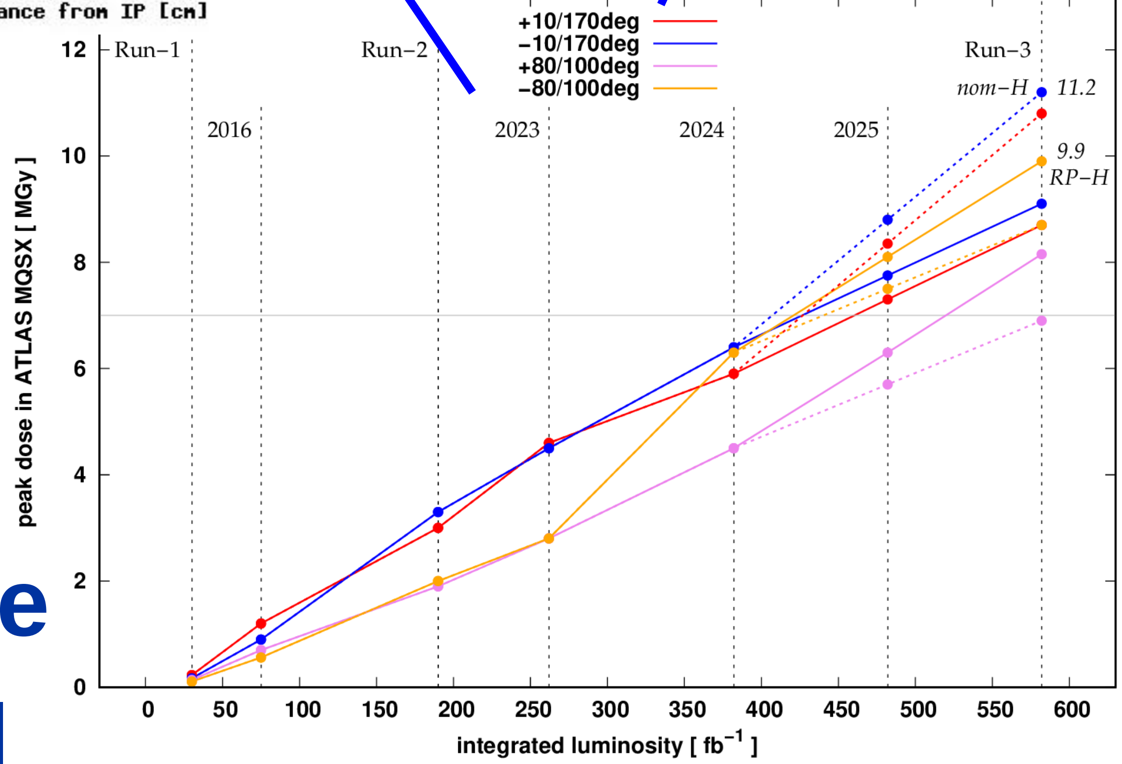




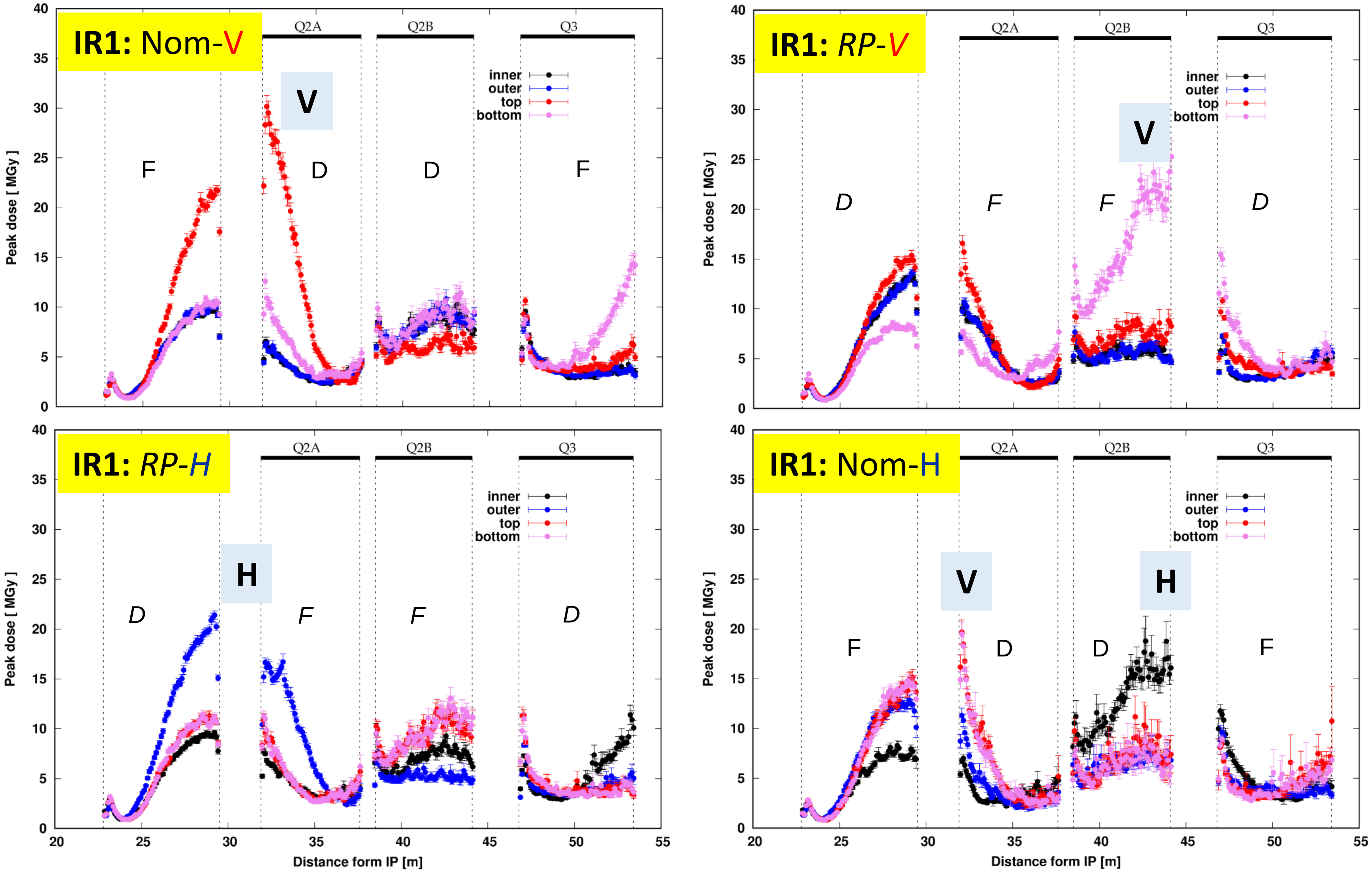


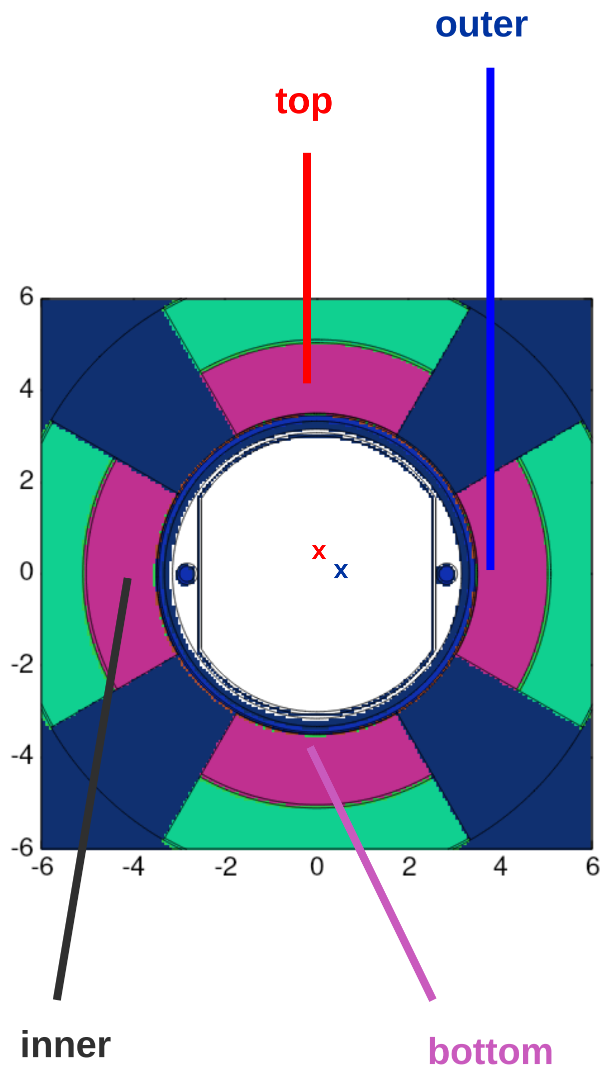


LHC lifetime



Optics mitigations

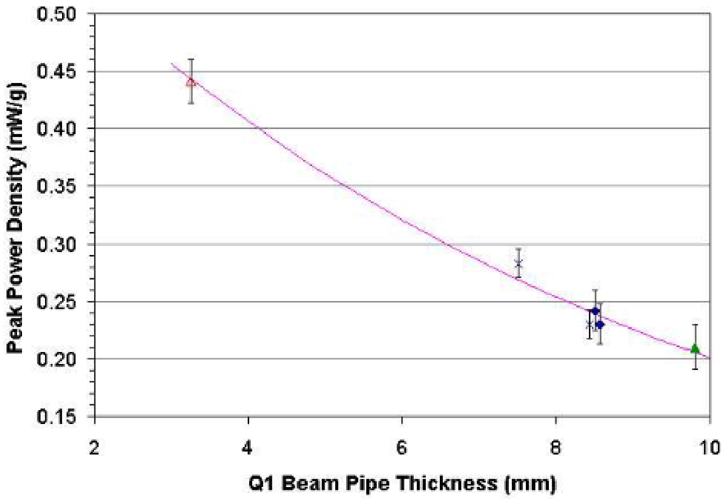


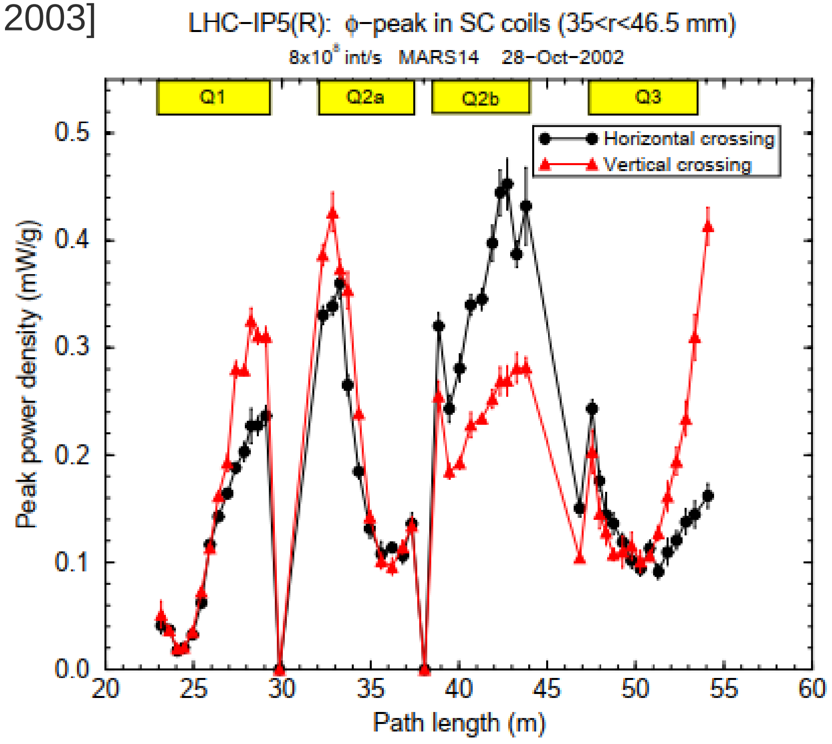


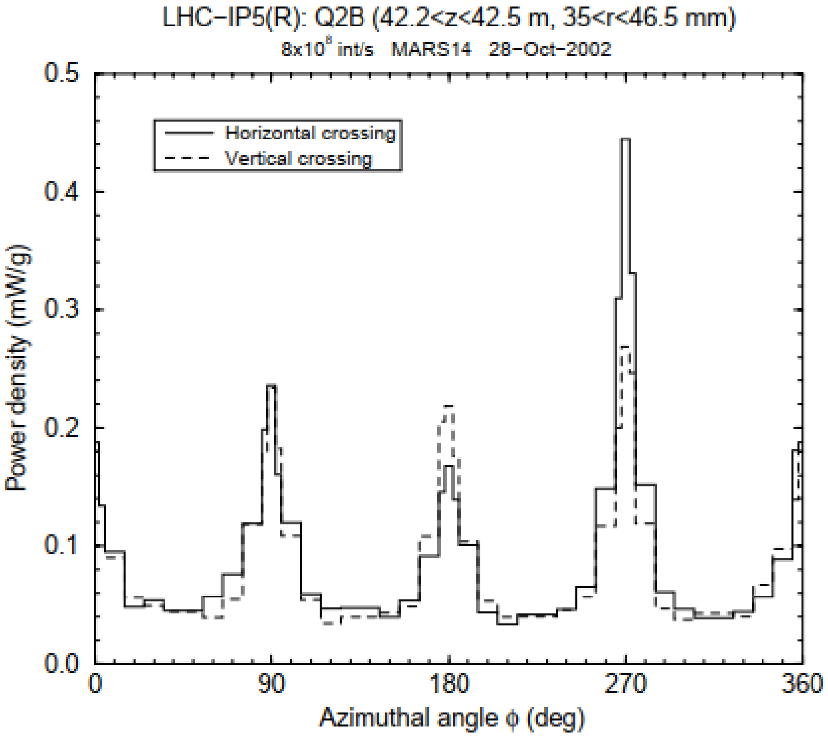
A long story

[N. Mokhov *et al*, LHC Project Report 633, 2003]

IR5 (CMS)

