Studies for the very forward energy measurement at LHC

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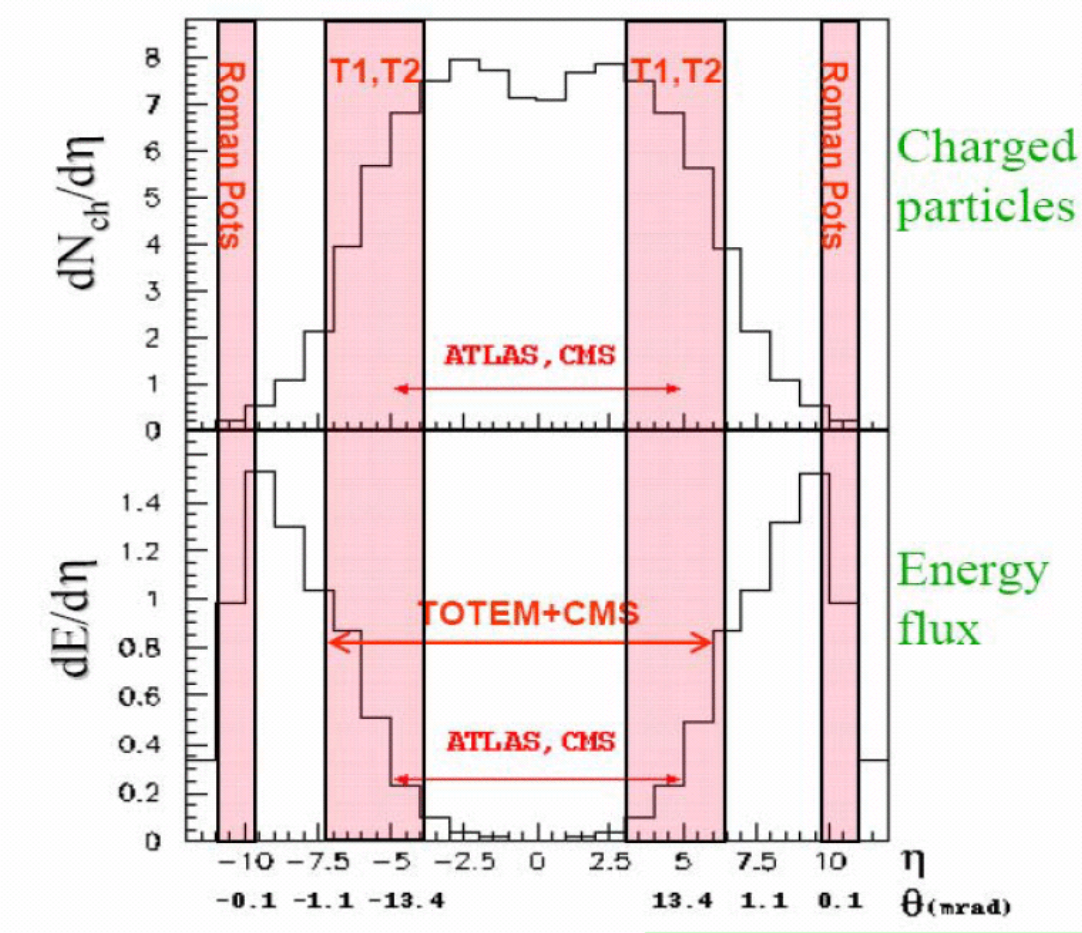
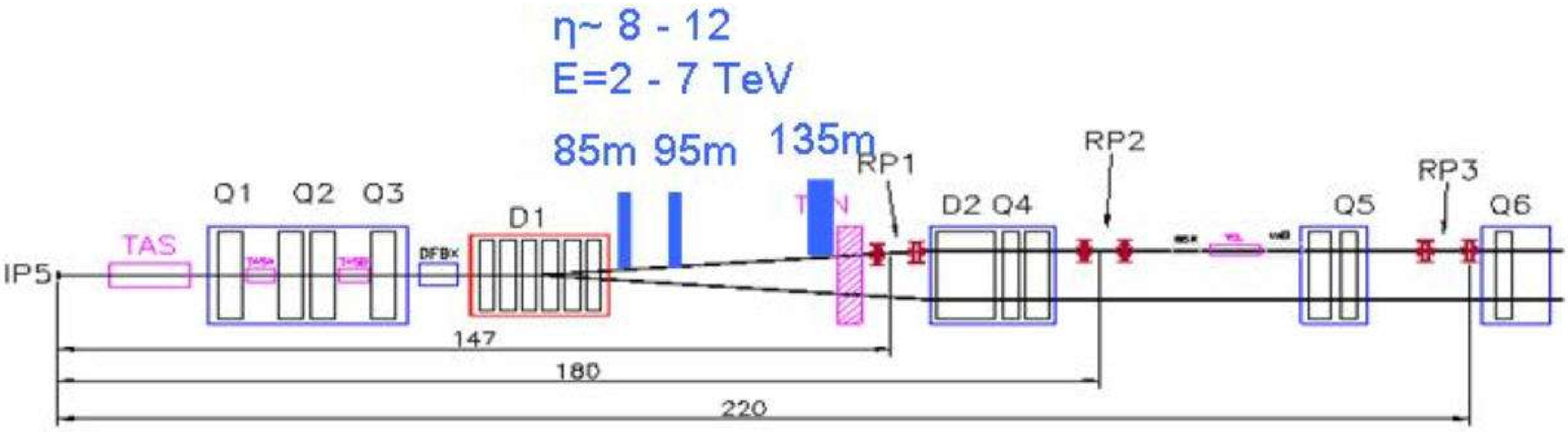
Introduction

Aim of this study is to investigate technical possibilities of increasing the acceptance of very forward energy measurement



In present configuration of LHC experiments, the pseudorapidity range 6.6 – 10.0 is not covered

