Status of work on energy deposition for LHC insertion

FLUKA meeting 26th July, 2007

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Outline

- Motivations for LHC upgrade studies
- PAC07 paper
  - **“ PARAMETRIC STUDY OF HEAT DEPOSITION FROM COLLISION DEBRIS INTO THE INSERTION SUPERCONDUCTING MAGNETS FOR THE LHC LUMINOSITY UPGRADE”**
  - C. Hoa, F. Cerutti, J-P. Koutchouk, G. Sterbini, E. Wildner, CERN, Geneva, Switzerland
F. Broggi, INFN/LASA, Segrate (MI), Italy

- Visit at Fermilab: benchmark on the LHC Insertion Region with MARS and FLUKA

LHC upgrade studies

- **Concept**
  To increase luminosity by reducing β^*=55 cm→ 25 cm

- **Staging in 2 phases**
  - LHC Upgrade phase I
    - Large aperture quadrupole (Nb-Ti): 130 mm
    - Longer triplet (+30%)
    - *“ Solution for phase-one upgrade of the LHC Low beta quadrupoles based on Nb-Ti”,* J-P Koutchouk, L. Rossi, E.Todesco, LHC report 1000, April 2007
  - LHC Upgrade phase II
    - Large aperture quadrupole (Nb_3Sn): 130 to150 mm
    - Early separation scheme with magnets in the detector
    - PAC07 paper (2 references)

LHC upgrade studies

- Energy deposition issues
  - LHC Upgrade phase I
    - The gain factor of **1.5 to 2** in luminosity induces same increase of the radiated power
    - **Scaling law for heat load and peak power density?**
  - LHC Upgrade phase II
    - The gain factor of **10** in luminosity induces same increase of the radiated power
    - Larger temperature margin for Nb_3Sn: sufficient?
      - Nb-Ti: quench limit: 12 mW/cm^3
      - Nb_3Sn : quench limit: 36 mW/cm^3
    - Optics solution with magnets in the detector (Q0 and/or D0 schemes). **What is the scaling law with L*, distance to the IP?**

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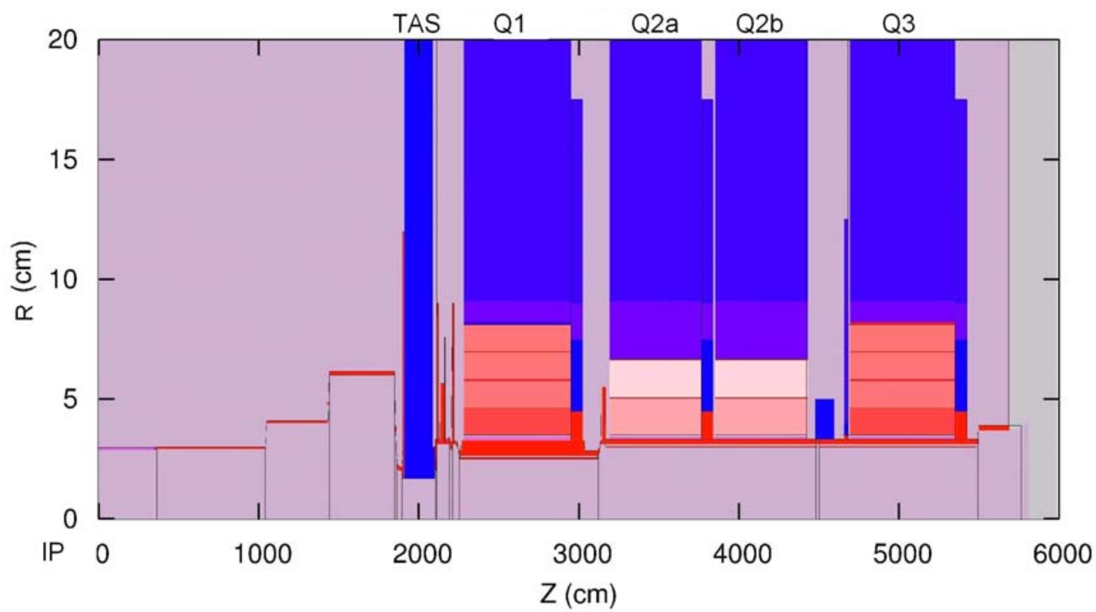
PAC 07 paper

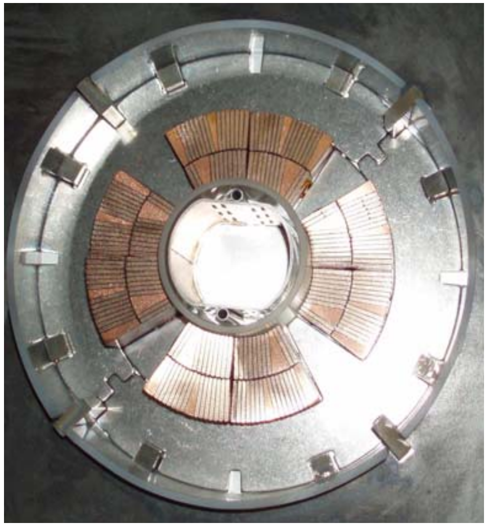
- Detailed model of the insertion region : Geometry layout

