

# **Wire Scanner and downstream magnets**

Mariusz Sapinski AB-BI

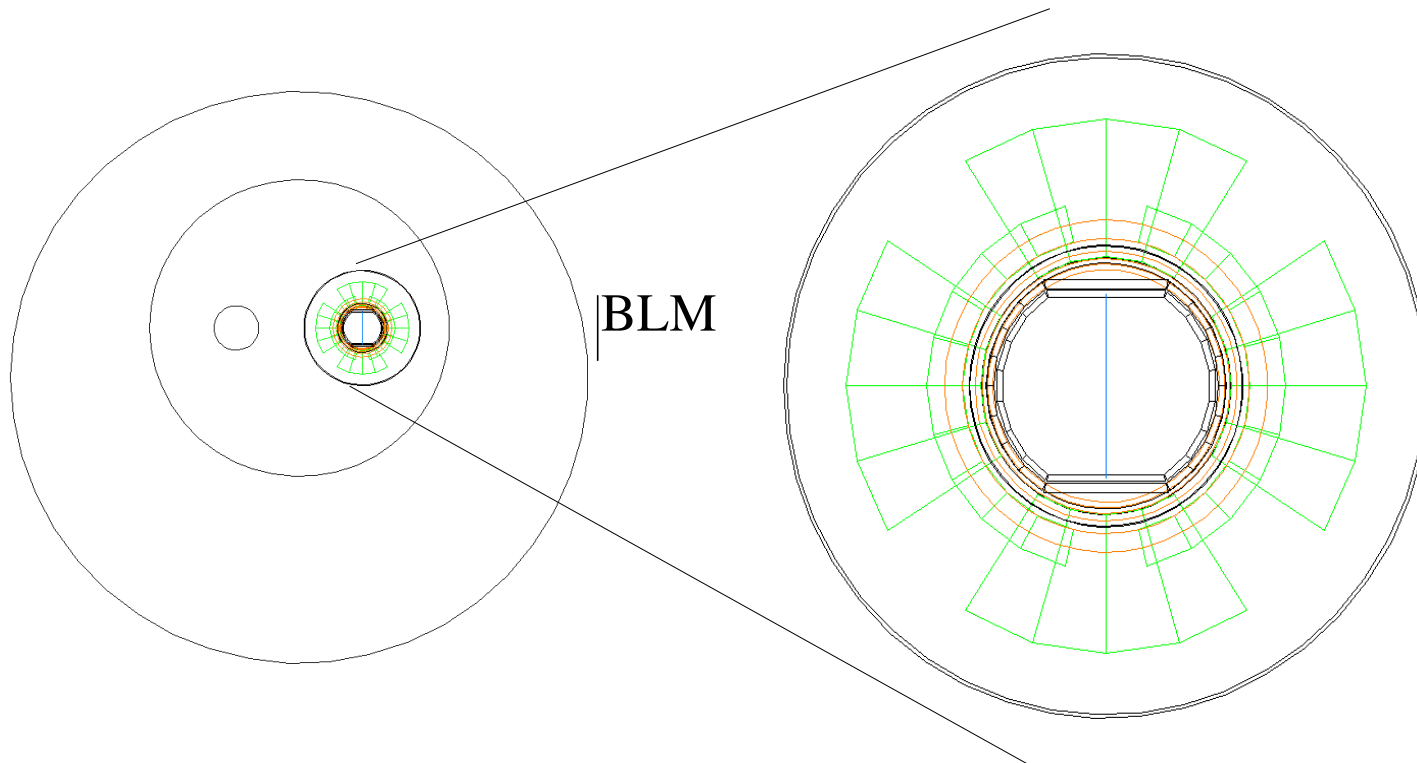
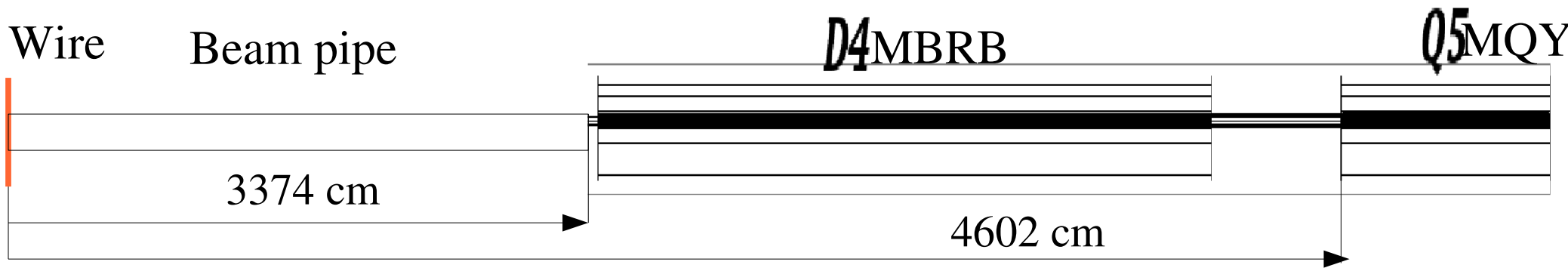
# Overview

- Previous estimations
- Simulated geometry
- Statistics
- Placement of scintillators
- Cascades in magnet coils (choice of mesh)
- Maximal beam intensity
- Errors and approximations
- errata

# Previous estimations

- J.Bosser, C.Bovet, “Wire scanners for LHC”  
LHC Project Note 108 (1997): “..no superconducting dipole is expected to be located in the 40 m downstream of a wires scanner...”; limit from wire overheating is about 12% of nominal beam at 7 TeV
- M. Lebat, E. Petit - summer students (2005 and 2006), who started this work

# Geometry



Coils are divided into small cells in  $(r, \phi, z)$  which energy is measured. Typically:  $2-4 \cdot 10^5$  cells