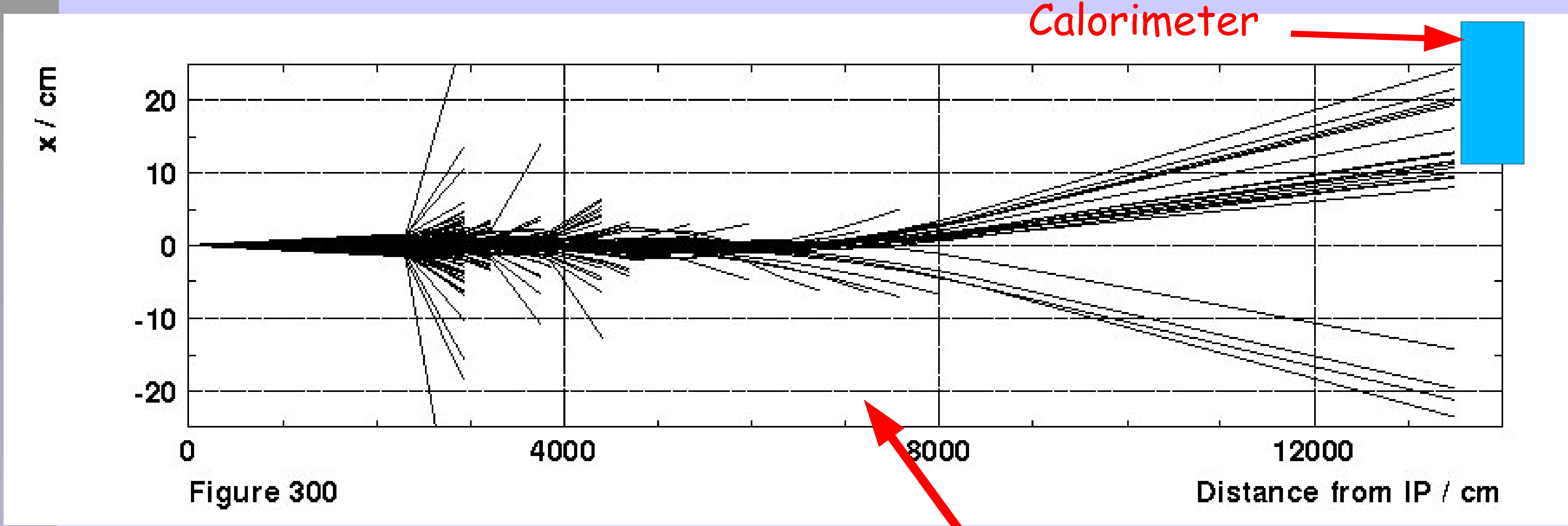
We try to "fill up" part of this "empty" range



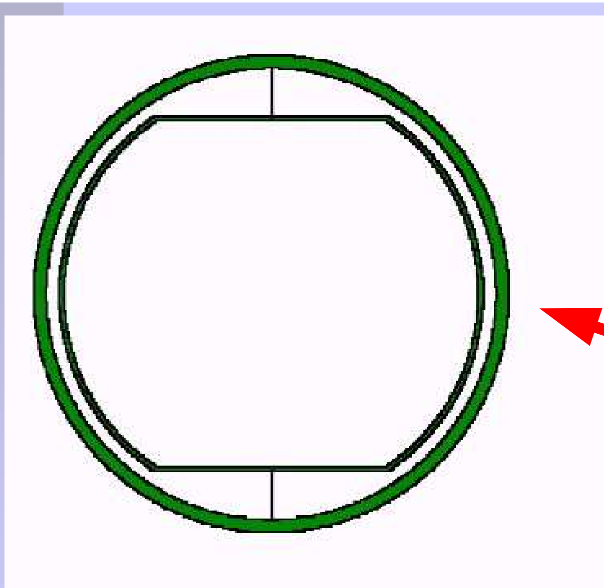
- Possible solution :
  - 2 horizontal Roman Pots at 85 m and 95 m behind the dipole magnets system D1, energy range E ~ 2.0 – 7.0 TeV (we presented this study in previous workshop)
  - hadron calorimeter at 135 m in front of TAN (E ~ 2.0 - 5.5 TeV and pseudorapidity range 8 – 12)

Beamline simulation

- Use transformation matrix for each mgnet element (dipoles, quadrupoles and drift spaces)
- The particle's trajectory is obtained by multiplying the matrixes of each element
- For each magnet element check acceptance using the real beampipe dimension
- Acceptance of calorimeter at 135 m from IP is determined from the space distribution of scattered particles