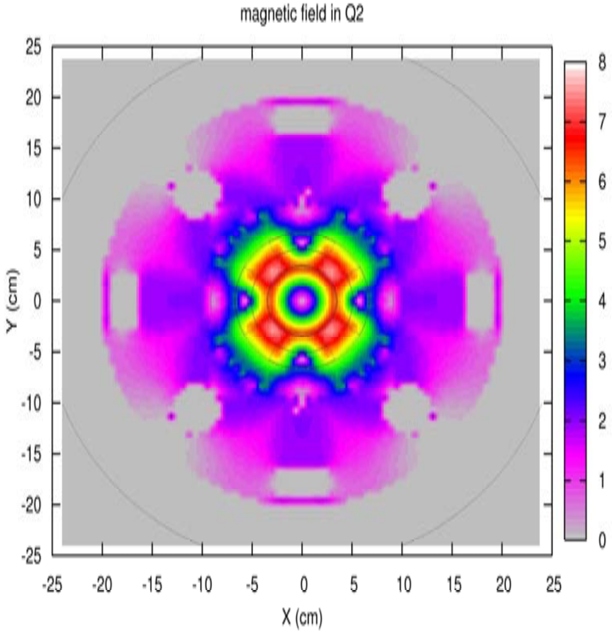


- Triplet magnets
  - SC 70 mm aperture
  - Nb-Ti quads
- Absorbers (TAS and liners)
- Beam screens

PAC 07 paper

- Insertion region detailed model: Magnetic description

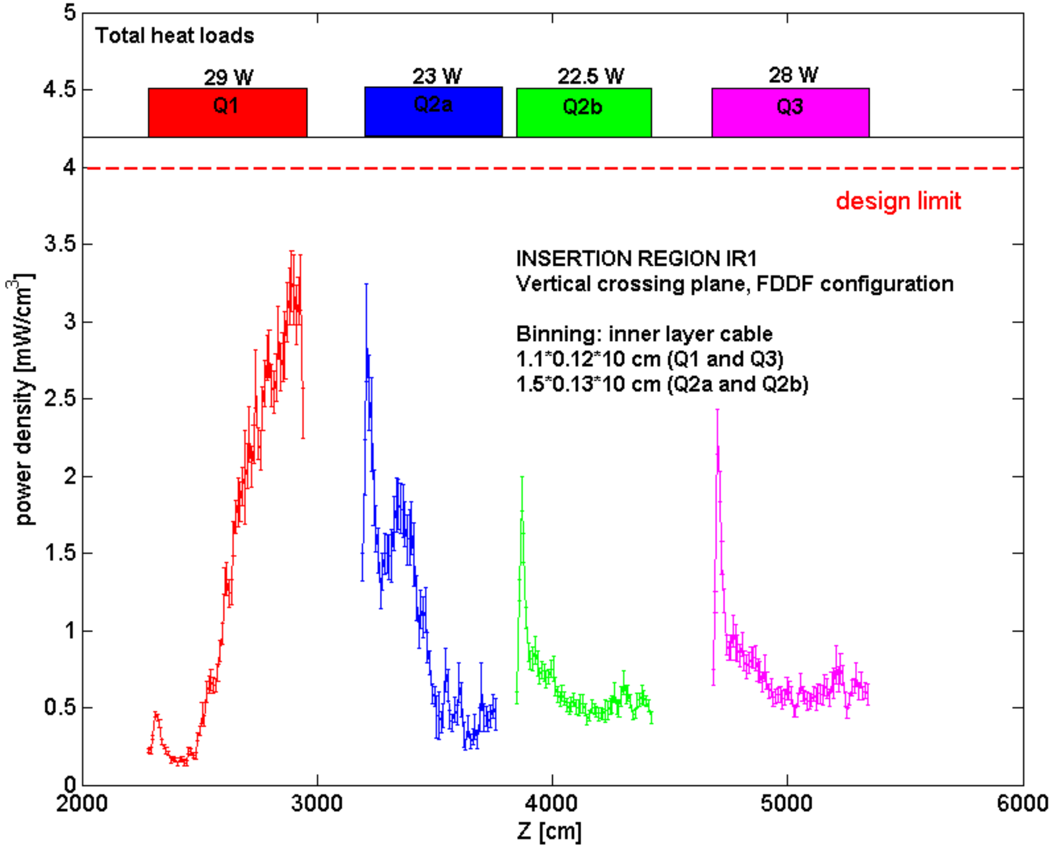




- 2D maps MQXA and MQXB
- Solenoid field of ATLAS 2 Tesla (analytic)