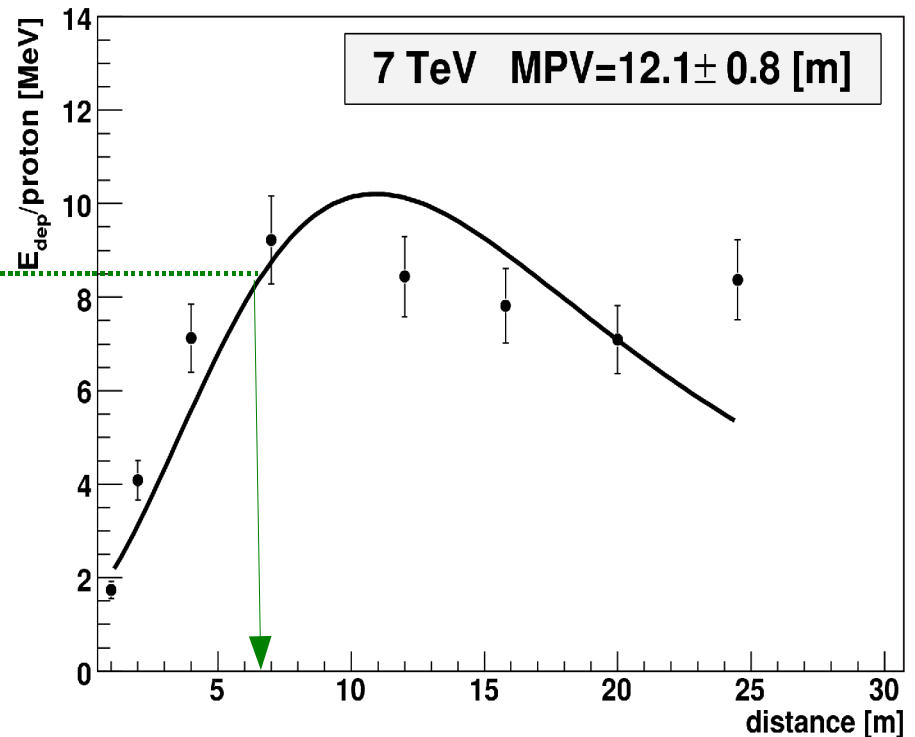
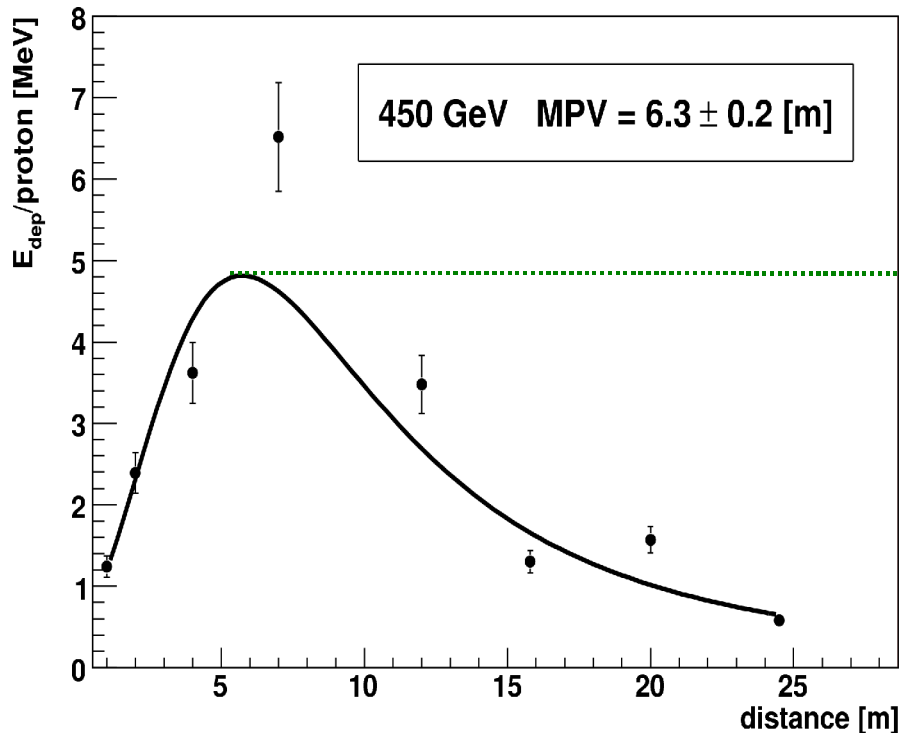
# Statistics

- Various Monte Carlo samples were generated (Geant4.8.1)
- Interaction efficiency (p-wire) is about  $1.32 \cdot 10^{-4}$  (among 8000 protons passing the wire center 1 interacts)
- Typical sample 300 – 400 events, simulation time about 20min/event (on P4 3 Ghz dual core)
- Ixbatch was also extensively used

# Placement of scintillators

Particles scattered by Wire Scanner are measured by scintillators (box 10x10x1 cm) placed next to beam pipe,

energy deposited in scintillators per interacting proton is:

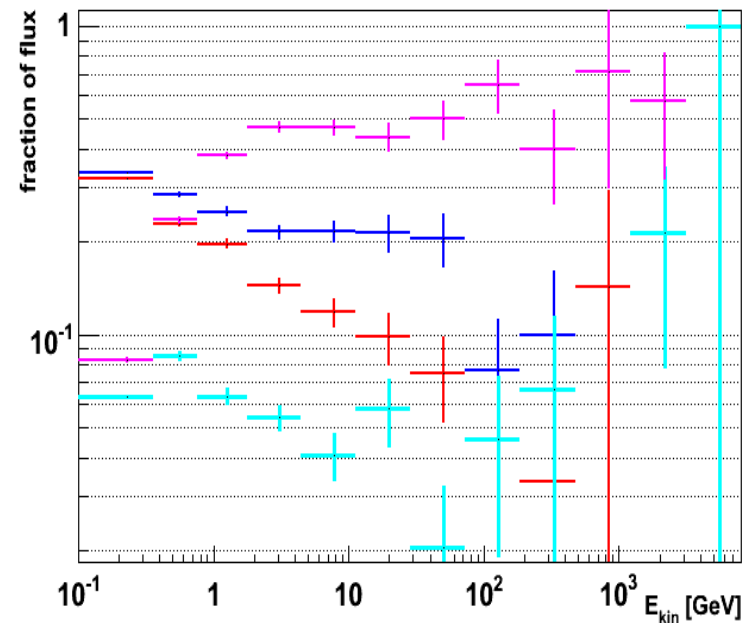
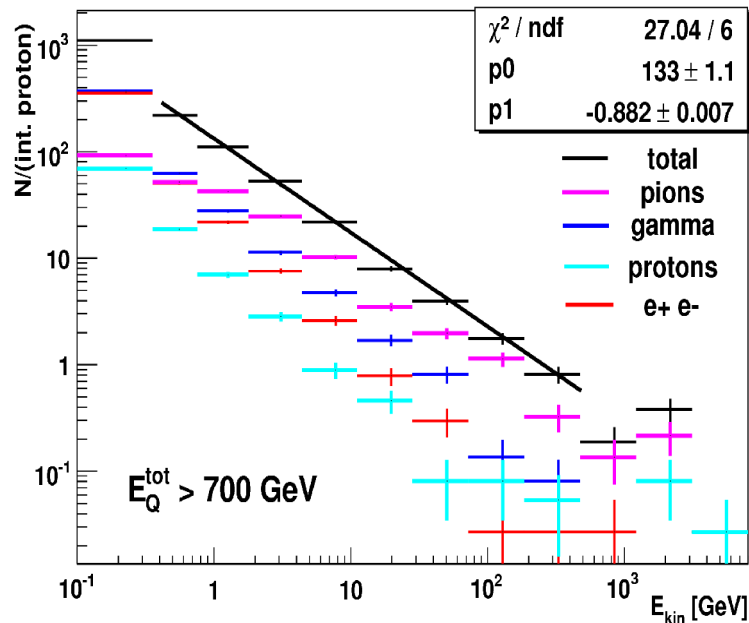