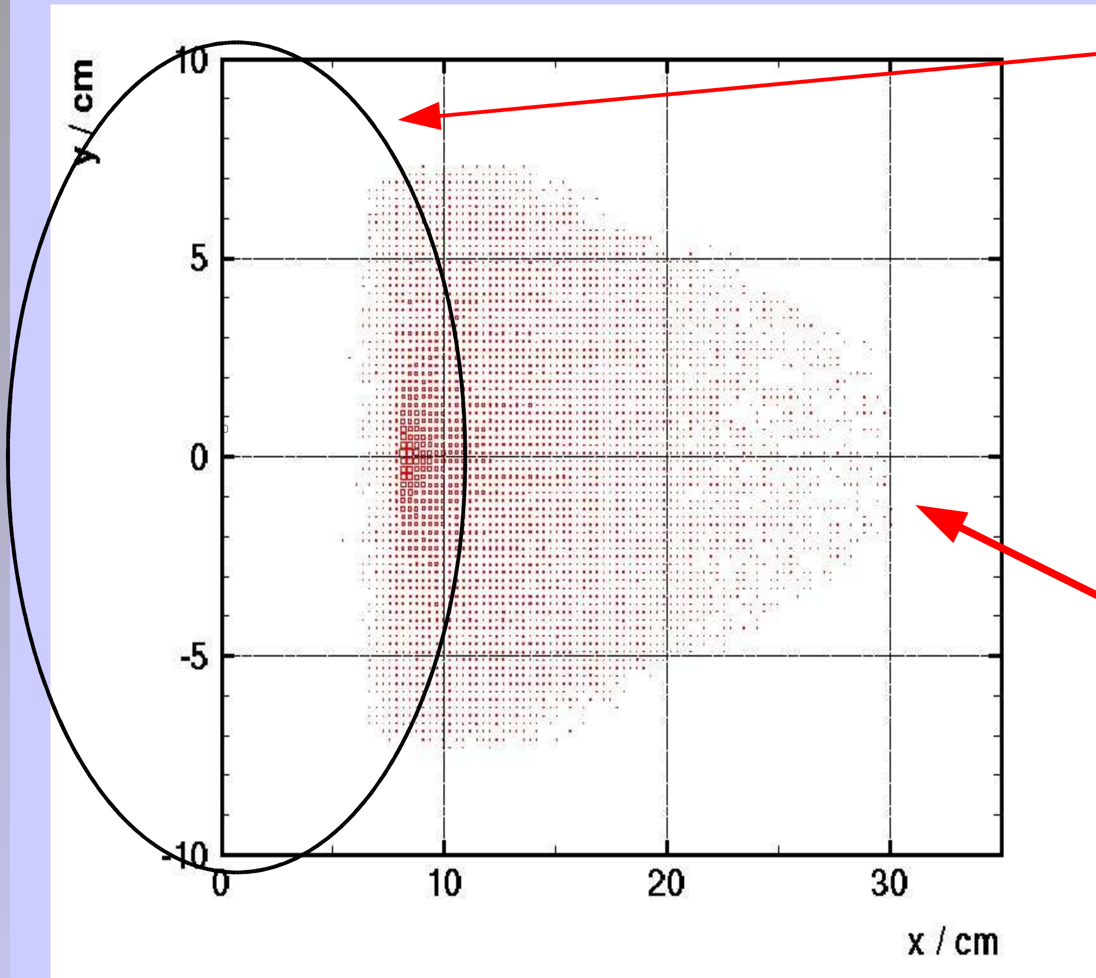


example of charged particles trajectory from PYTHIA simulation



beampipe apperture with V type beam screen

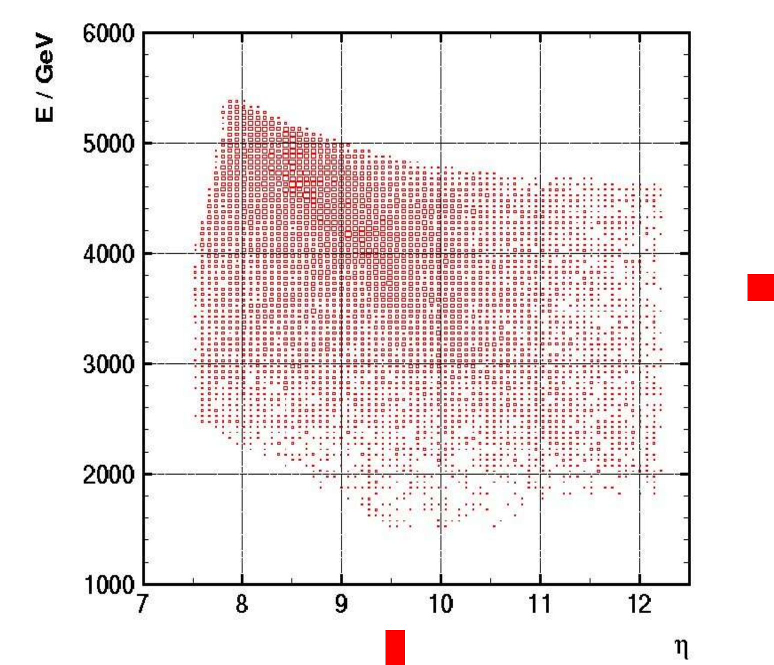
Acceptance

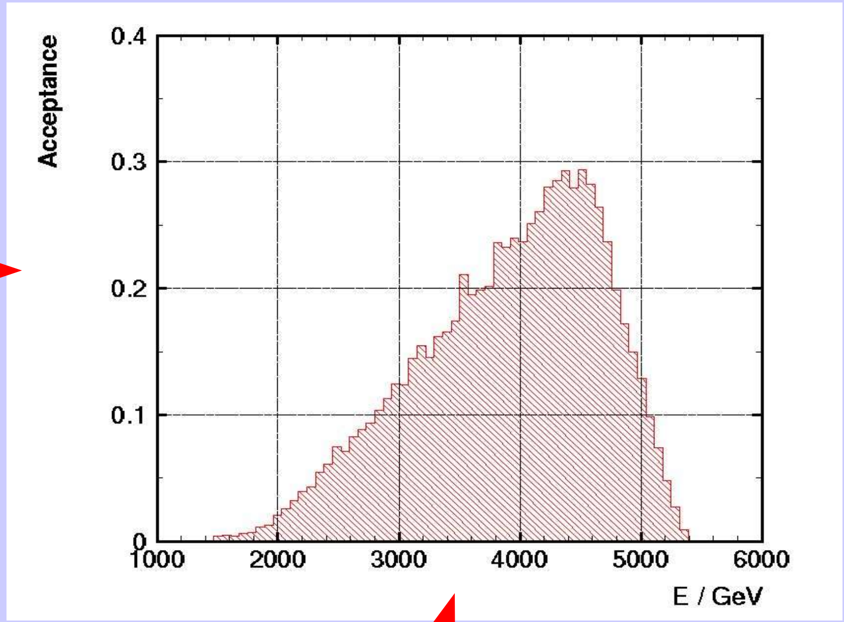


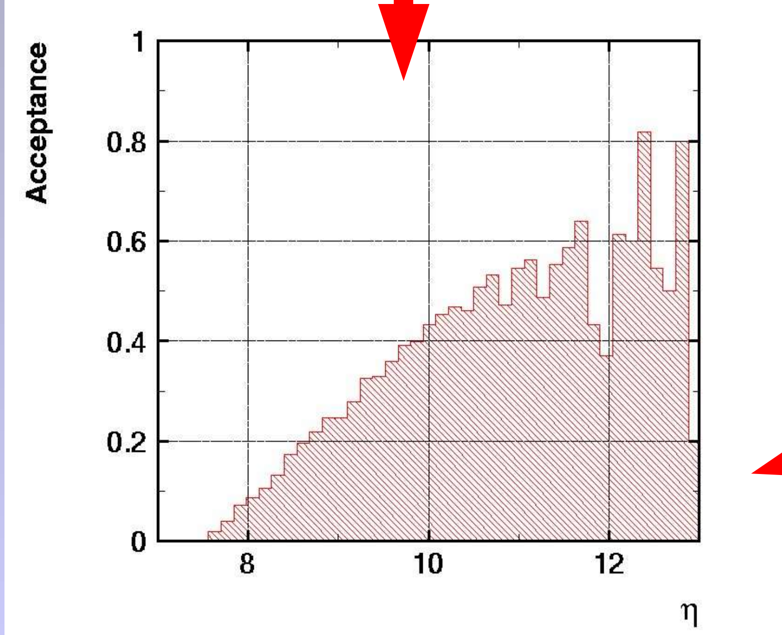
beampipe at this position (circle d = 21.2 cm)