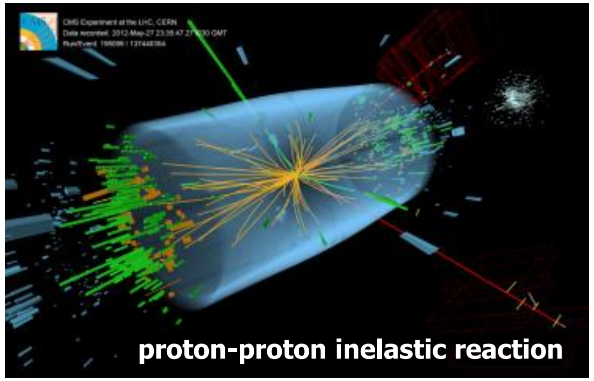




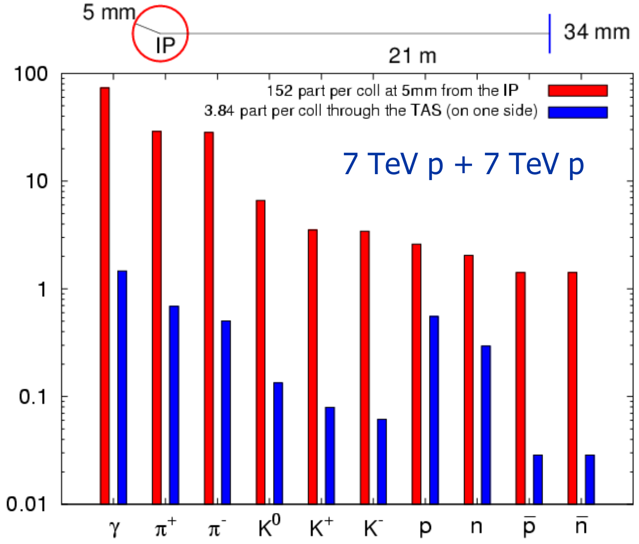


Source terms [I]

hadron colliders



proton-proton inelastic reaction



with 7.5 10^{-10} Higgs bosons

LHC

@ 2 10^{34} cm^{-2} s^{-1} , i.e. 1.6 10^{9} s^{-1} inelastic collision rate

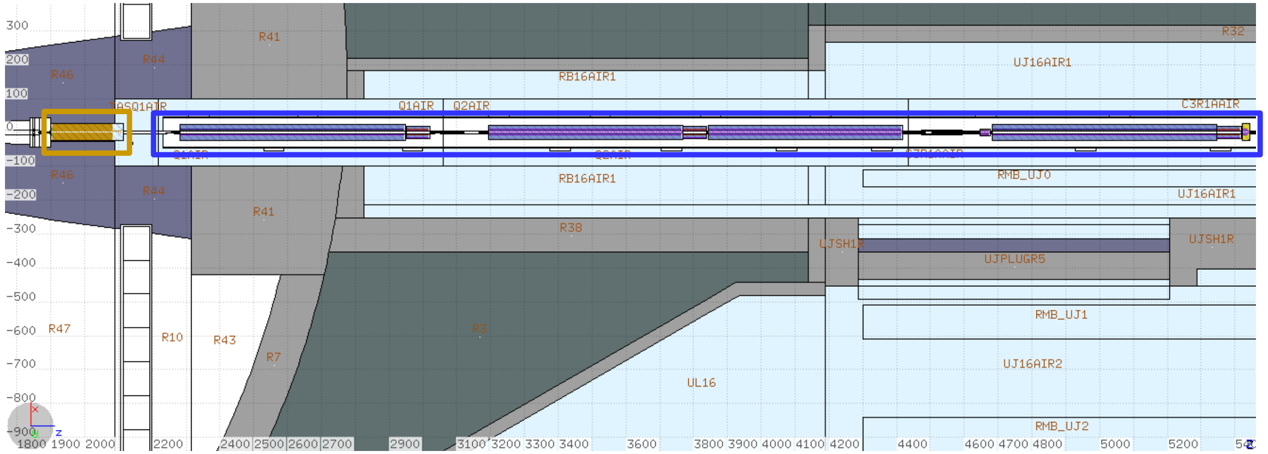
1740 W towards each (L&R) side with 6.8 TeV beams