Signal in PMT scales with energy deposited in scintillators – there is a lot of signal at nominal luminosity – maximum **6-12 meters** from WS, the signal level at

6 meters does not change with energy!

# Particles hitting coils

Spectra: low energy dominated by electrons and gamma,  
high by pions and protons

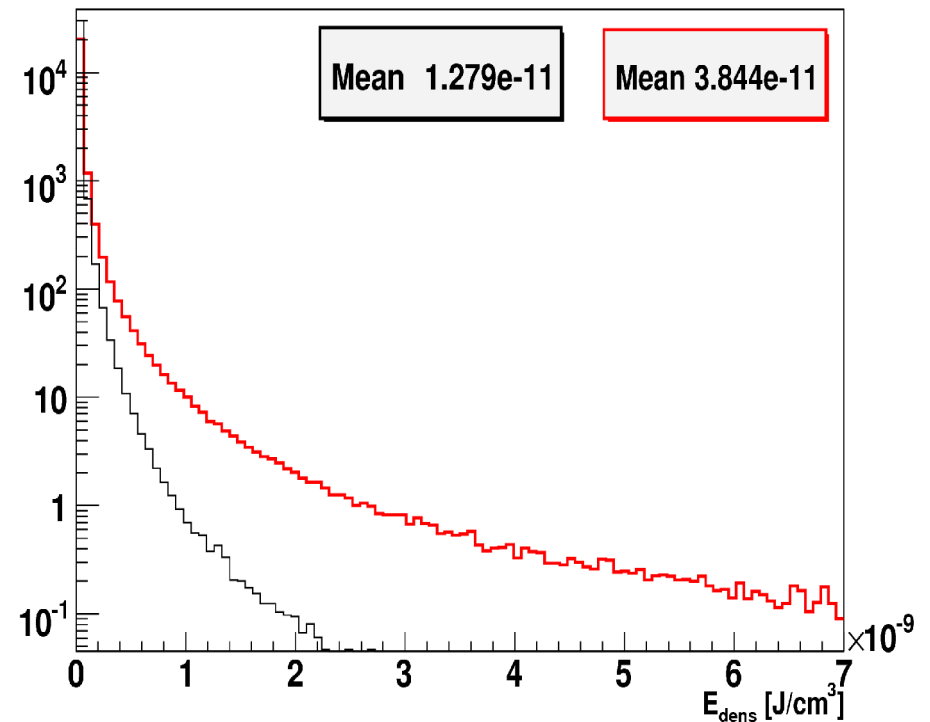
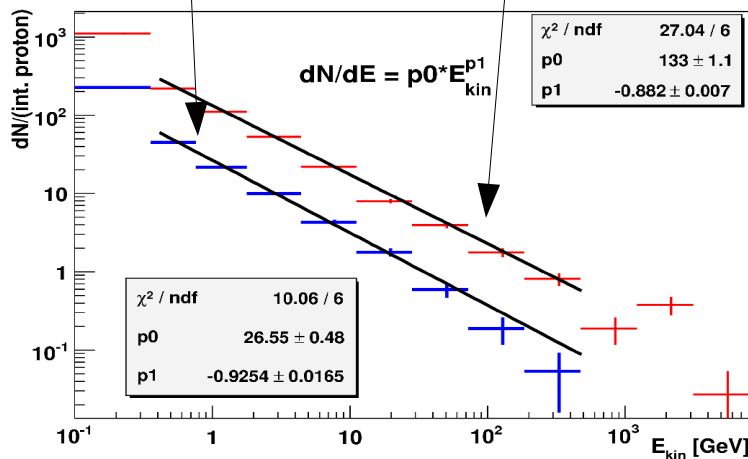
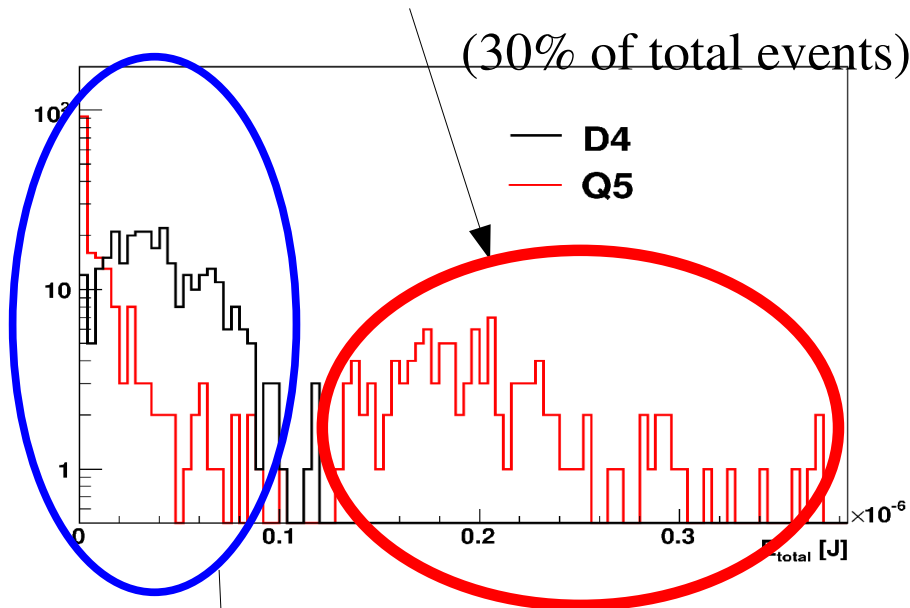