acceptance defined by the apperture of beampipe and magnet elements

X-Y distribution of particles at 135.0 m from IP

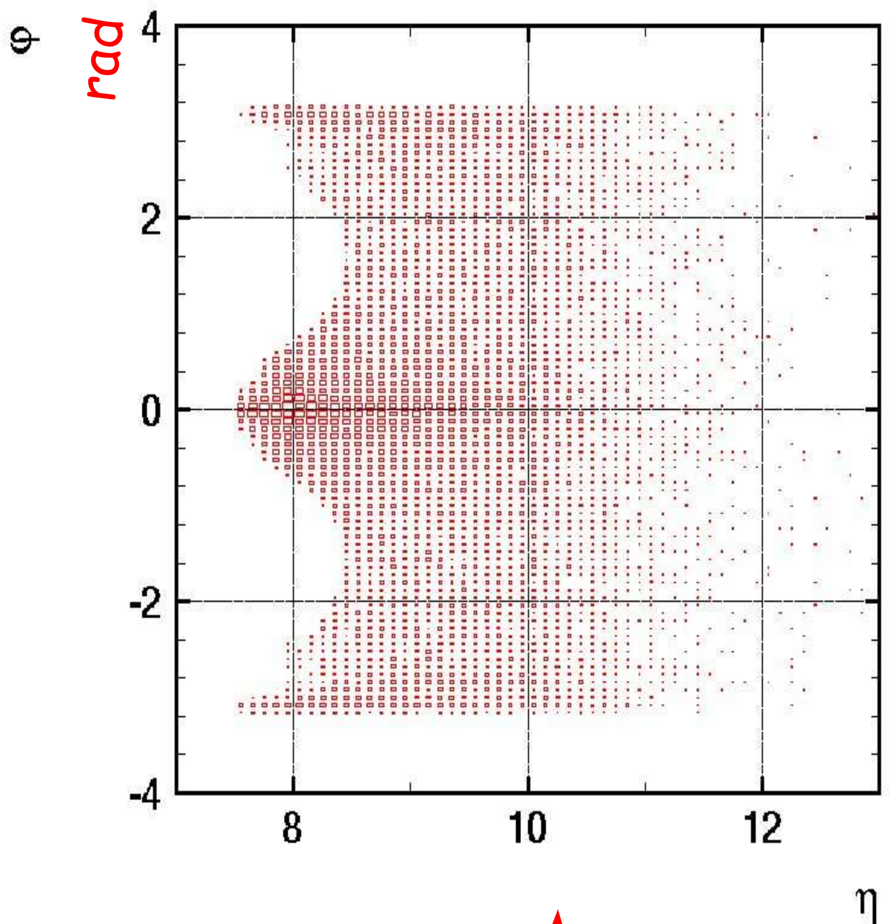






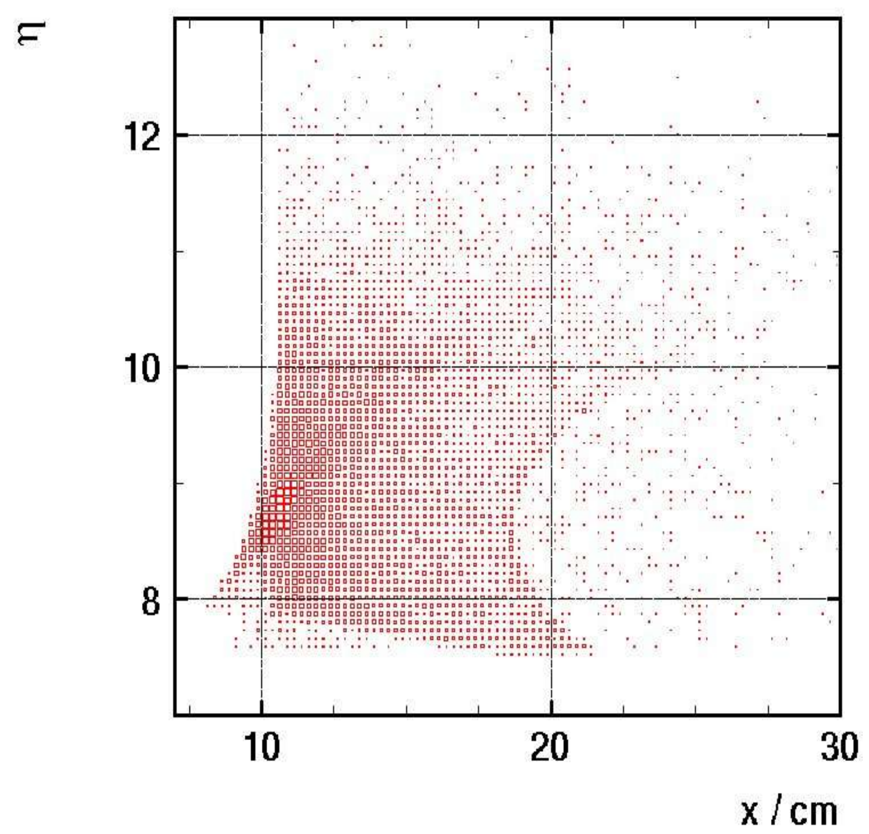
energy range for accepted particles
~2.0 – 5.5 TeV (A ~ 5% - 30%)