270 W absorbed in the TAS absorber

1200 W going through the TAS

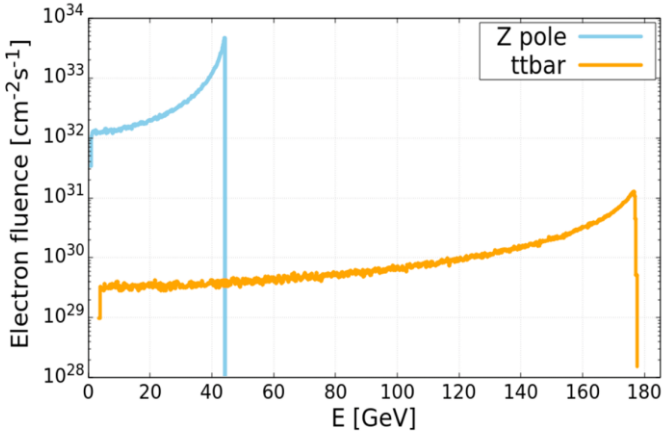
of which

260 W absorbed in the triplet cold magnets



Source term [II]

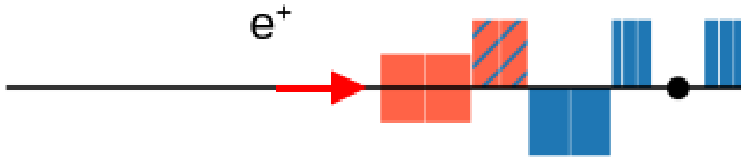
lepton colliders (FCCee)

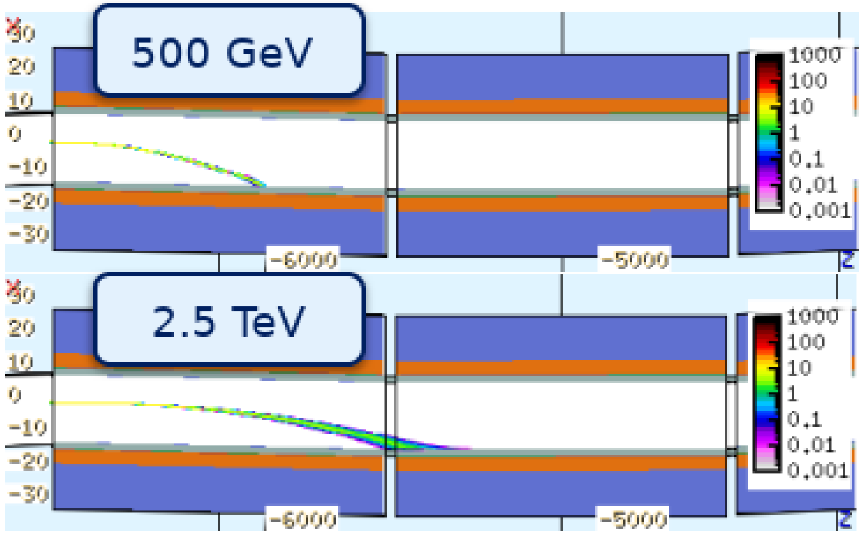


radiative Bhabha electrons/positrons

[A. Frasca]

muon colliders



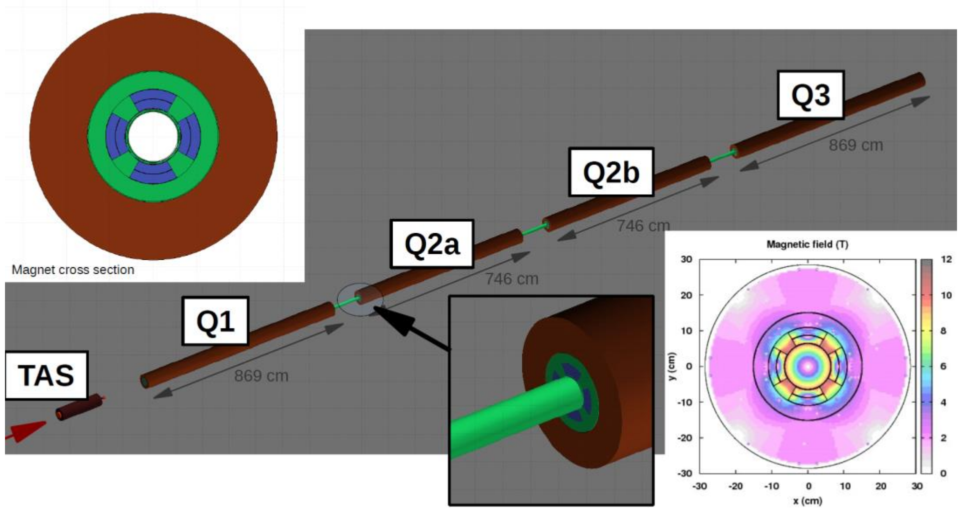


synchrotron radiation emission has a major effect

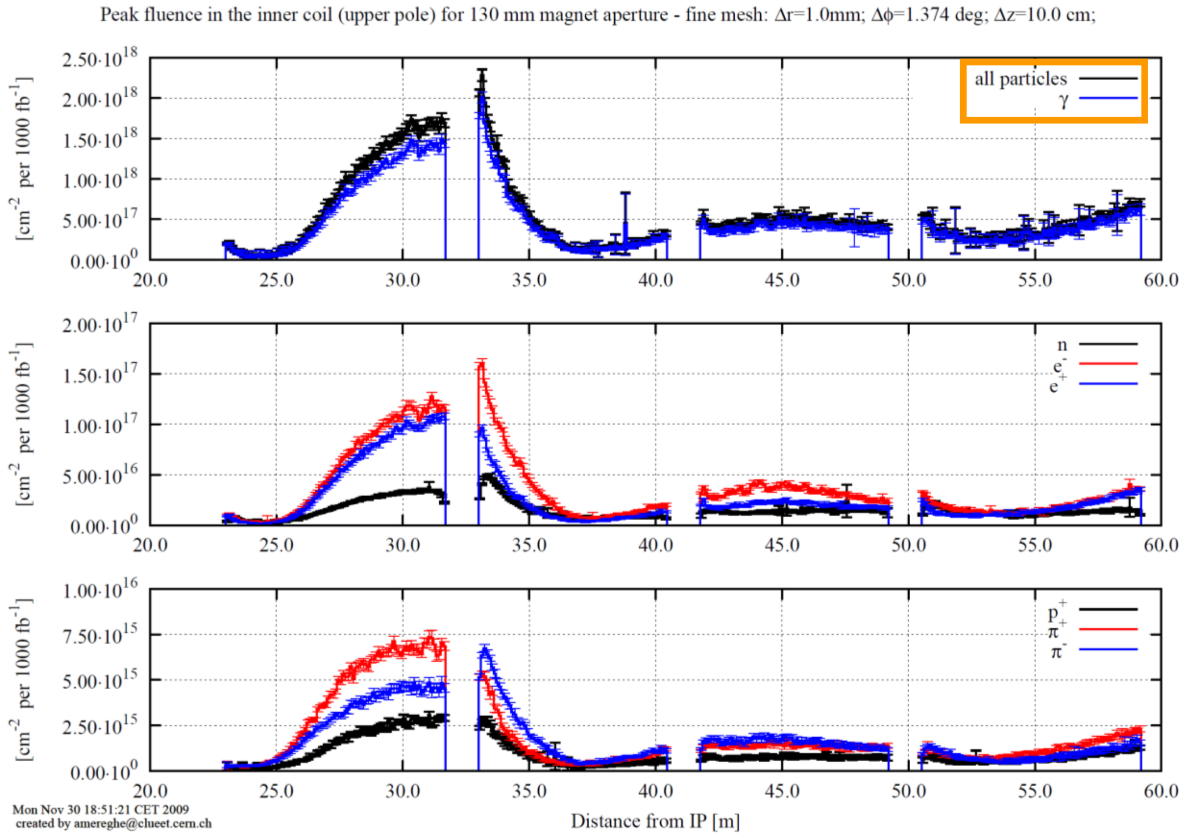
[D. Calzolari]