Origin: there are almost no particles directly from the wire;  
impacting angle of the most energetic particles corresponds  
to locations on the beam screen of D4

# Coils: total energy depositions

Q5: there are events with large energy depositions

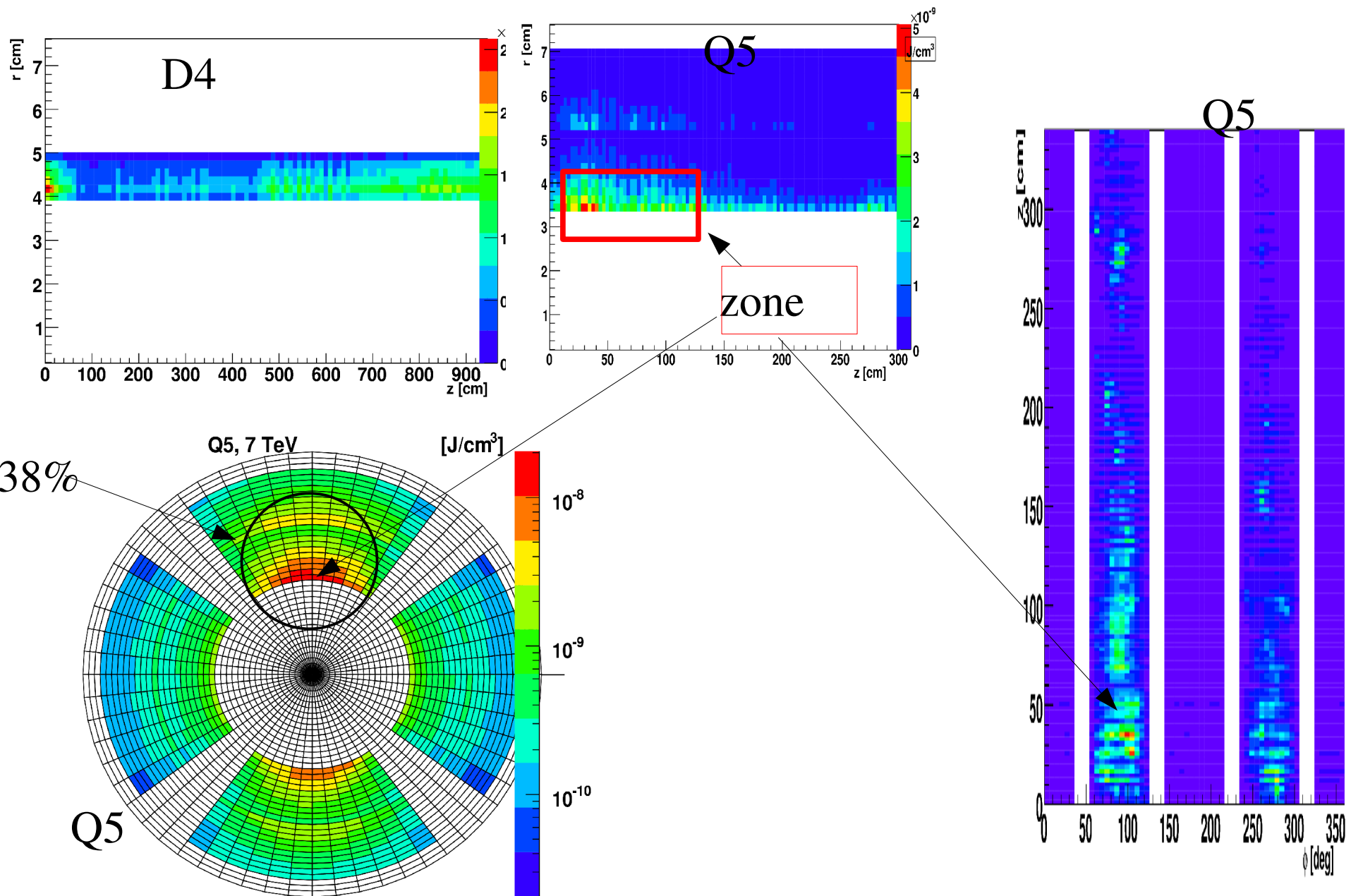
The average energy density is larger in Q5



Q5 is a problem!