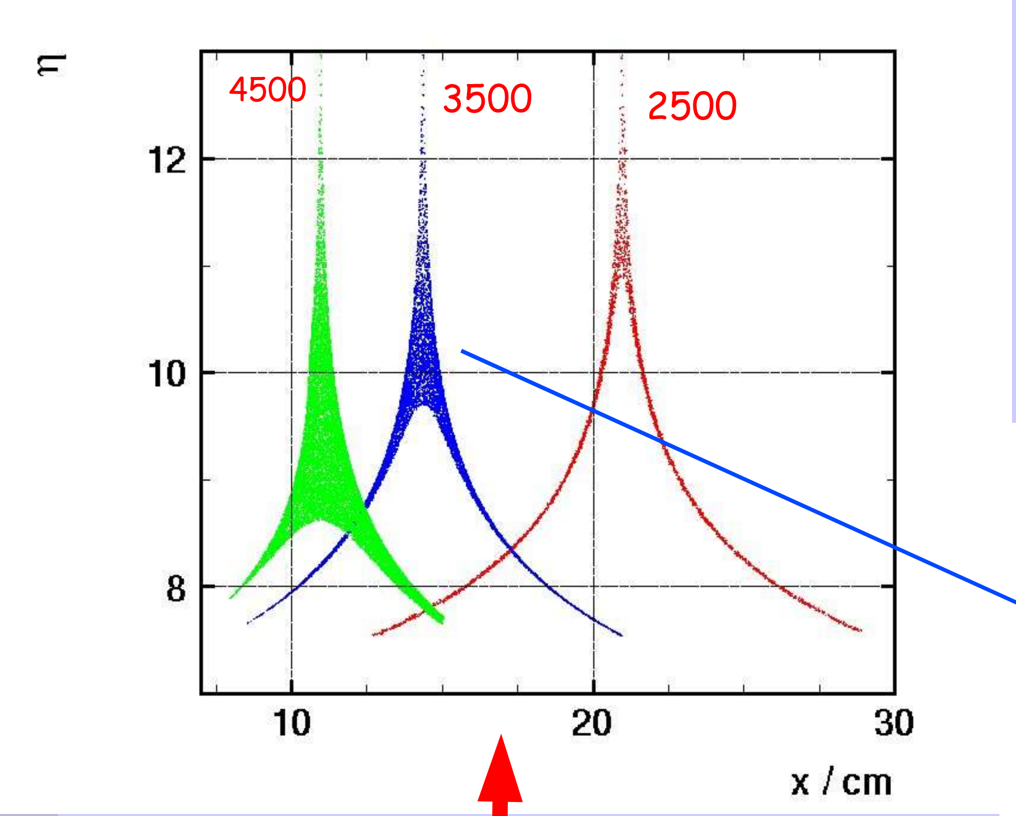
and for pseudorapidity η > 8.0



For η reconstruction one needs both coordinate and energy measurement

This shape of acceptance vs phi is due to the V beam screen appertures

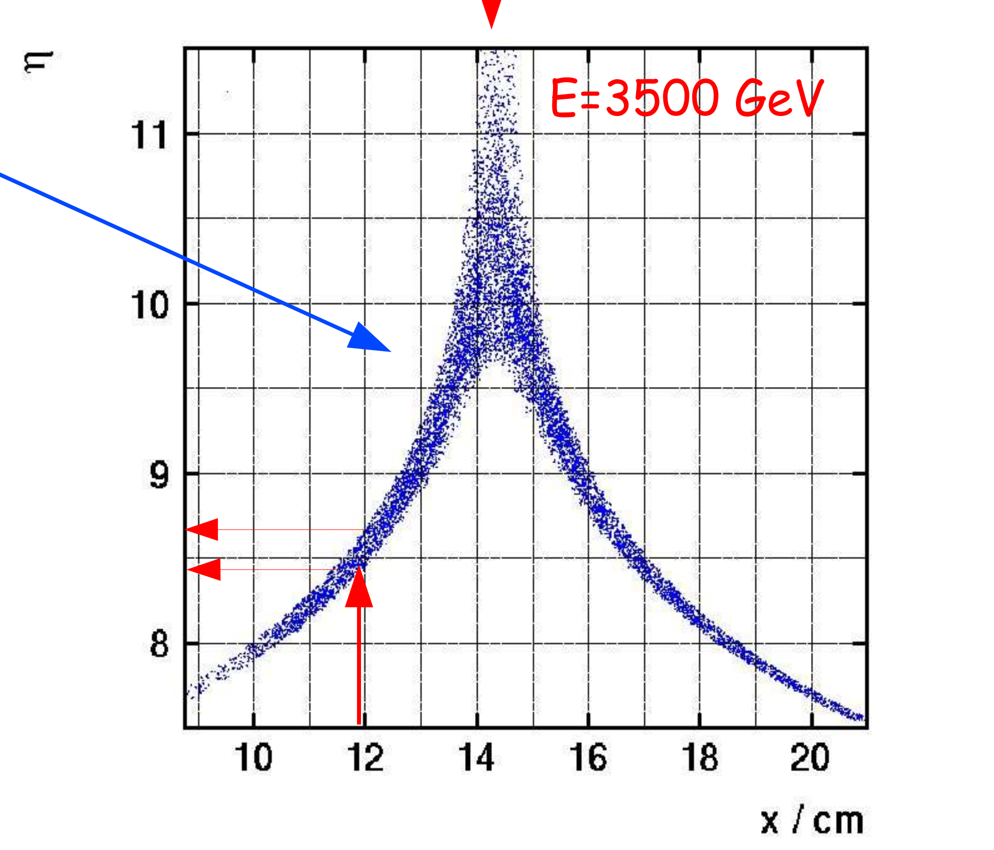




assume energy resolution

dE/E ~ 100% / sqrt(E) + 2%

(dE ~100 GeV) leads to broading of η - x correlation



η - x correlation at position of calorimeter for the fixed particle energy

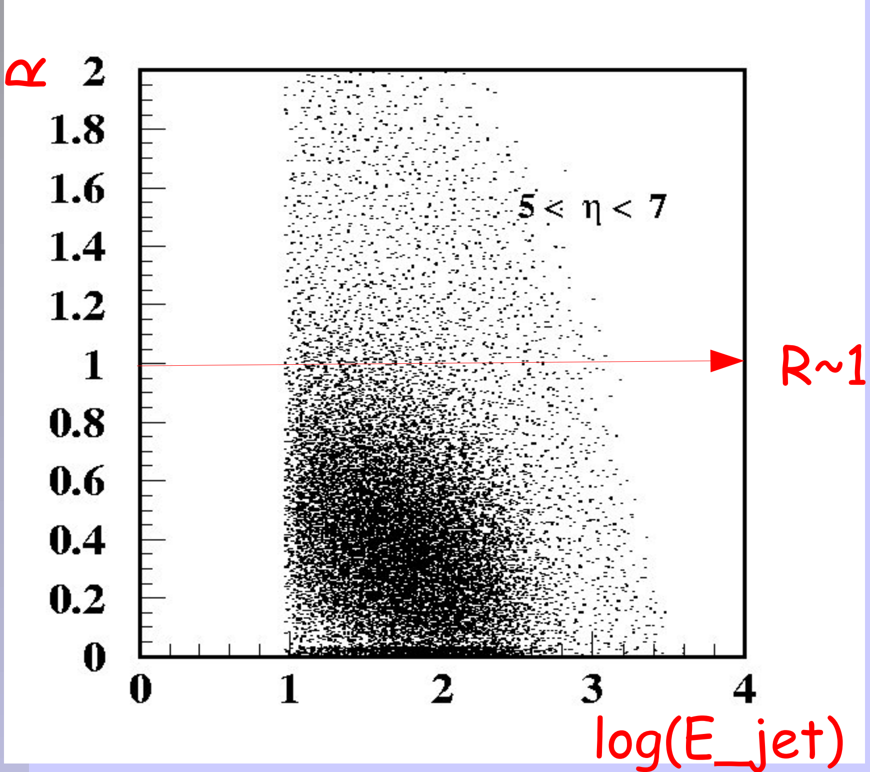
Short summary for acceptance

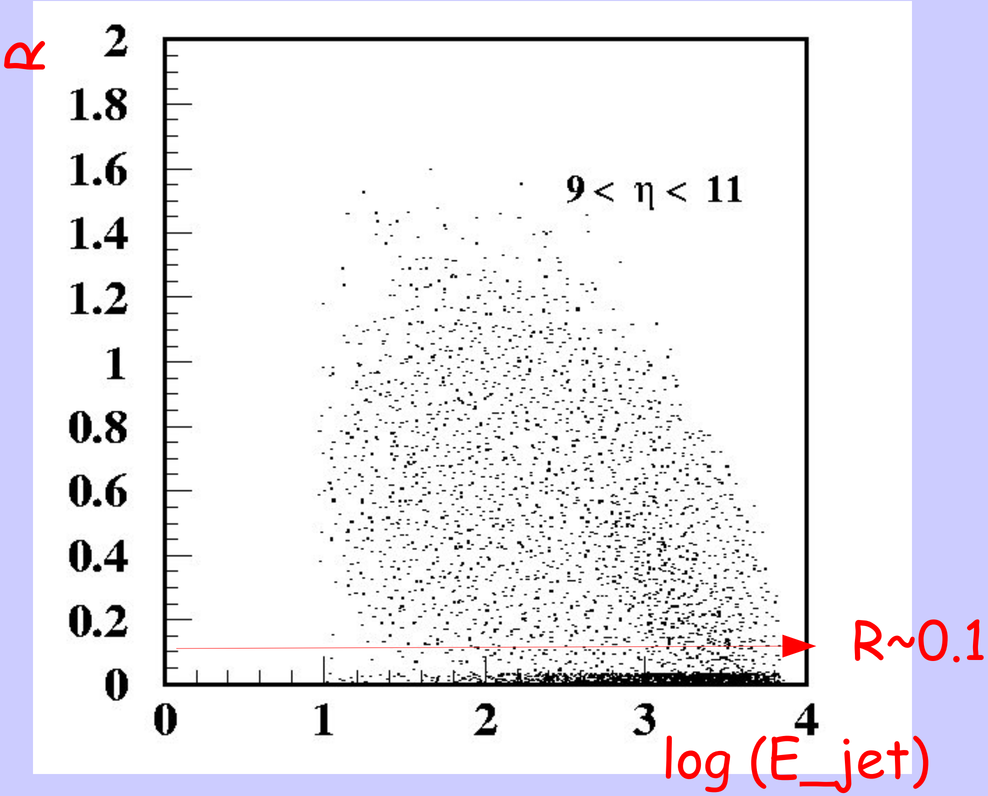
- The calorimeter at 135 m will accept the positive charged particles with E ~ 2.0 – 5.5 TeV in pseudorapidity range ~ 8 - 12
- Assume precision of hit point reconstruction in calorimeter ~ 5 mm and energy resolution ~ 3.5 % (coordinate resolution can be improved if a tracker (GEM) will be installed in front of calorimeter)