Radiation field

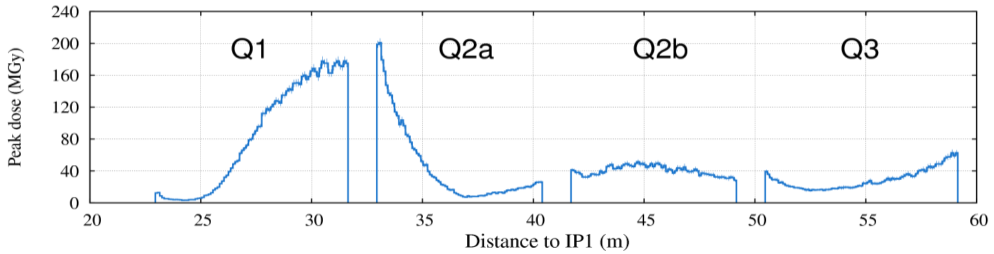
preliminary studies for
LHC upgrade to 3,000 fb^{-1}



peak fluence **in the inner cable**



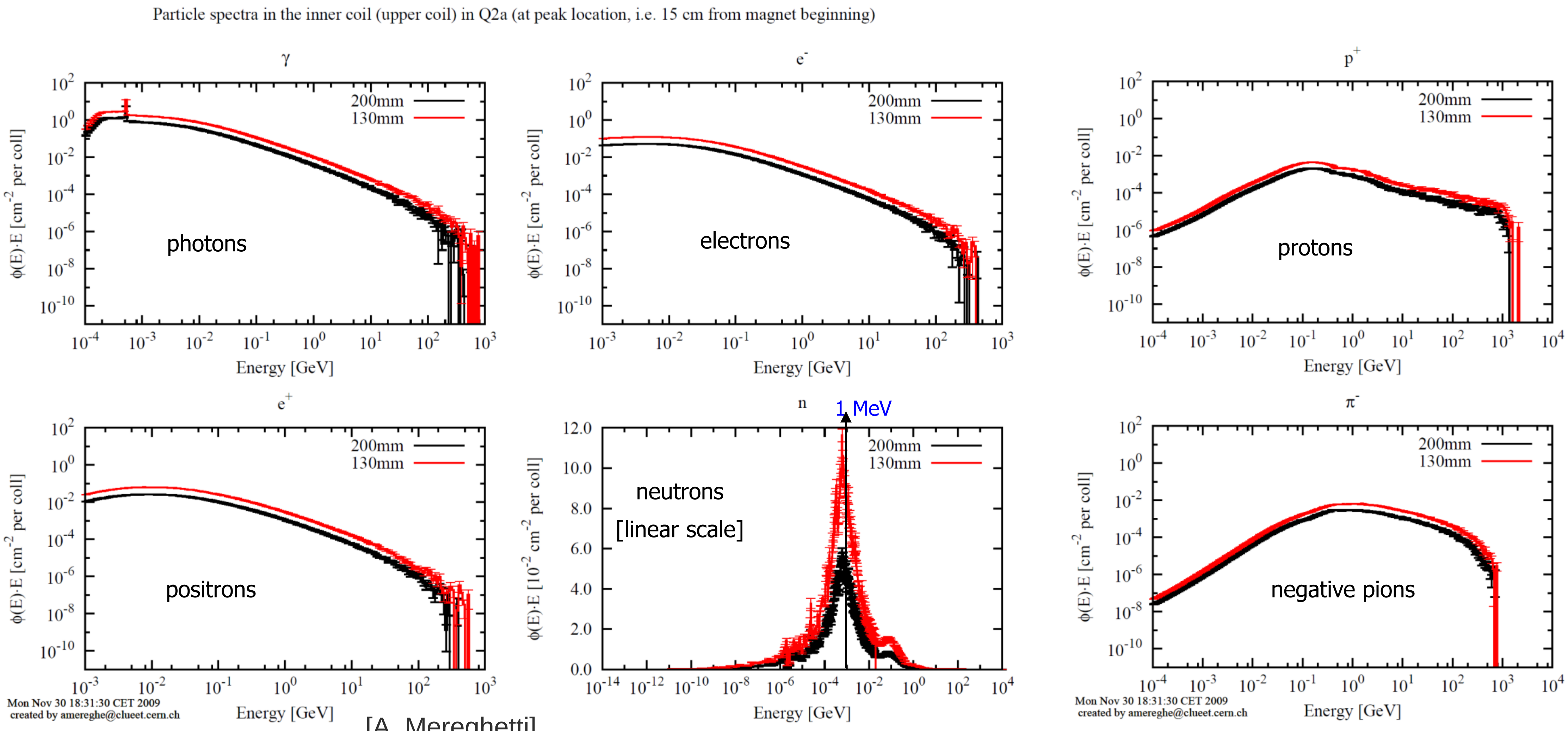
[A. Mereghetti]



tracklength fraction [%]	
photons	**88**
electrons/positrons	7
neutrons	4
pions	0.45
protons	0.15

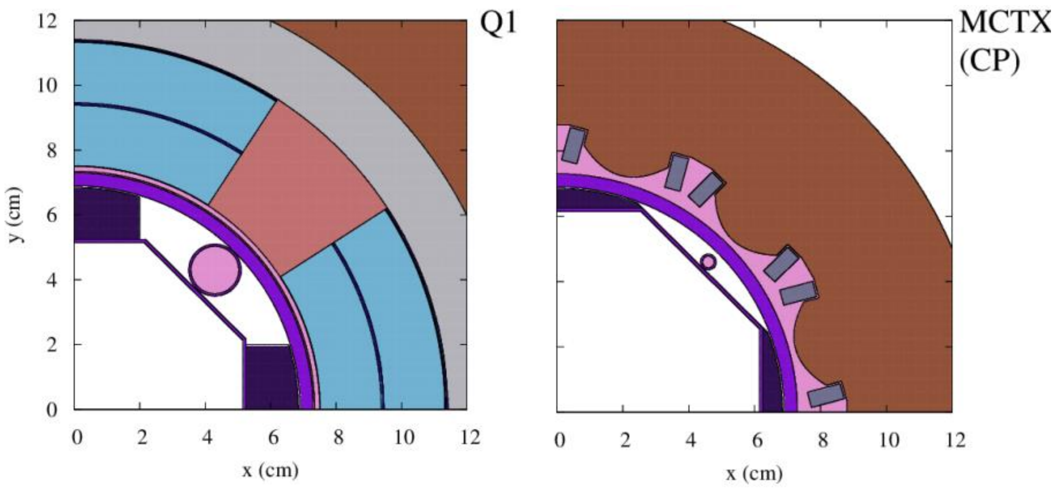
few hundred MGy
with no shielding included!

Particle spectra

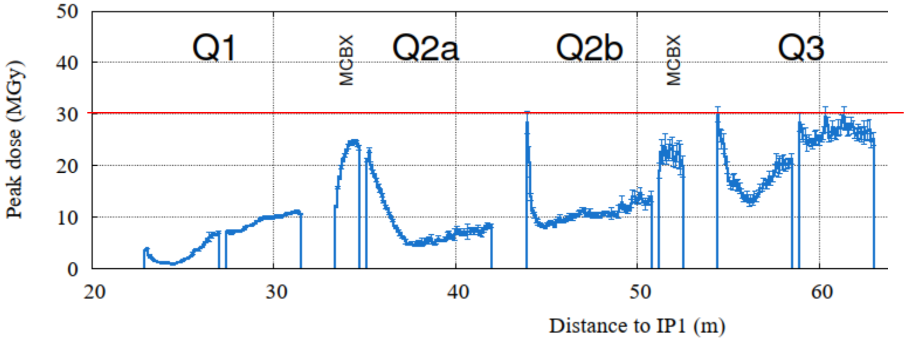


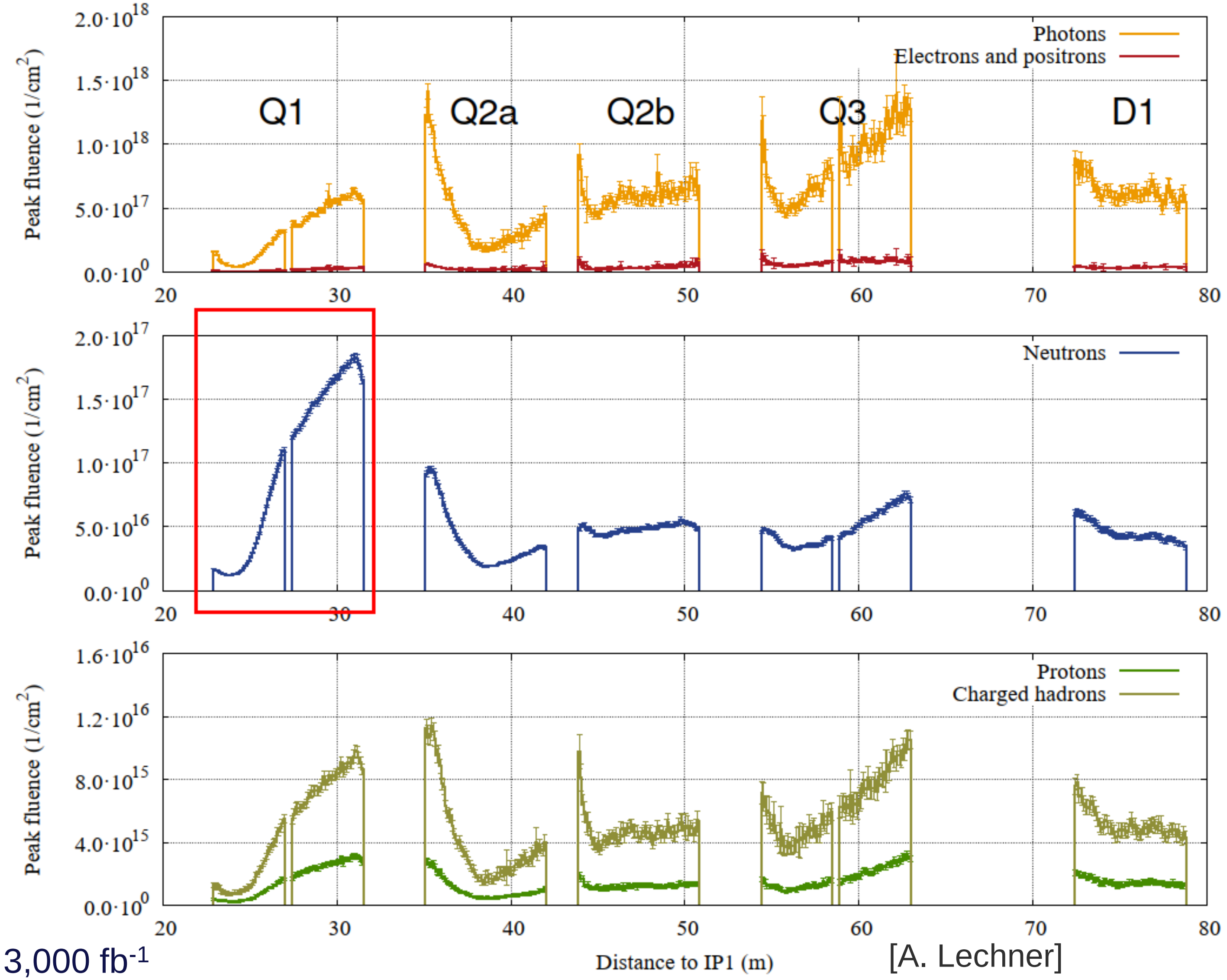
[A. Mereghetti]