# Events geometry (in coils)



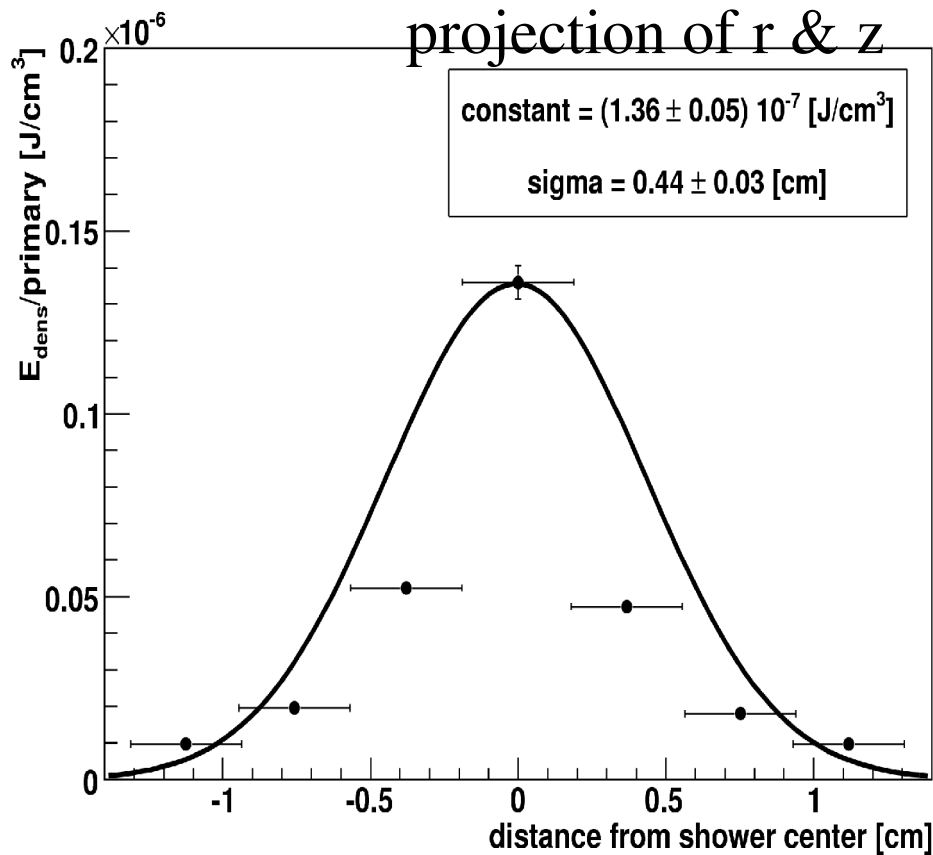
# Cascades in coils

- Superconducting coil quenches if a local temperature raises above quench temperature
- Local temperature depends on the local deposited energy density; for Q5 coil at 7 TeV  $\rho=4.95 \text{ mJ/cm}^3$  is the assumed quench threshold  
(loss duration 0.3 ms, only cable entalphy used)
- It is crucial to chose correctly the volumes  $V$  in which energy deposits are measured  $\rho=E_{\text{dep}}/V$   
(overestimated  $V \mapsto$  underestimated  $\rho$ ,  
underestimated  $V \mapsto$  computing problems)

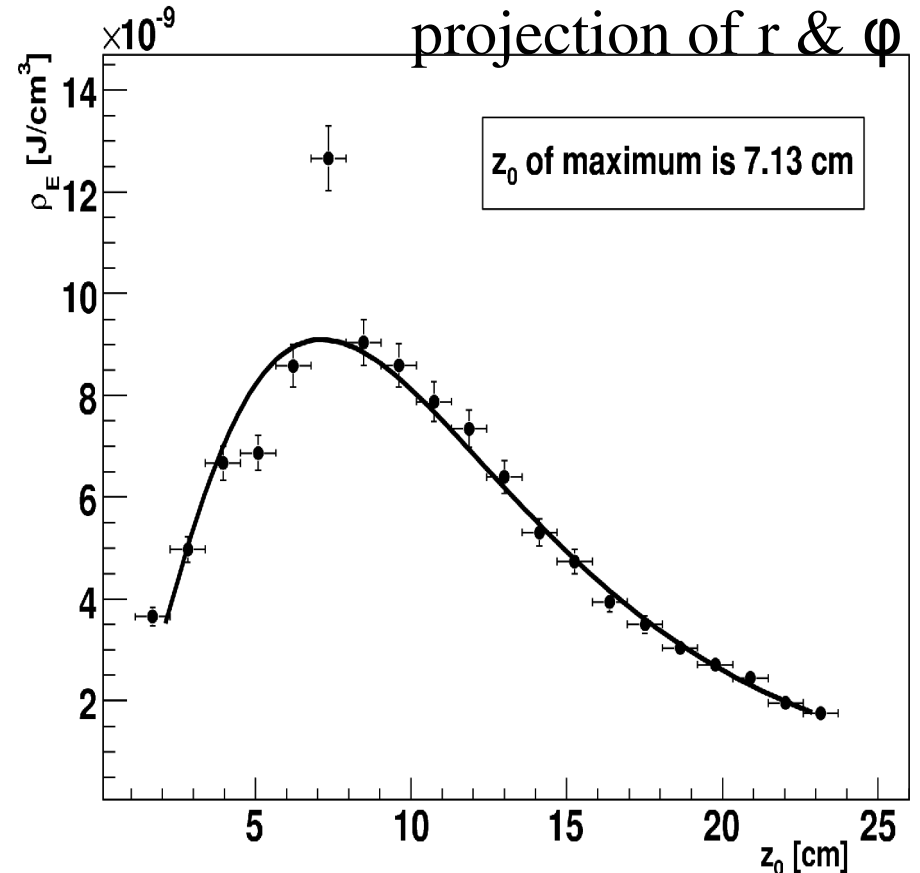
# Choice of the volume

Volume size should be tuned to the shape of the shower.

Average cascade measured around a hit with the highest  $\rho$ :



Sum of Gaussians



$$\rho = k[w t^{a-1} \exp(-bt) + (1-w) l^{c-1} \exp(-dl)]$$

w - "electromagneticity" of the cascade

# Choice of the volume (II)

Q5 cell volume has been altered (only in z-direction)

Variations of maximal energy density are not critical,

Slow increase of the energy density with decrease of the volumes is observed down to  $0.05 \text{ cm}^3$

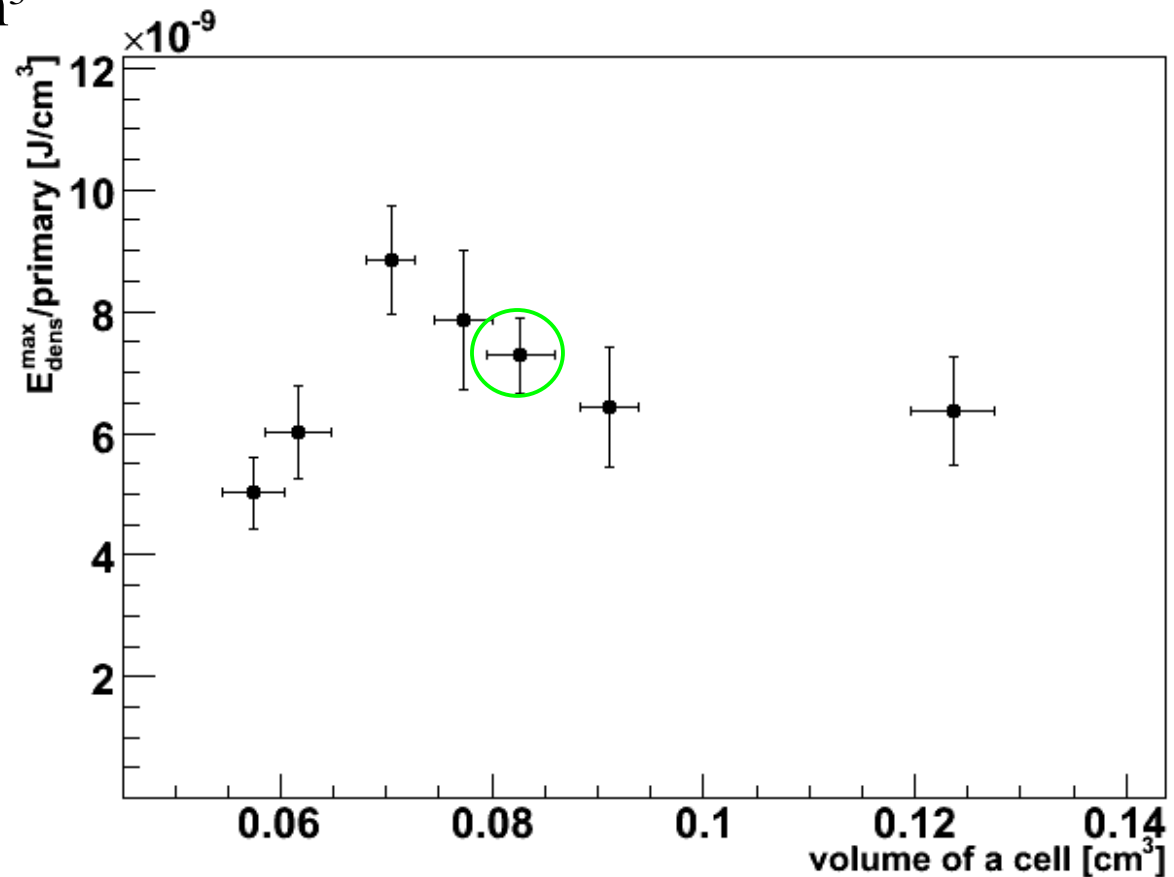
Standard range cut used in Geant4 ( $<1\text{mm}$ )