↓

- Pseudorapidity resolution ~ 0.25-0.5 (depends on the selected energy and pseudorapidity ranges)

Energy measurement

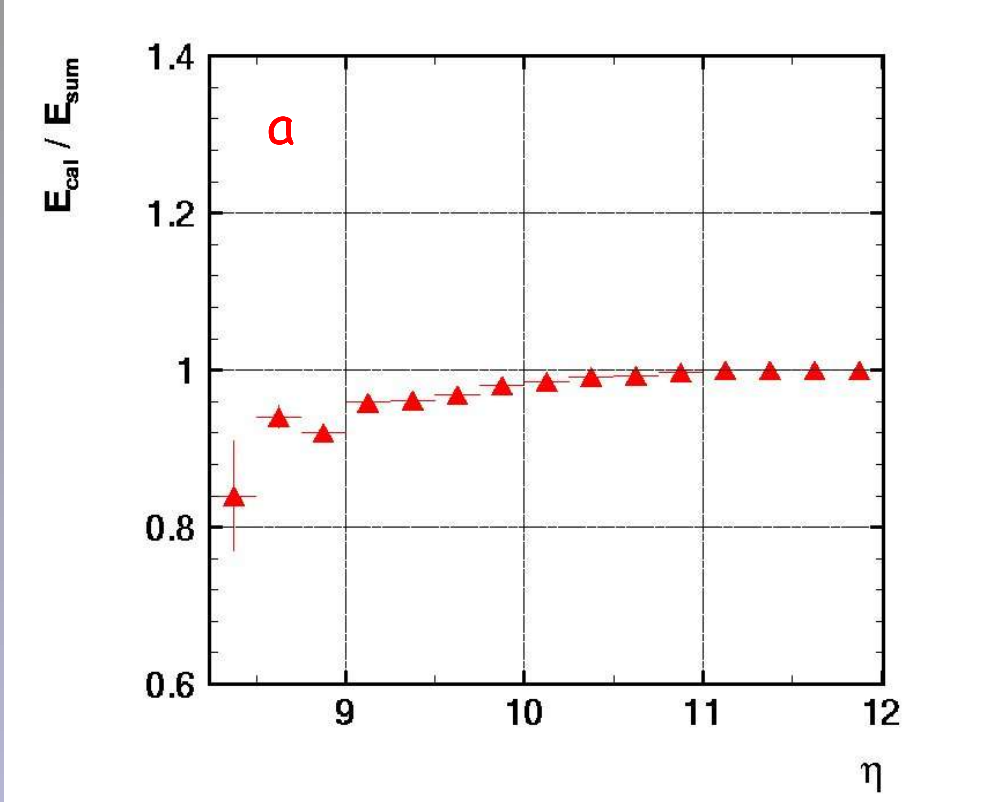


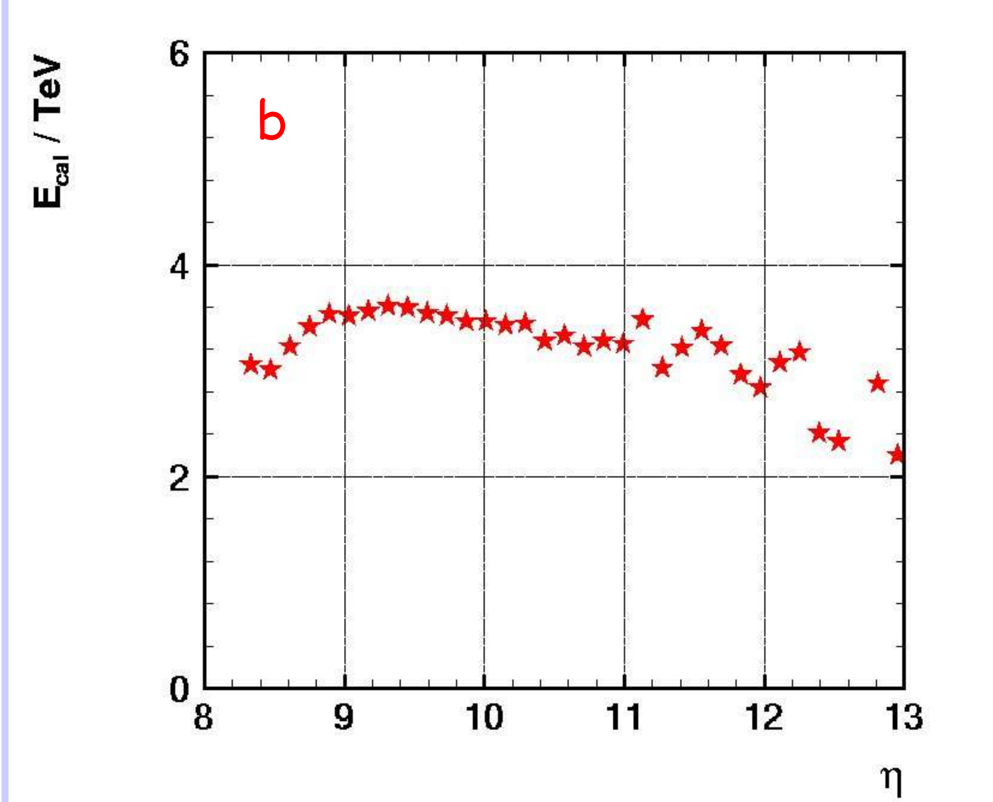


Jet radius vs jet energy

Narrowing of forward jet: R ~ 1.0 ($5 < \eta < 7$) ==> R ~ 0.1 ($9 < \eta < 11$)