Shielding effect



16 mm 6 mm
tungsten (INERMET)

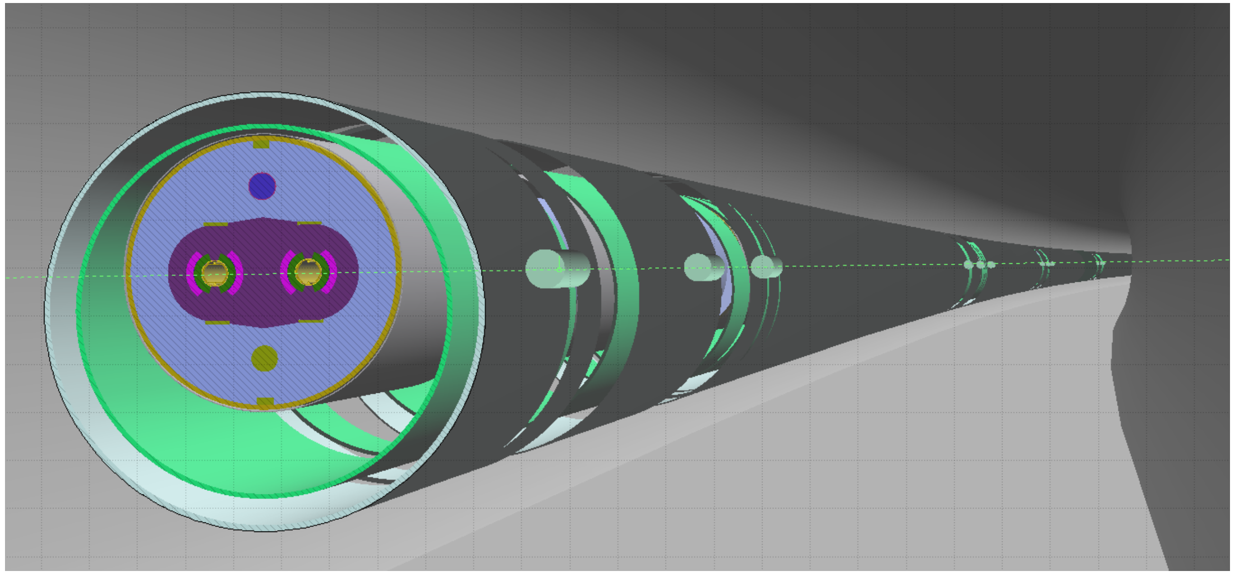


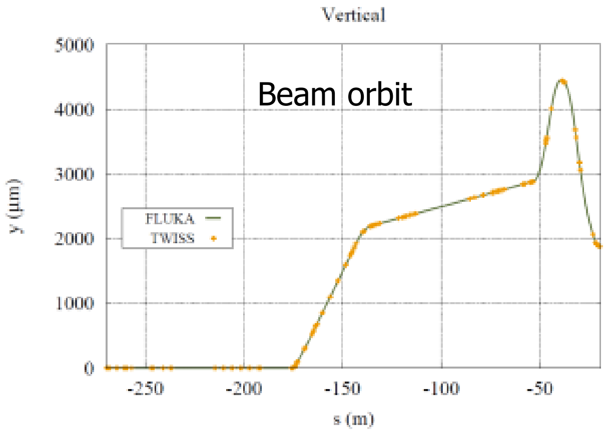


values for 3,000 fb^{-1}

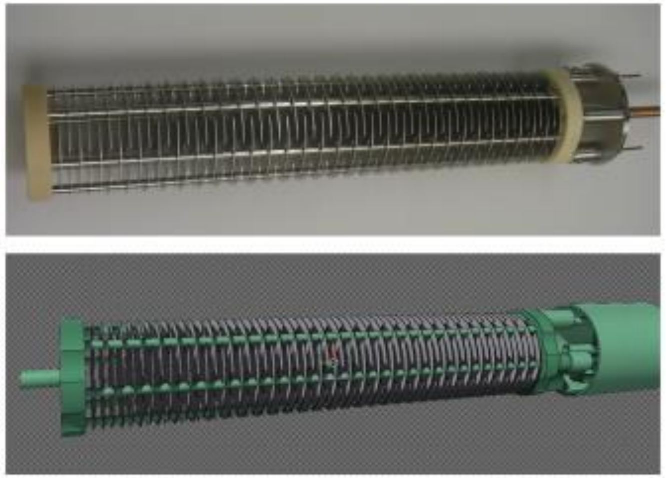
[A. Lechner]