PAC 07 paper

- Insertion region detailed model: power deposition 1



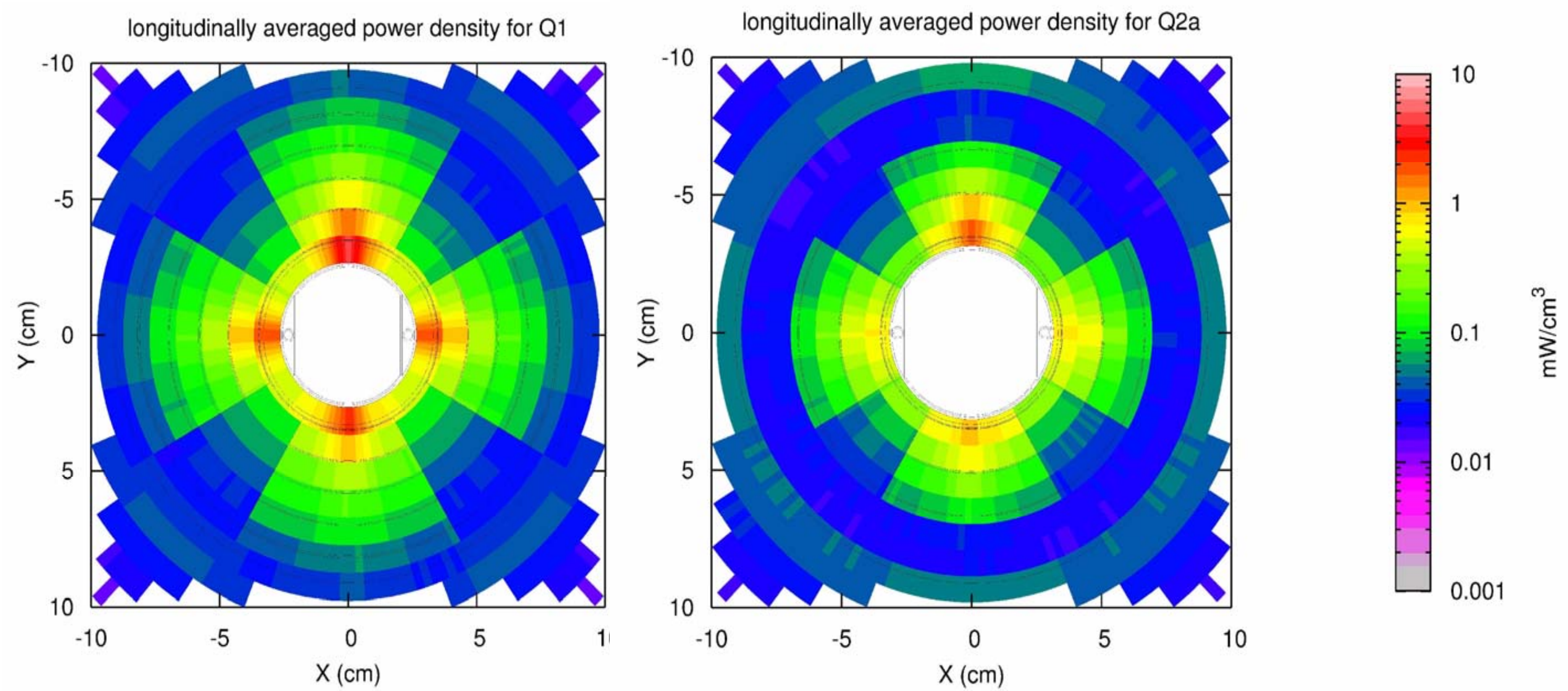
- Nominal luminosity: 10^{34} cm^{-2} s^{-1}
- Total heat loads
- Peak power density

Values < 4 mW/cm^3

→ Very good agreement with Nikolai's calculation with MARS

PAC 07 paper

- Insertion region detailed model: power deposition 2



Cylindrical binning size: ΔR=1cm, $\Delta\theta$=2°, z=2 cm

PAC 07 paper

- Parametric studies: L* distance to the IP
  - Aperture of 100 mm
  - Same beam dynamics for β*=25 cm
  - Same upgrade luminosity 8.7 $*10^{34} cm^{-2} s^{-1}$
  - TAS opening adapted to each L*

Cases	1	2	3	4
l* distance to the IP (m)	23	19	16	13
Gradient (T/m)	193	204	208	213
Crossing angle (μrad)	512	514	507	500
TAS opening (cm)	2.0	1.7	1.5	1.3

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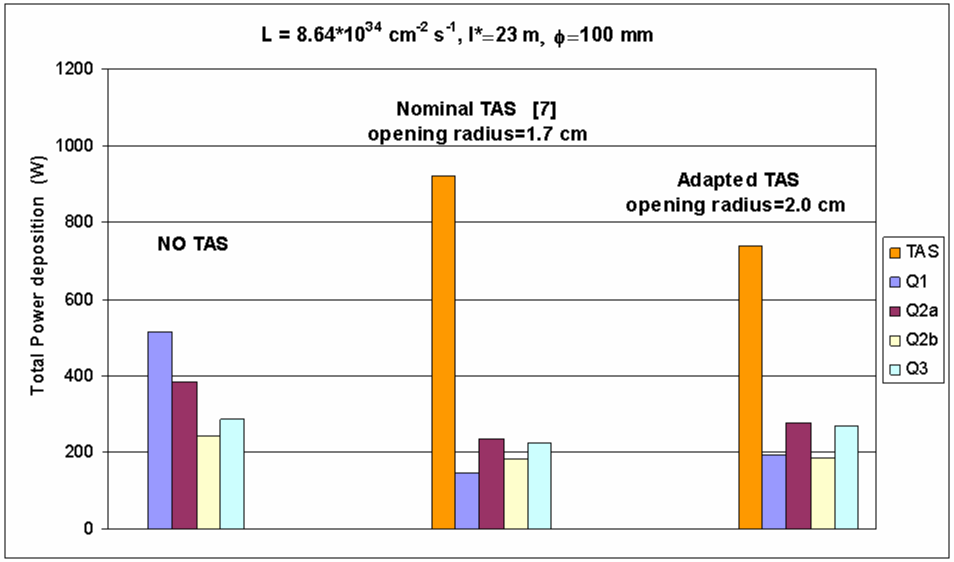
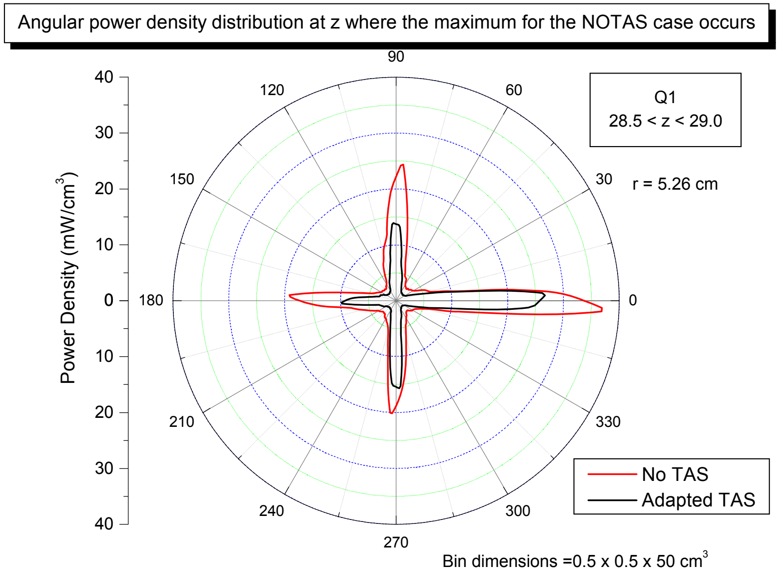
- TAS protection analyses
  - Total heat loads
  - Peak power density