* Forward jet with > 90% at $9 < \eta < 11$ → equivalent to leading particle



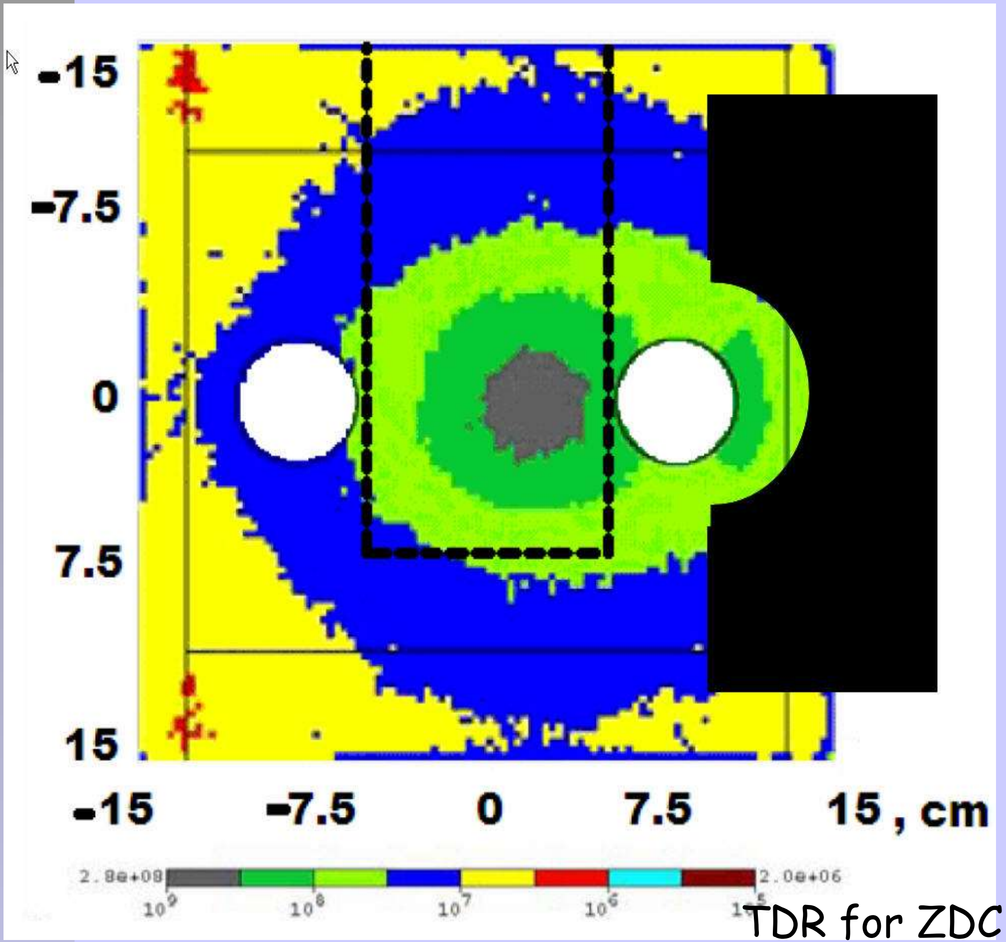


a) Esum is total energy of generated particles inside 0.25 rapidity range around "leading" particle accepted by calorimeter

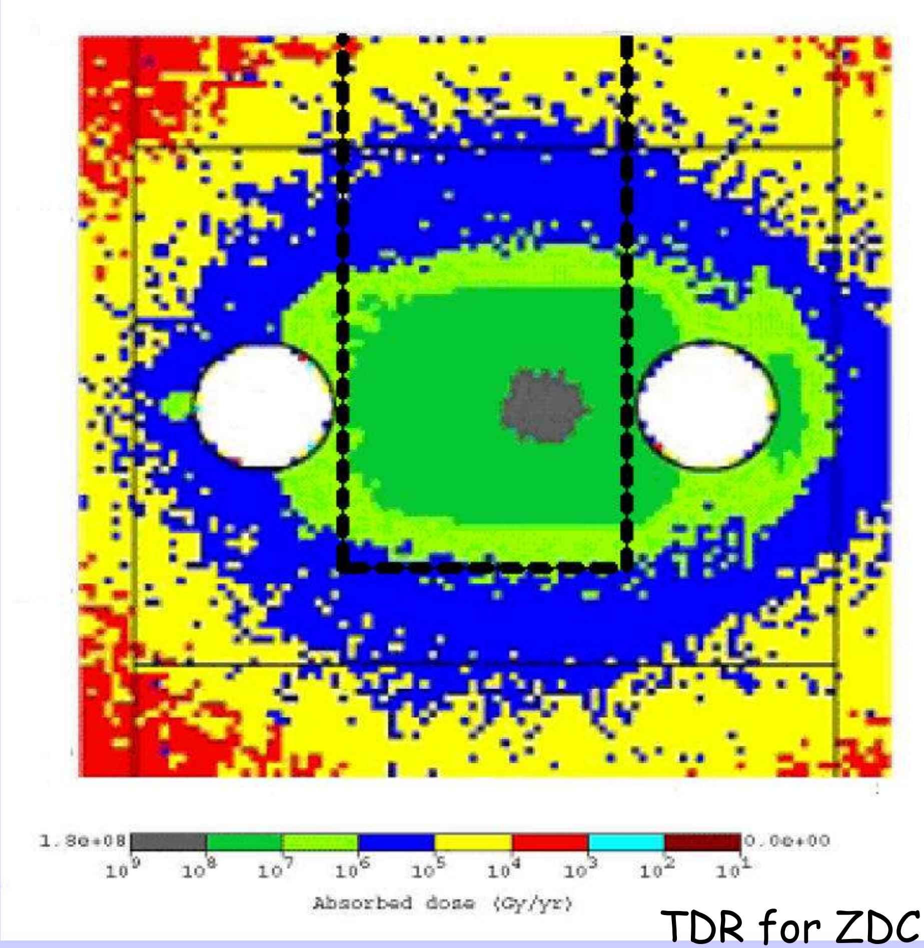
b) Energy flow vs pseudorapidity of the detected in calorimeter particle for events generated by PYTHIA

Calorimeter

- Radiation level near the calorimeter at 135 m is reasonable
  (plots from TDR for ZDC)
- Sandwich calorimeter: lead + sensitive layers
- Possible option for sensitive layers : quartz plates (or fibers), silicon diodes (for example pad diodes 3cm*3cm as in Hadron-Electron-Separator in ZEUS, presently investigating possibilities in terms of radiation hardness of the diodes, exchange of original pre-amplifiers ...), or water
- Tracker in front of calorimeter to improve coordinate resolution (GEM)