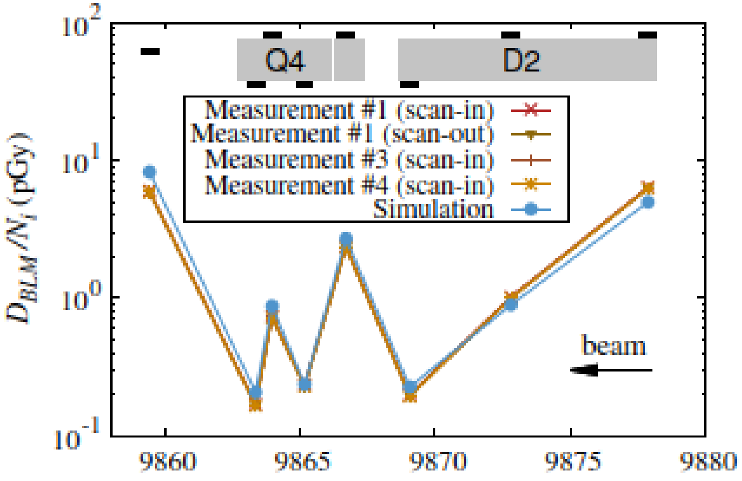
Simulation and benchmarking





Beam Loss Monitor

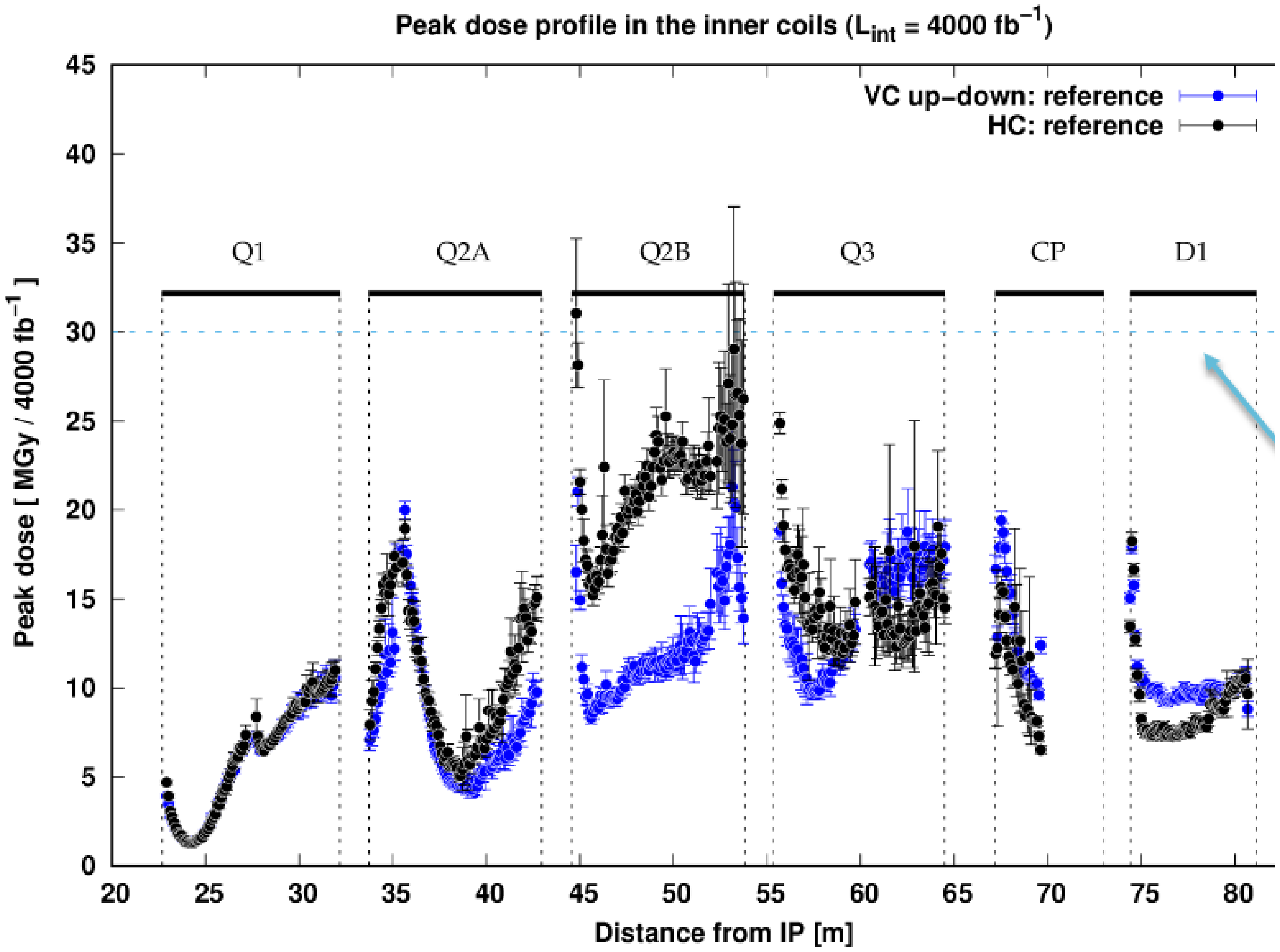




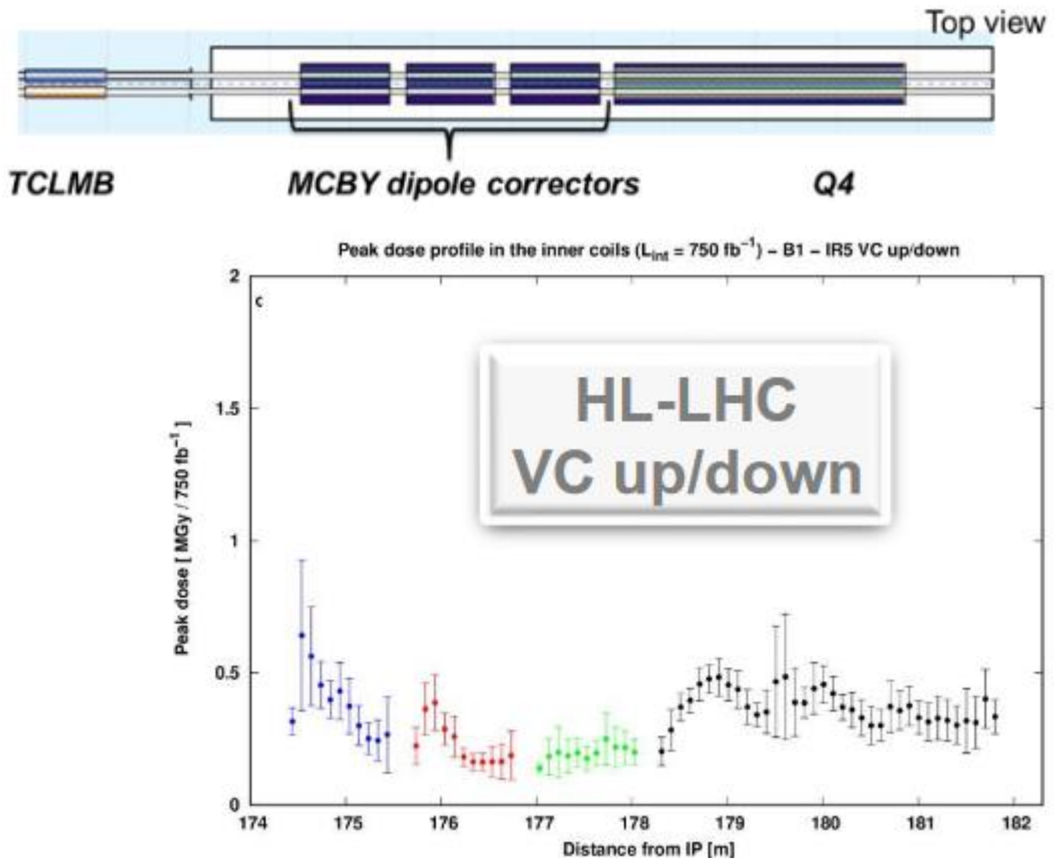
2010 wire scanner quench test

10.1103/PhysRevAccelBeams.22.071003

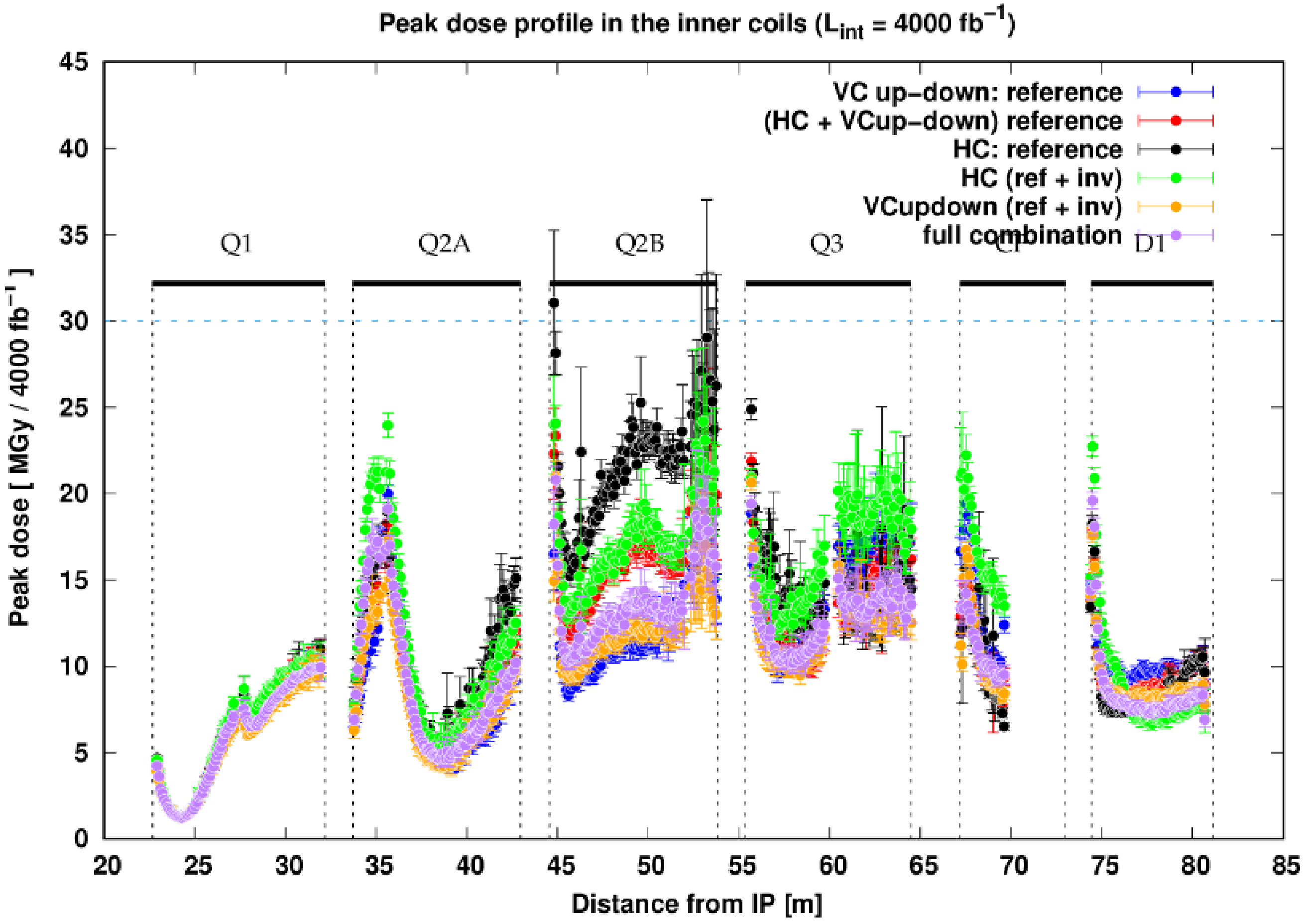
HL-LHC doses



[M. Sabaté-Gilarte]