The TAS protects the front face of the triplet, mainly Q1 (-62%) but protection is much less for Q3 (-7%)

-30% decrease of peak power density at the end of Q1

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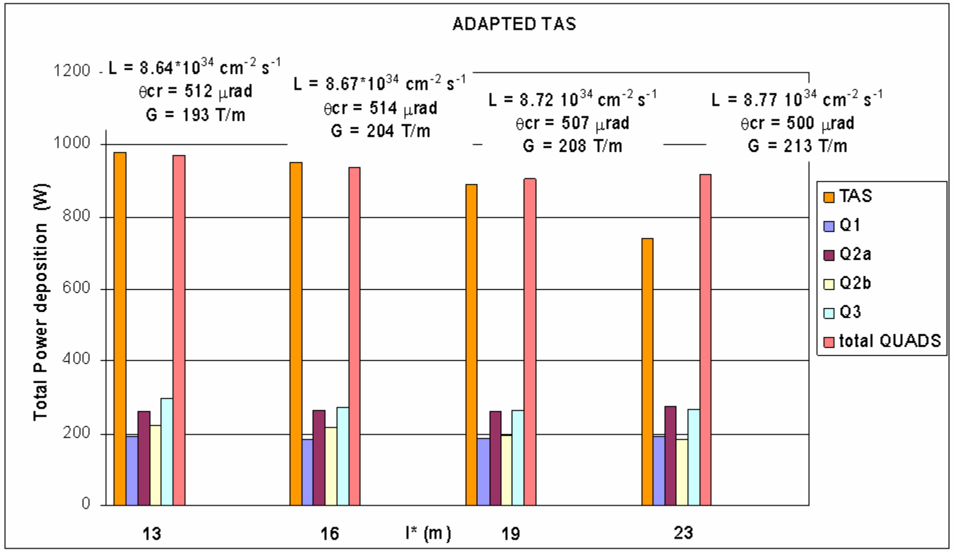
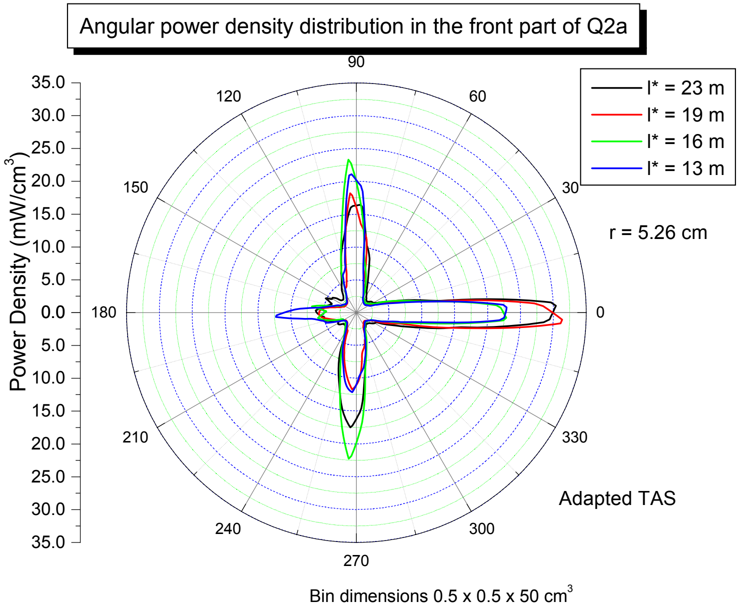
- Parametric studies: l* distance to the IP
  - Total heat loads
  - Peak power density