TDR for ZDC



TDR for ZDC

- Radiation conditions are reasonable (blue range) ~0.5 MGy/y

and hadron flux $\sim 0.5 \cdot 10^8$ (E > 20 MeV) $cm^{-2} s^{-1}$

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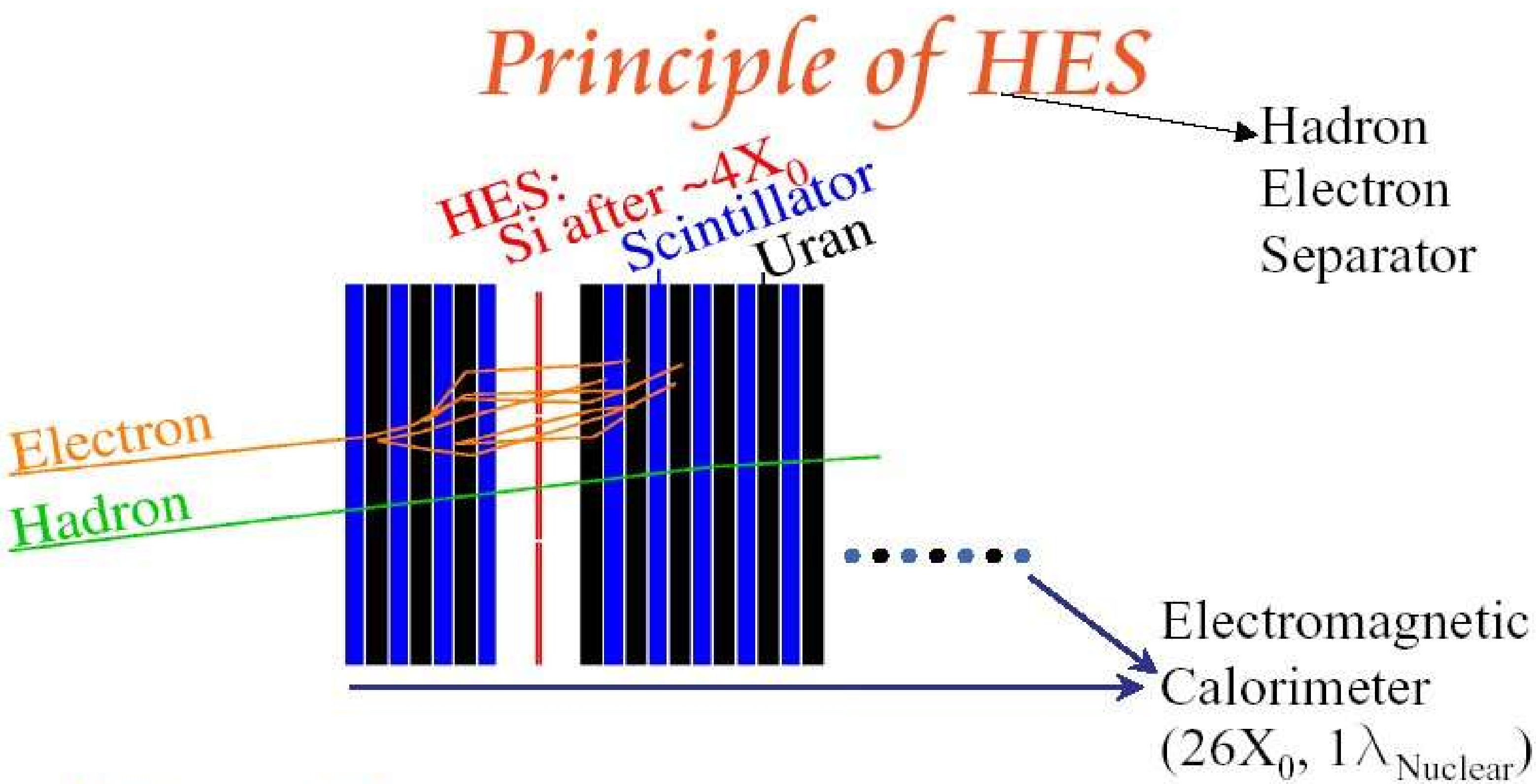
Summary

- Proposed calorimeter complements the existing forward detectors in CMS (CASTOR, TOTEM, ZDC)

- Rapidity range covered by the new detector is $8.0 < \eta < 12$ and accepted energy range E ~ 2.0 – 5.5 TeV

- With this calorimeter one can measure : "forward" energy flow, energy flow measurement in calorimeter with complement to energy in others detectors of CMS, to tag a forward jet with high-x and then study the full evolved parton shower in different schemes (multiple interaction ...)

Principle of HES



Use: $e^{\pm},\gamma$ early and narrow shower

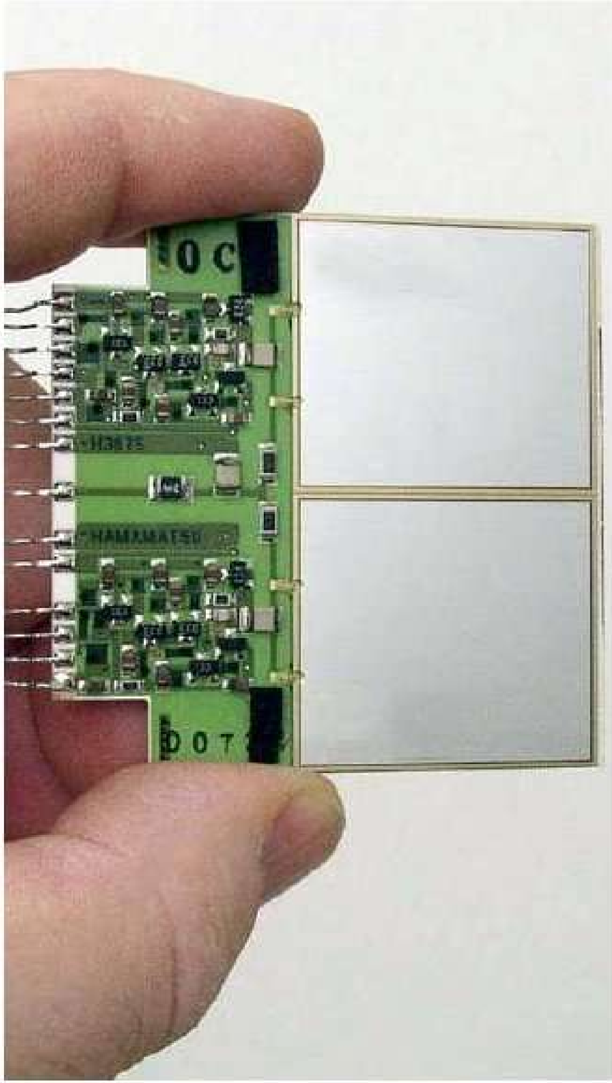
Strategy: Measure deposit of energy of particles at given longitudinal position

Detector: Plane at 3-5 X_0 (maximum of intensity)

Segmentation helps : $e^{\pm},\gamma$ in jets

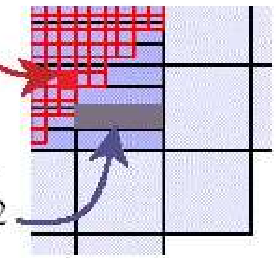
Experimental Set-up

Diode as Active Part



Advantage: High charge in small space
400μm, 33000 e-h-pairs/particle

Active area : 3.32×2.96 cm^2
Compatible to shower size
$R_{Molière} = 2$cm
Calorimeter cell 5×20cm^2



⇒ HES consists:

20518 diodes or 20m^2 silicon

Stations at 85m and 95m