< 7 MGy after 4000 fb^{-1}



HC ref:
100% HC nominal
Max.
> 30 MGy

VC up/down ref:
50% VC-up nominal
50% VC-down nominal
Max.
21 MGy

(HC + VC up/down) ref:
25% VC-up nominal
25% VC-down nominal
50% HC nominal
Max.
23 MGy

HC (ref+rev):
50% HC nominal
50% HC rev. pol.
Max.
24 MGy

HL-LHC optimization scenarios

% is the HL-LHC operation time

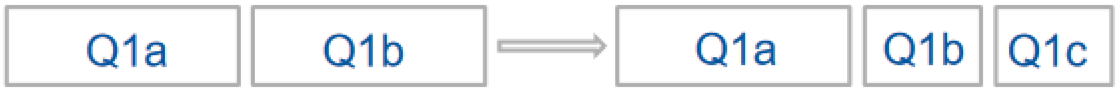
[M. Sabaté-Gilarte]

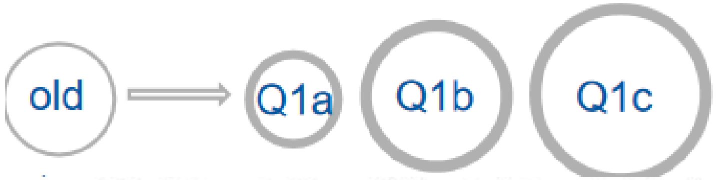
Full combination:
- 25% HC nominal
- 25% HC reverse polarity
- 12.5% VC-up nominal
- 12.5% VC-up rev. pol.
- 12.5% VC-down nominal
- 12.5% VC-down rev. pol.

Max.
21 MGy

VC up/down (ref+rev):
25% VC-up nominal
25% VC-up rev. pol.
25% VC-down nominal
25% VC-down rev. pol.
Max.
21 MGy

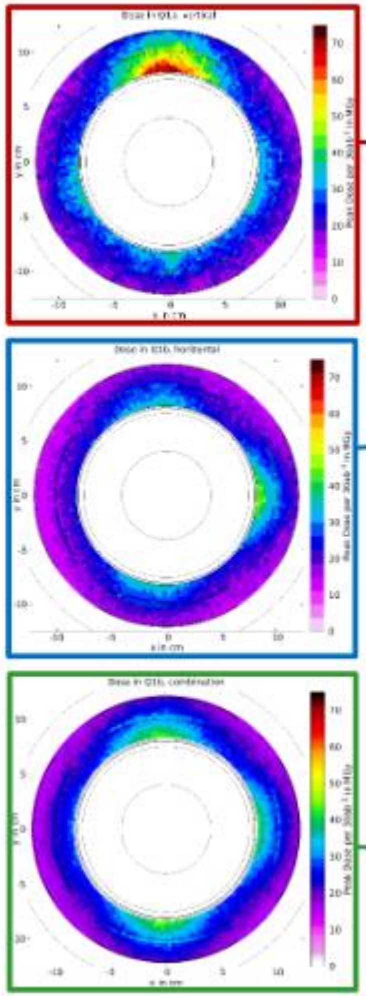
FCChh doses

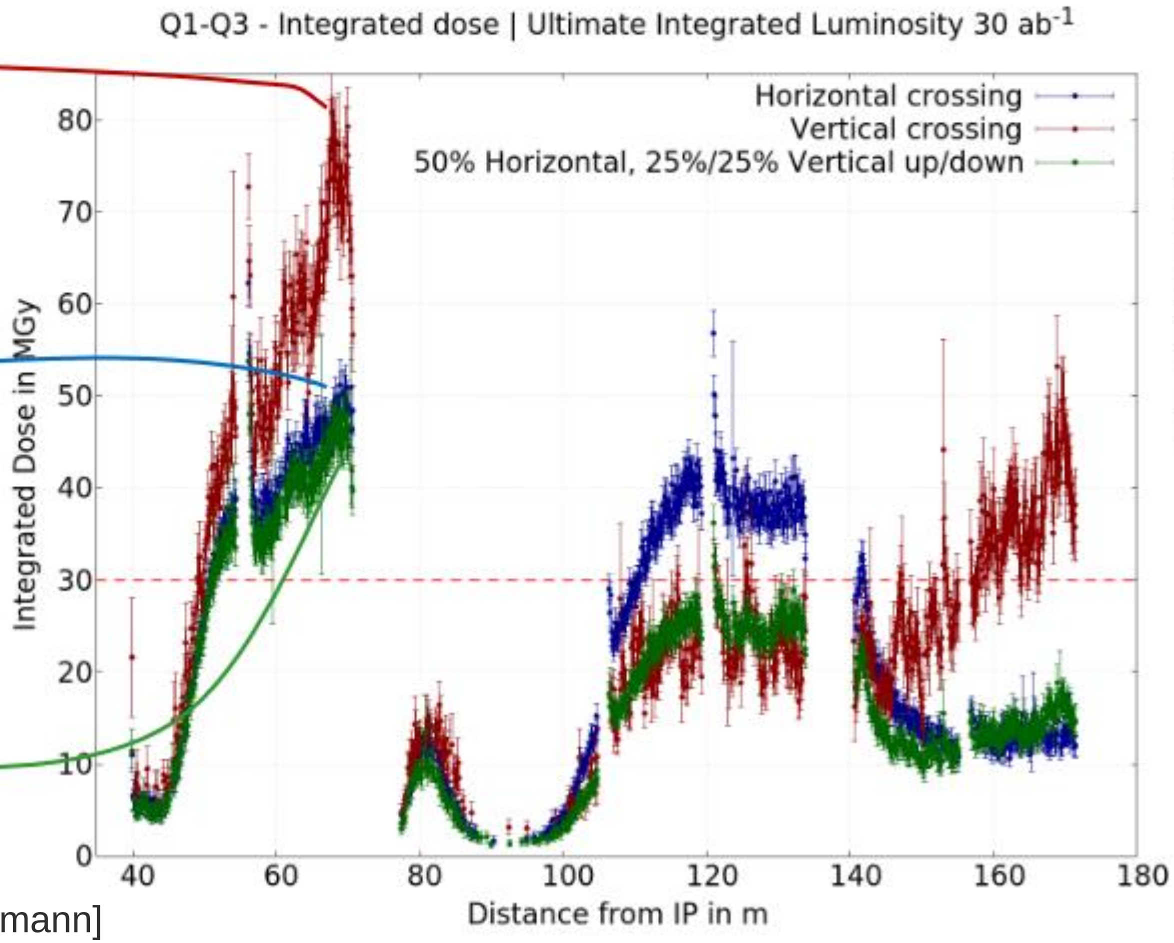




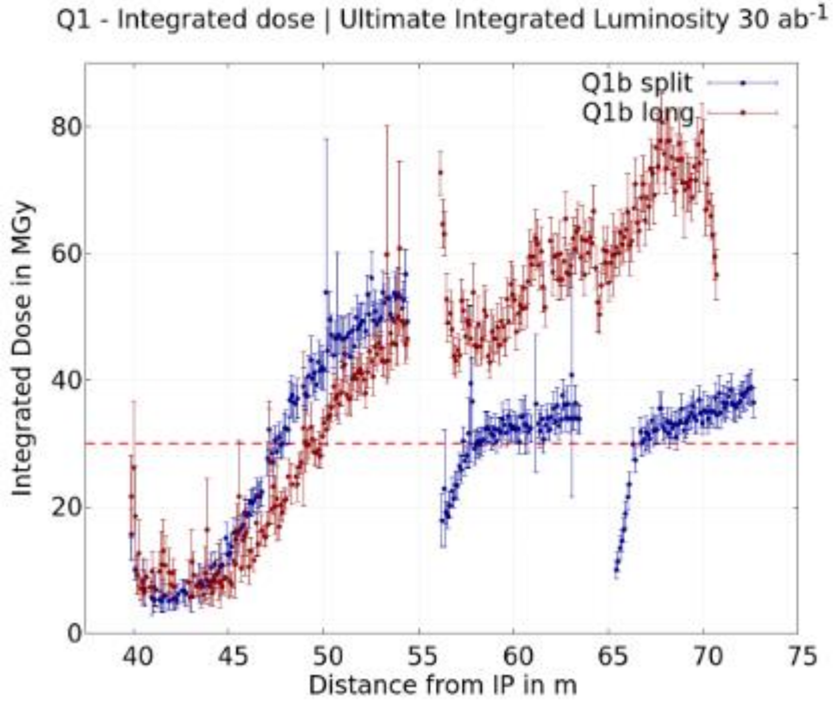
164 mm aperture quadrupoles, 100-125 T/m, 12-15 m long