Moderate increase of heat load in the quads +6%

Peak power density varies in the range of 22 mW/cm³ to 36 mW/cm³

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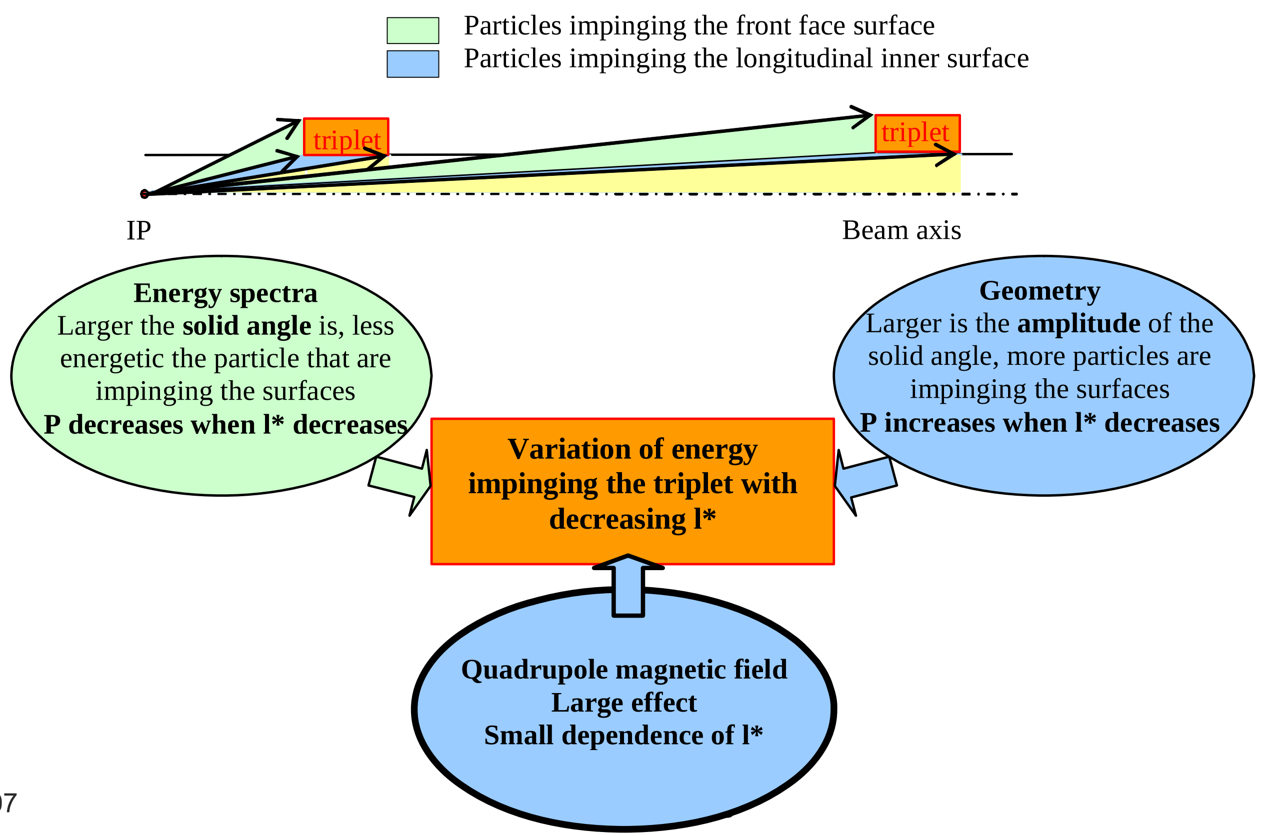
- Counterbalancing effects



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- Main outcome of the study
  - **Moderate** variation of power deposition

with decreasing L*. It leaves possibilities to have magnets closer to the IP.

  - The magnetic field of the quadrupole is a driving parameter. Protection of the triplet has to be optimized accordingly.

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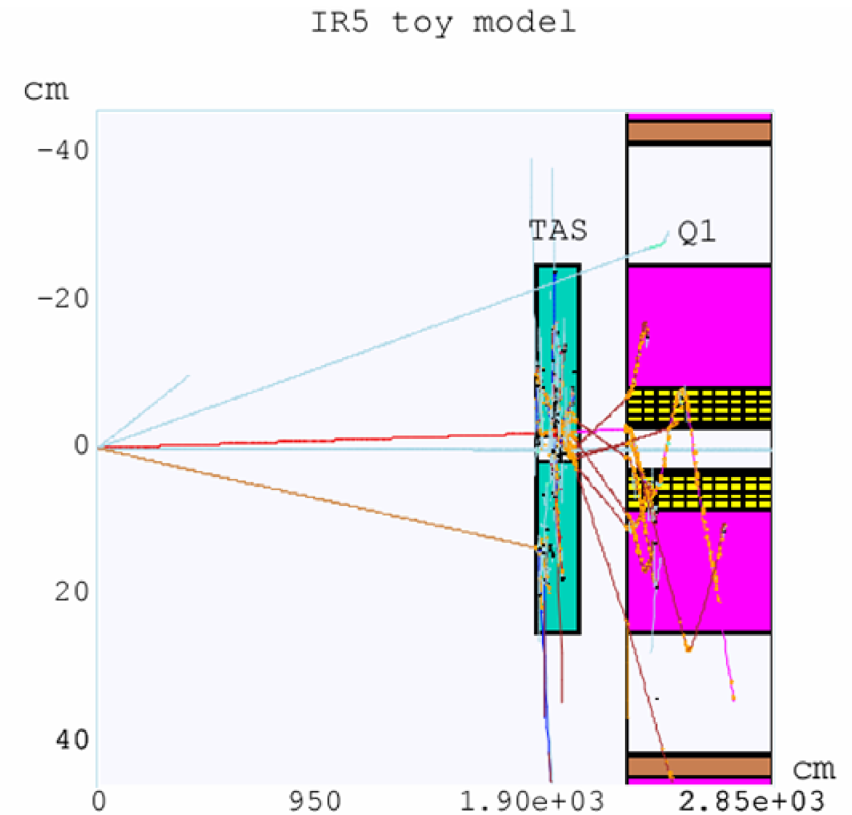
Benchmark on the LHC Insertion Region



- IR5 Toy model
  - Same simple geometry layout
  - Same magnetic field definition
  - Same materials

Benchmark on the LHC Insertion Region

- Results: heat loads

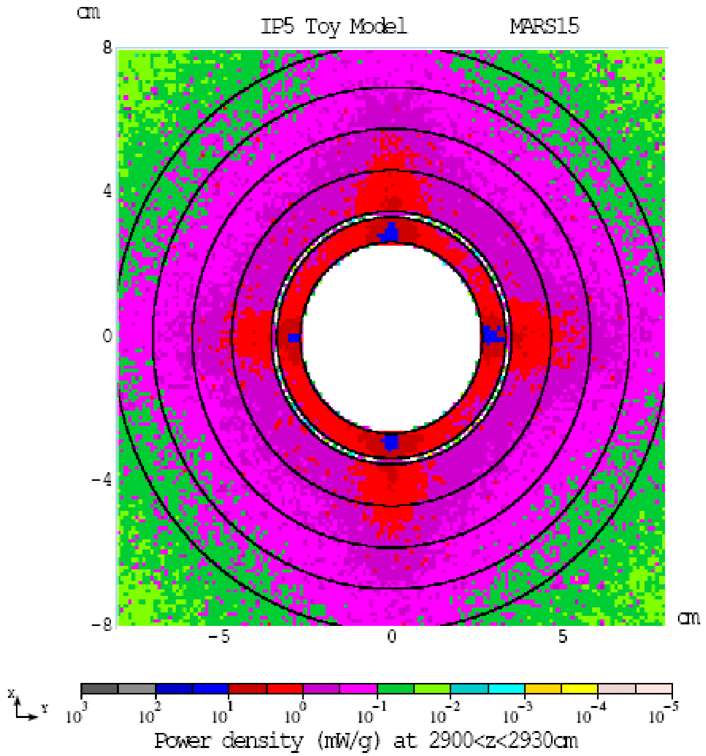
Total heat loads in the insertion region elements (W) for upgrade luminosity L=10*L0