Finally the mesh used in Q5 coil is:

$$\Delta r = 0.1872 \text{ cm},$$

$$\Delta \phi = 2\pi/60,$$

$$\Delta z = 0.9714 \text{ cm}$$



# Maximal energy density - the method

- We suffer from small statistics  
(how to conclude about  $10^{10}$  events having sample of 400)
- Define the most “hot” region of the coil (zone)
- Find probability distribution for a cell in the zone to reach a given energy density
- Use the parametrized probability to estimate how many protons are needed to deposit critical energy in magnet coil

# “Hot” zone

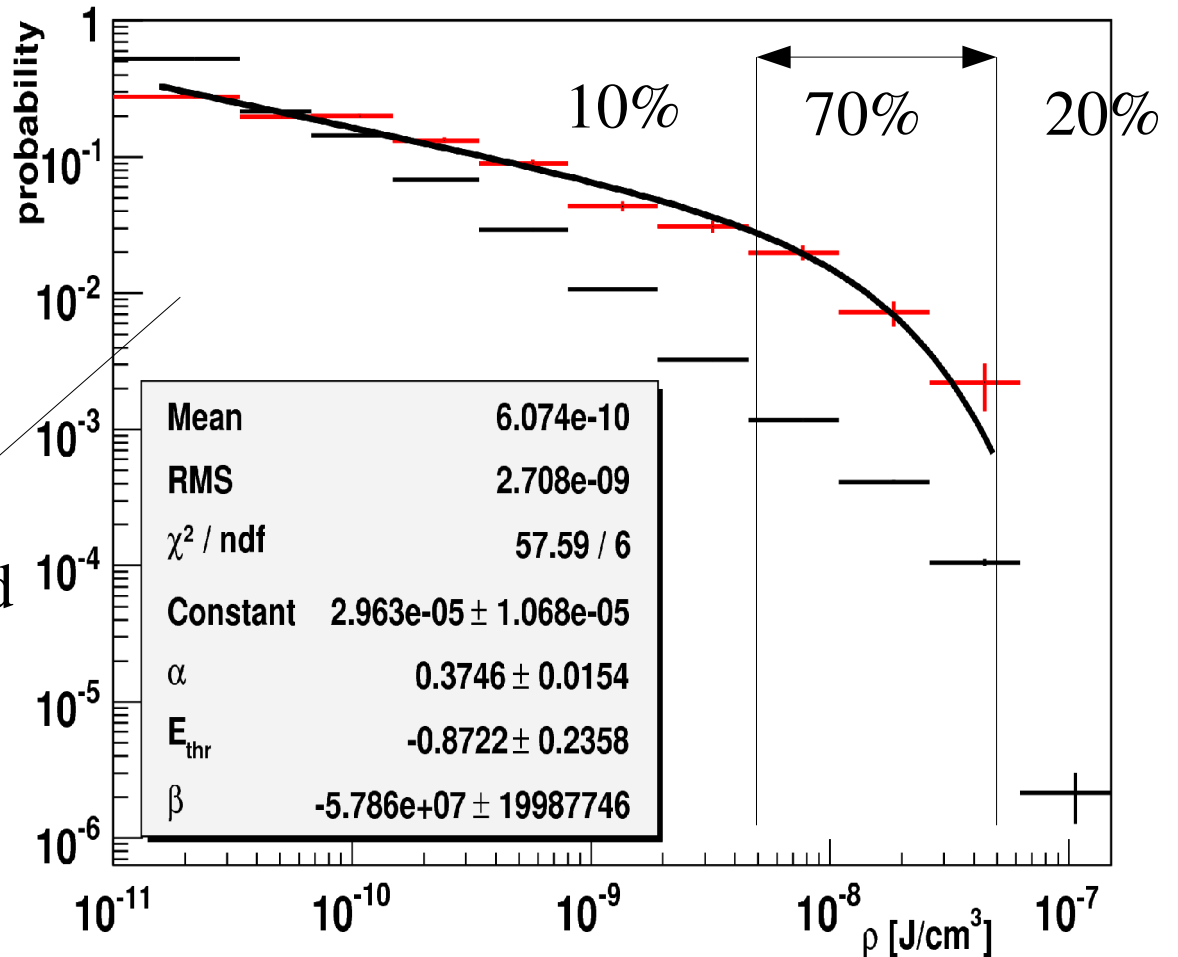
The “hot” zone is:

- $10 < z < 40$  cm
- $78^\circ < \varphi < 102^\circ$
- $\rho < 3.687$  cm

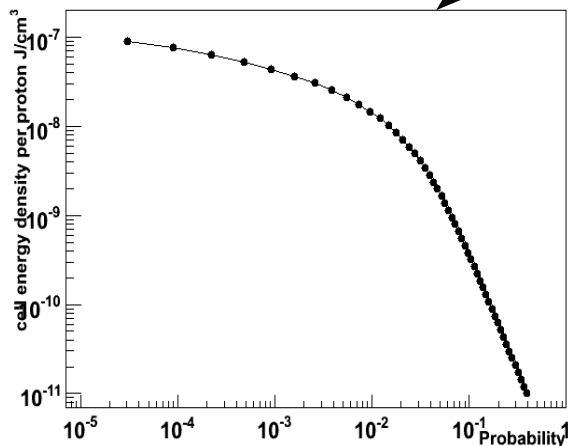
(variations were tested)

$$P(\rho) = \text{Constant} \cdot \rho^{-\alpha} \cdot \exp^{\beta}(\rho/\rho_{\text{thr}})$$

exponential cutoff at 0.87 J/cm<sup>3</sup>



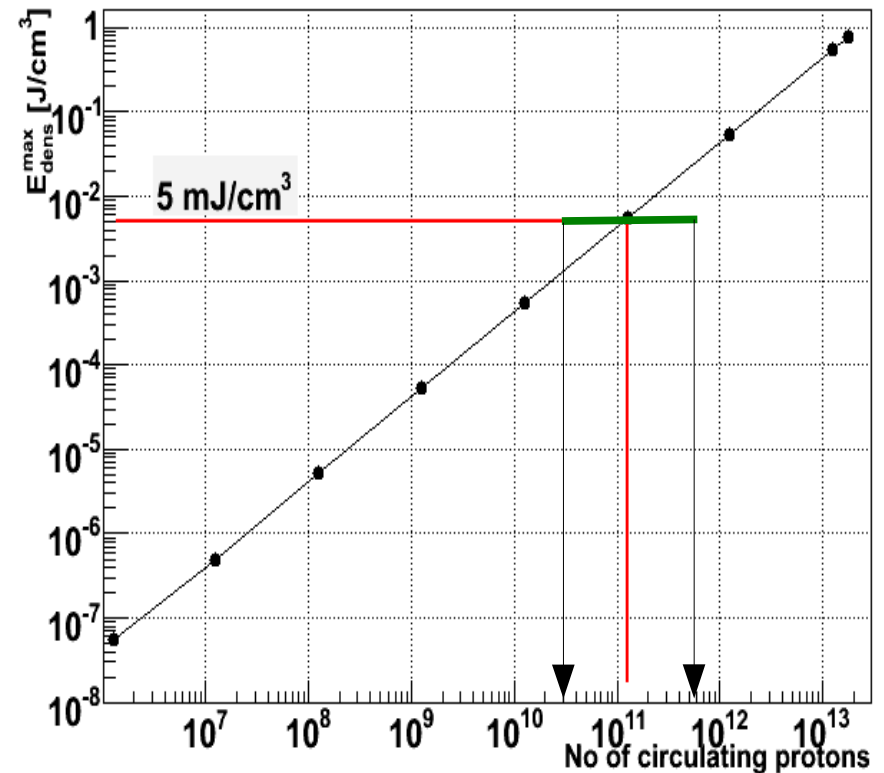
inversed



# Maximal beam intensity

convert the probability per interacting proton into maximal beam intensity, assuming:

- $V_{\text{wire}} = 1 \text{ m/s}$
- $\Sigma_x = 0.16 \text{ mm}$  ( $3\sigma$  beam)
- $t_{\text{scan}} = 0.48 \text{ ms}$
- $N_{\text{LHC}}^p = 3.2 \cdot 10^{14}$  protons
- $\varepsilon = 1.3 \cdot 10^{-4}$  interaction efficiency (cross section)

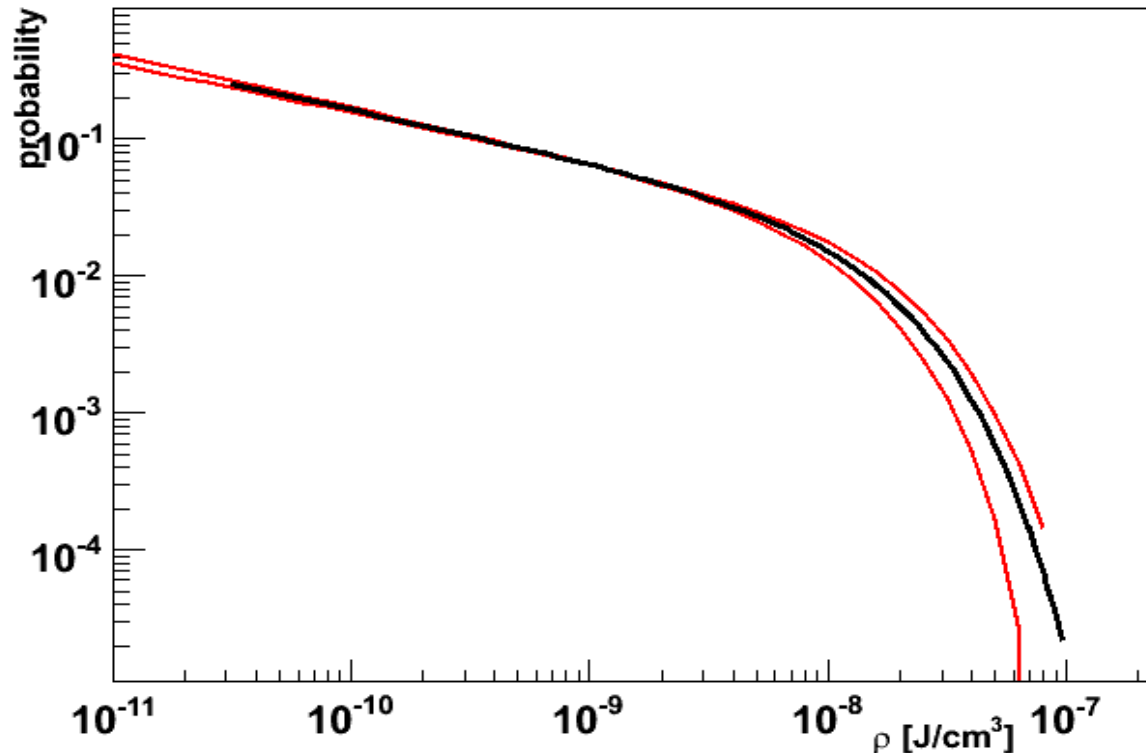


**$0.3-7.2 \cdot 10^{11}$**

central value 1.1

# Discussion of errors

- Starting with value:  $1.1 \cdot 10^{11}$  (adding errors in square)
- Details of geometry seems not to be crucial, although they can change the results by about 20% ( $0.88-1.32 \cdot 10^{11}$  )
- The method (used due to statistical limitations) – accuracy roughly estimated (by varying the “zone” and the fit parameters) to be around 50% ( $0.5-1.7 \cdot 10^{11}$  )
- Error due to size of volume 20% ( $0.29-1.91 \cdot 10^{11}$  )
- Fit quality error (asymmetric): ( $0.28-7.15 \cdot 10^{11}$  )





# Potential gains

One bunch

Approximation	Estimated factor	Number of circulating protons	Optimistic
Initial		1.00E+011	7.00E+011
Wire movement	0.5	2.00E+011	1.40E+012
Wire shape	0.8	2.50E+011	1.75E+012
Magnetic field			
Inside coils	0.5	5.00E+011	3.50E+012
Shottky	0.5	1.00E+012	7.00E+012

Nominal beam:  $3.2E+14$ , ie.