35 mm INERMET shielding



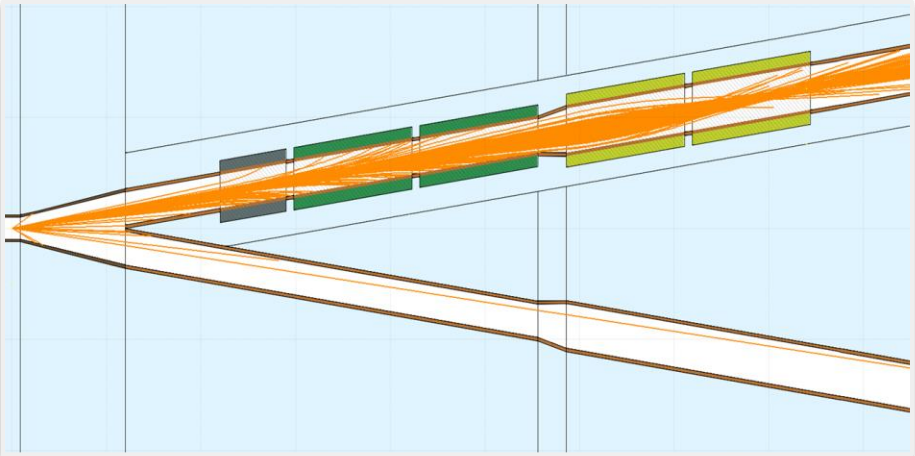


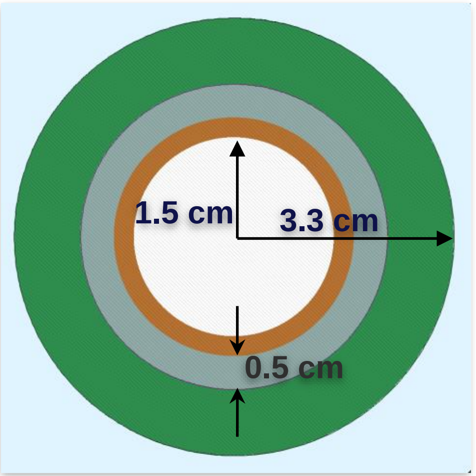
[B. Humann]

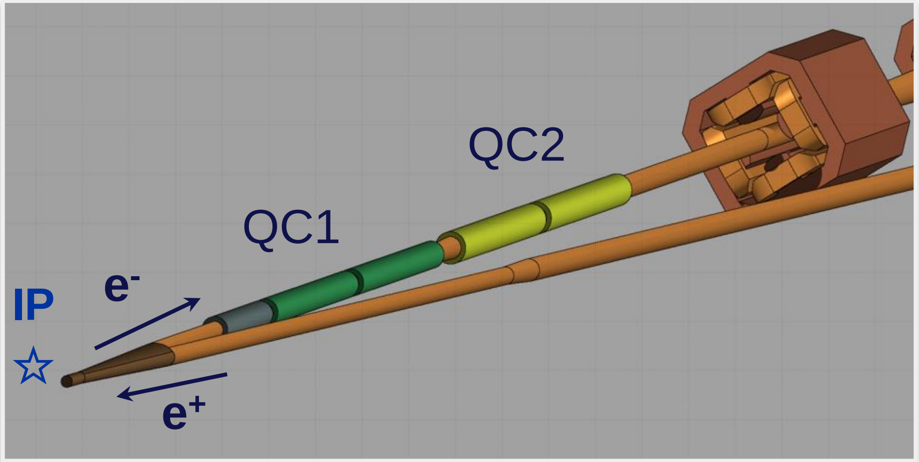


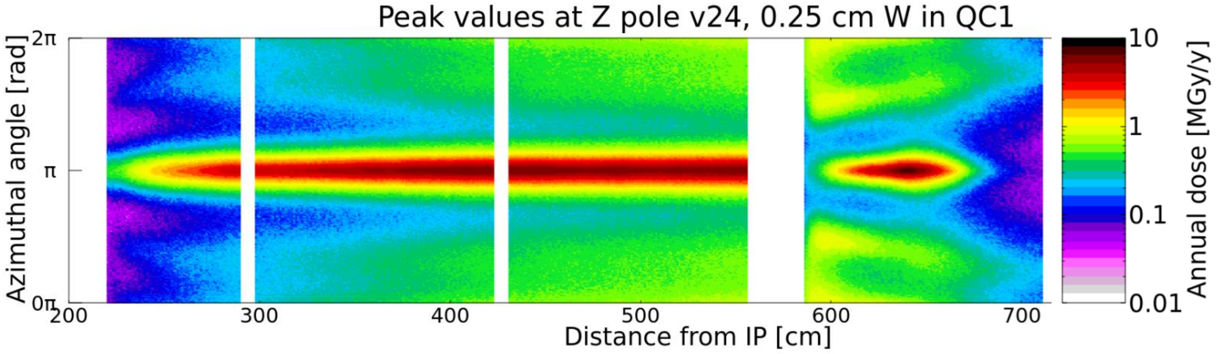
Aperture in mm		Shielding in mm		Gradient in T/m	
old	new	old	new	old	new
164	150	35	38	126	139
164	180	35	47	126	119
-	190	-	47	-	111

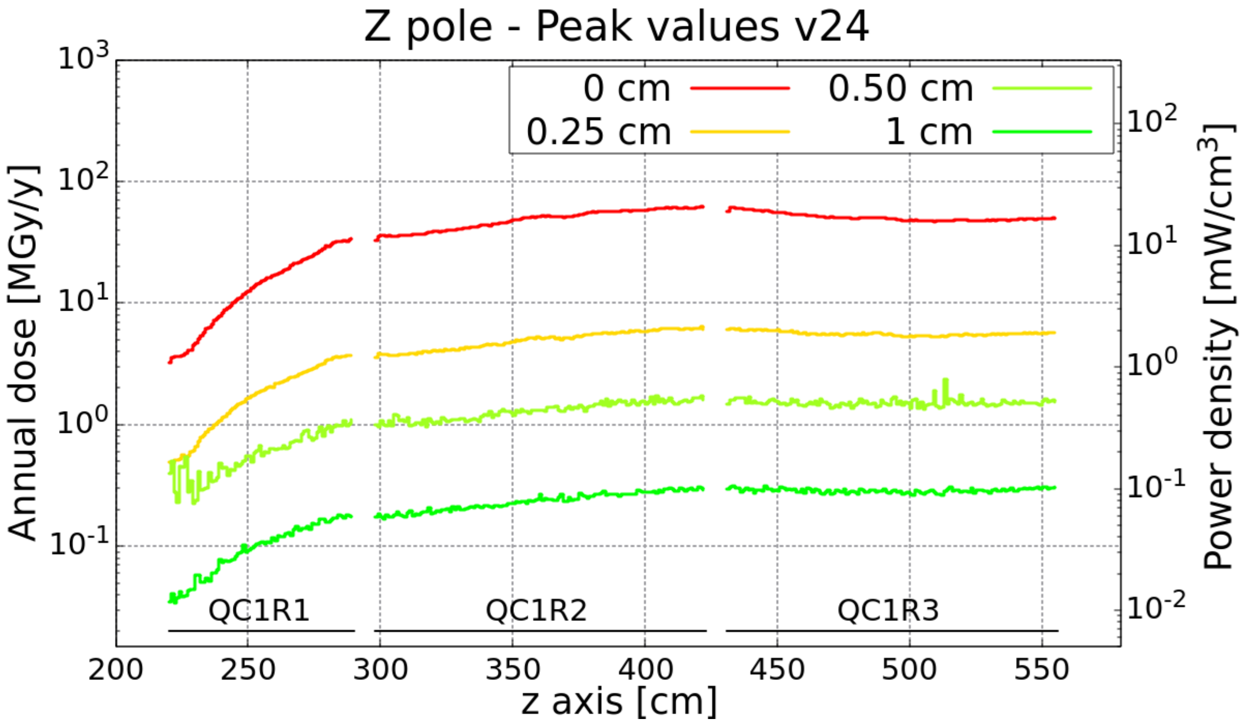
FCCee doses











[A. Frasca]

Muon collider doses

Final focus magnets

Name	L [m]	Shield thickness [cm]	Coil aperture (radius) [cm]	Peak TID [MGy/y]
IB2	6	6	16	1.3
IB1	10	6	16	3.1
IB3	6	6	16	4.9
IQF2	6	4	14	7.7
IQF2_1	6	4	13.3	4.6
IQD1	9	4	14.5	1.1
IQD1_1	9	4	14.5	3.7
IQF1B	2	4	10.2	6.4
IQF1A	3	4	8.6	3.6
IQF1	3	4	7	3.5

[D. Calzolari]

Magnet shielding design in present and future colliders *Daniele Calzolari*

30/7-018 - Kjell Johnsen Auditorium, CERN 11:25 - 11:45

Closing

Dose to organic insulator materials used in magnet coils is often the parameter limiting the machine lifetime;

In the design phase, its value can be calculated and reduced by suitable shielding solutions making use of high-Z dense materials, in view of the electromagnetic nature of the relevant radiation;

Optics optimization can play a significant mitigation role;

Design values typically lie in the ten MGy range.