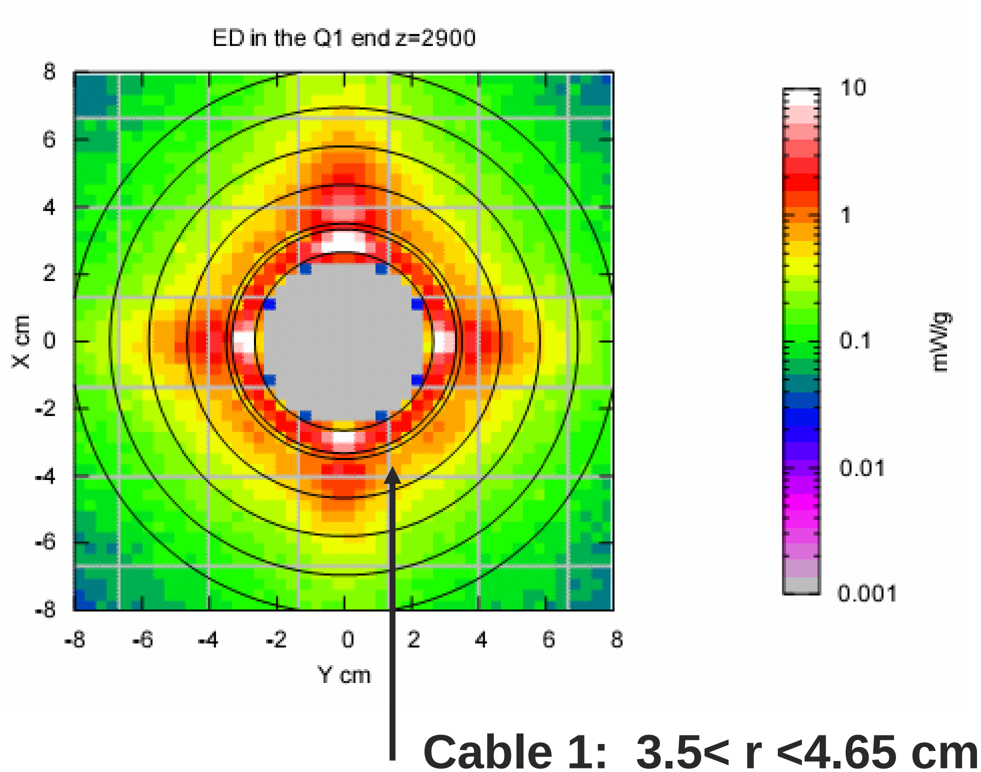
	FLUKA	**+/- (%)**	**MARS**	**+/- (%)**	**discrepancy FLUKA/MARS (%)**
TAS	1910.3	0.5	1821.6	0.1	4.9
Q1 tube	94.6	1.2	97.6	0.4	-3.1
Q1 cable	166.3	1.1	158.5	1.6	4.9
yoke	100.5	1.0	77.0	0.4	30.6
alu	2.4	1.2	2.4	0.5	-0.4
mila	20.2	1.1	20.5	0.3	-1.2
vessel	17.9	0.9	17.3	0.3	3.4

Good agreement for the TAS and Q1 within 5%

Benchmark on the LHC Insertion Region

- Results: peak power deposition maps
  - MARS
  - FLUKA





Cable 1: 3.5< r <4.65 cm

Benchmark on the LHC Insertion Region

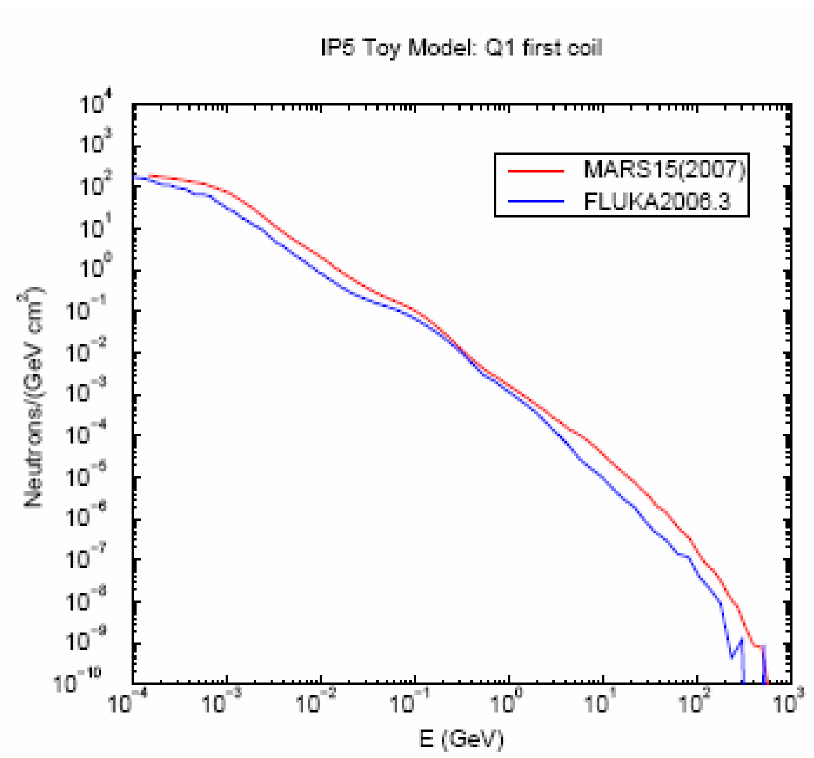
- Results: peak power density in cable 1
  - Same binning size (0.33*0.33*30 cm^3)
  - Maximum values in the vertical plane
  - Peak power density
    - MARS :17.5 mW/cm^3
    - FLUKA: 18.2 mW/cm^3 +/- 4.4% (statistical error)