Wire Scanner should not quench the magnet up to 0.3-2.2% of the nominal beam (at 7 TeV plus error ie. 0.1-15%).

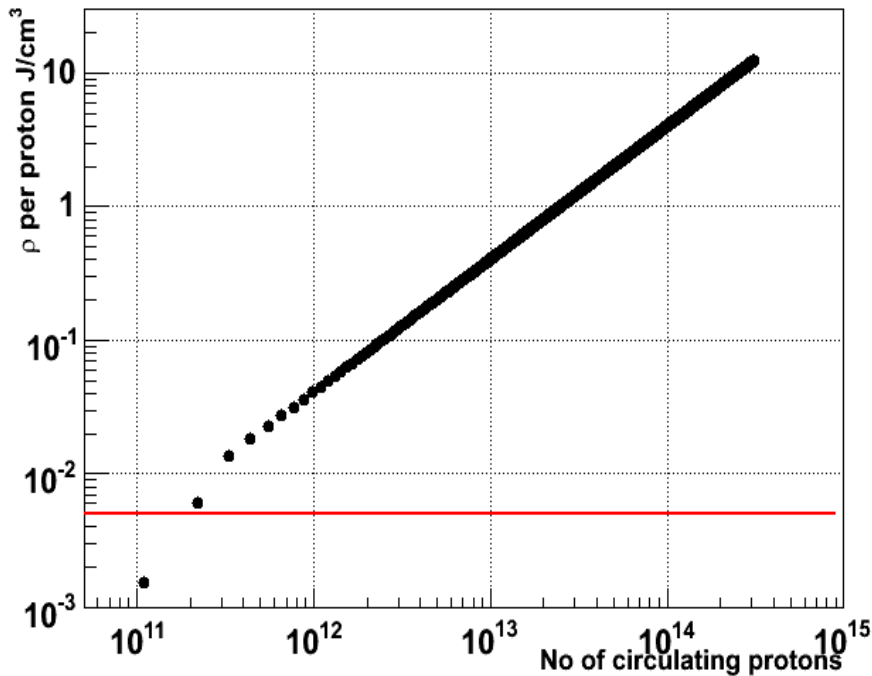
**$(0.3-7)10^{12}$  to  $(1.8-49)10^{12}$  circulating protons**

# Conclusions

- The Q5 magnet is critical – it is more fragile and cannot be shielded – particles are hitting from the beam pipe.
- Wire scanner can run up to  $1-7 \cdot 10^{12}$  protons in the circulating beam, ie. about 0.3-2% of the nominal intensity at 7 TeV  
(ie. One bunch – safe, conservative)
- What could be done: faster scanner, thinner wire (there is plenty of signal in scintillators – it can be reduced without loosing accuracy)
- Additional error of the estimation of the maximal beam current is large, – accuracy of the estimation still can be increased by increasing statistics.

# Errata

- A small correction to results due to bunch structure of the beam should be done



The final result is that Q5 quench limit is reached at:

$$2.1^{+5.3}_{-1.2} \cdot 10^{11}$$

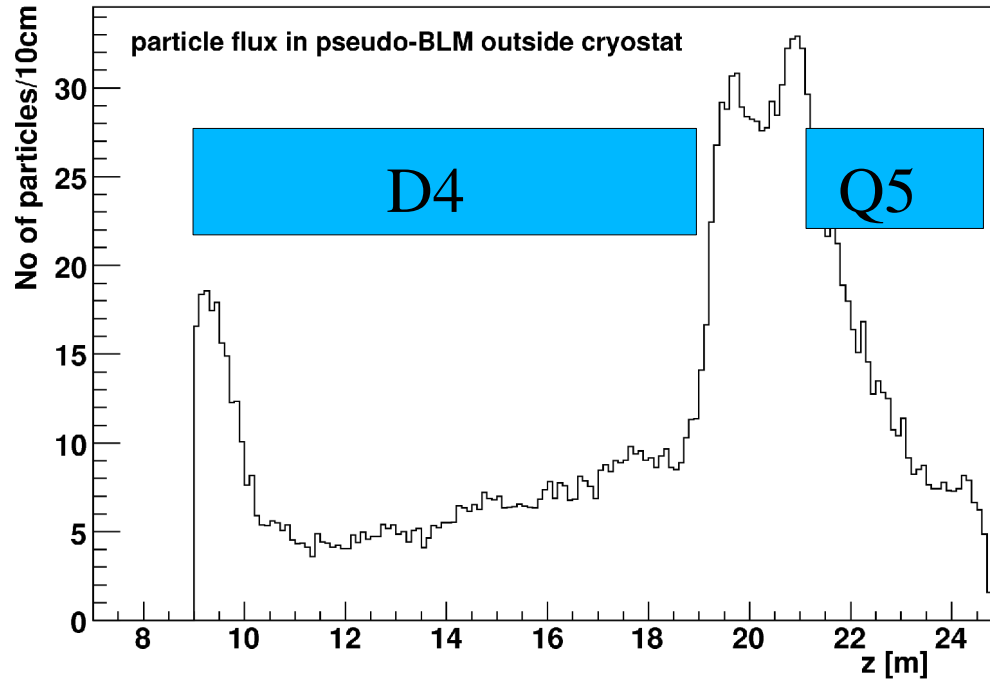
circulating protons in one beam  
(without taking into account  
potential gains)

# Open questions (asked by LHC TB)

1. does wire scanner affect any magnet after Q5? (Q6, 30m)
2. what is the time of recovery for Q5 after one scan (without quench) – when the next scan can be performed (seconds)
3. could we slow down the wire in case of scanning of one bunch, so we could have more points on beam profile
4. what are the destruction limits for the wire (7 TeV and 450 GeV)

# Backup slides

# BLM locations



# Choice of the volume (II)

- Particles hitting the Q5 coil:

12 events