Good agreement within the statistical error range

Benchmark on the LHC Insertion Region

- Results: particle spectrum in cable1

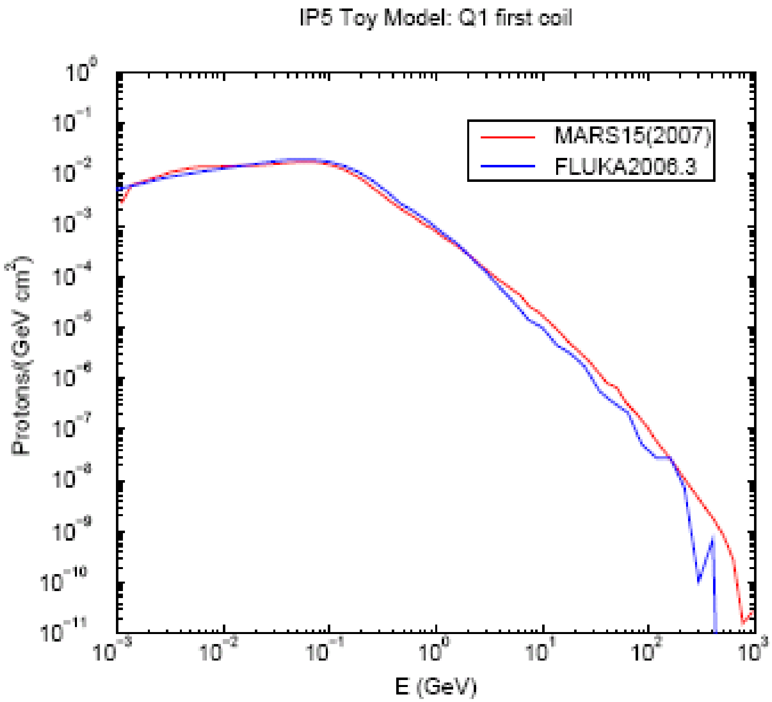
NEUTRONS



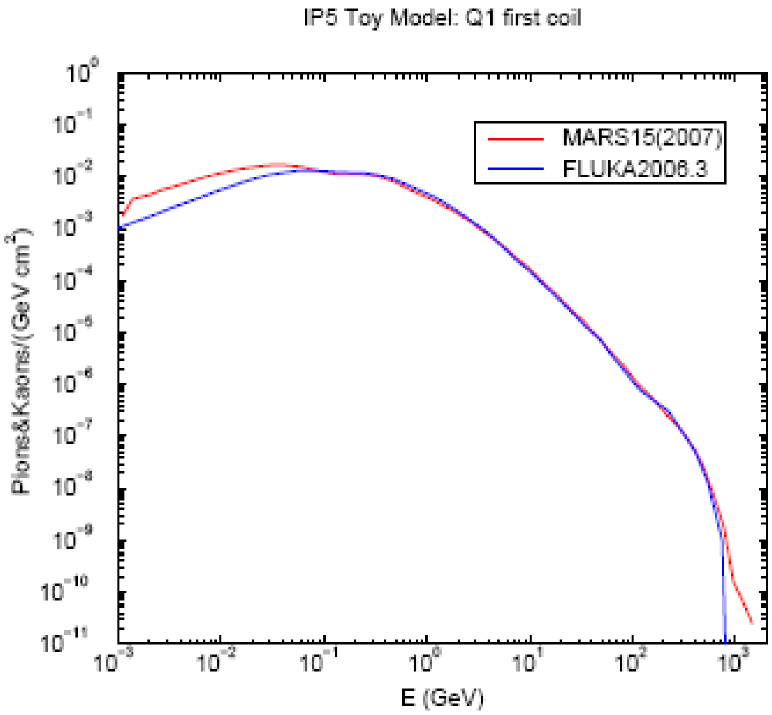
Benchmark on the LHC Insertion Region

- Results: particle spectru

PROTONS



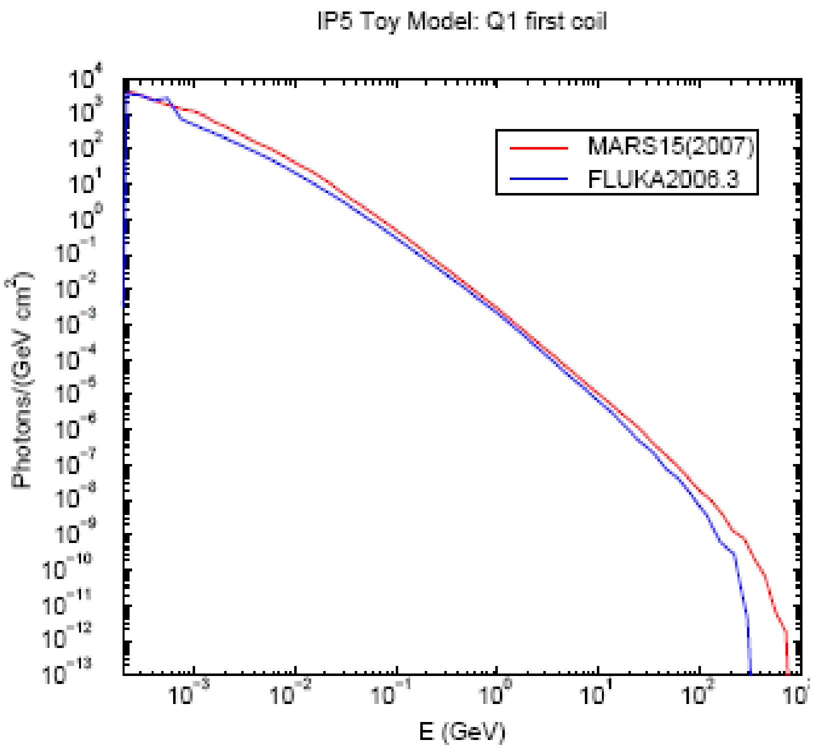
PIONS and KAONS



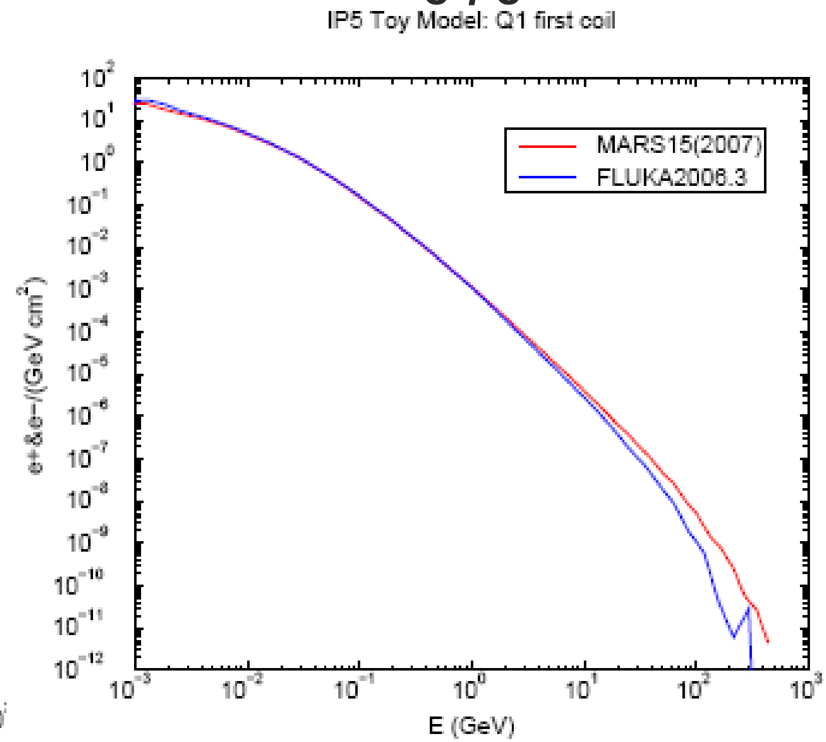
Benchmark on the LHC Insertion Region

- Results: particle spectrum

PHOTONS



e+/ e-

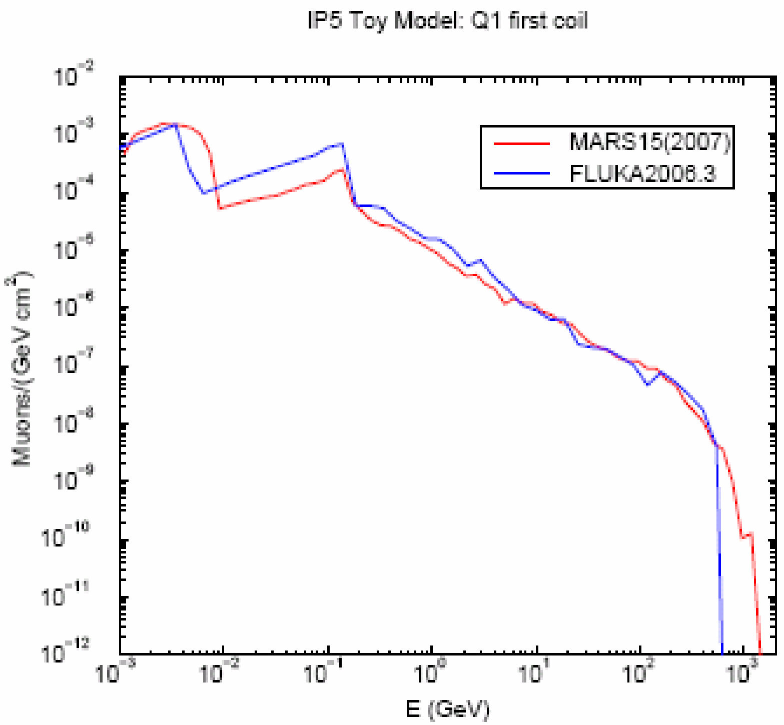


More high energy photons and e+/e- for MARS (E>100 GeV)

Benchmark on the LHC Insertion Region

- Results: particle spectrum

MUONS



Conclusion

- Perspective work & collaboration
  - High energy physics for LHC: benchmark studies for the IR
    - MARS
    - FLUKA
  - Magnetic field impact of the solenoid field (3D detailed maps)
  - LHC Upgrade phase
    - Baseline solution 130 mm aperture to be addressed
    - Optimization for the protection of insertion region

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- FLUKA team: Alfredo Ferrari, Francesco Cerutti, Markus Brugger, Stephan Roesler…
- Nikolai Mokhov and his group

References

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