The all-silicon tracker of the CMS experiment

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On behalf of the CMS tracker collaboration

- Design Considerations
- Layout
- Performance
- Schedule and Conclusions

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Design Considerations for the Central Tracking System (1)

- **Momentum resolution for isolated leptons in the central rapidity region**

  $\frac{\Delta p_T}{p_T} = 0.1 \times p_T$ with p_T in TeV.

  This momentum resolution will allow to reconstruct $Z \rightarrow \mu^+\mu^-$ with $\Delta_{M_Z} \leq$ 2 GeV up to $P_Z \sim$ 500 GeV.

- **Ability both to tag and to reconstruct in detail b-jets and B-hadrons within jets.**

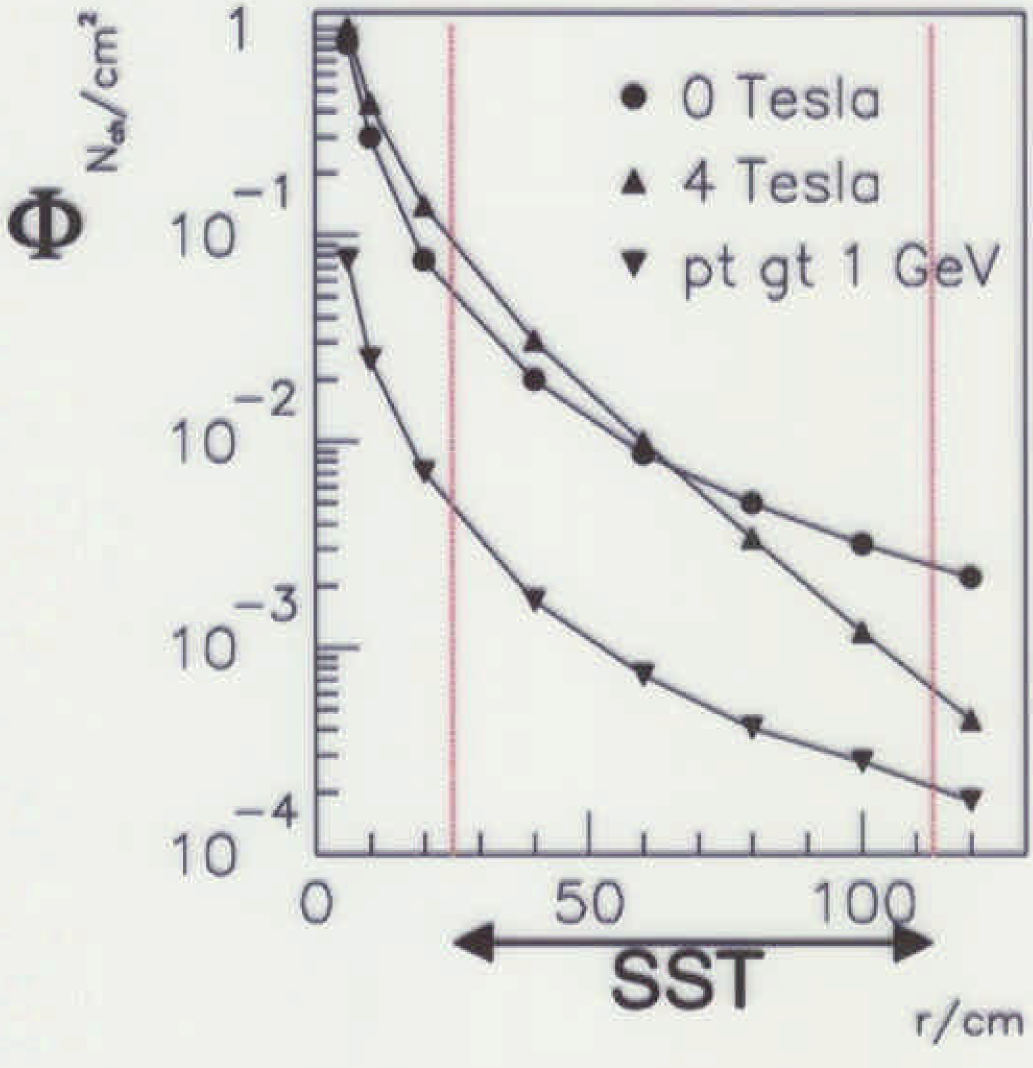
- **Reconstruction efficiency $>$ 95 % for isolated high p_T tracks and $>$ 90 % for high p_T tracks within jets.**

Design Considerations for the Central Tracking System (2)

- Resistance to high radiation dose
- Fast detector response ($<$ 25 ns) to reduce pile-up effects
- Minimize the amount of material in front of the calorimeters
- Capability to cope with the CMS trigger requirements

Resistance to high radiation dose

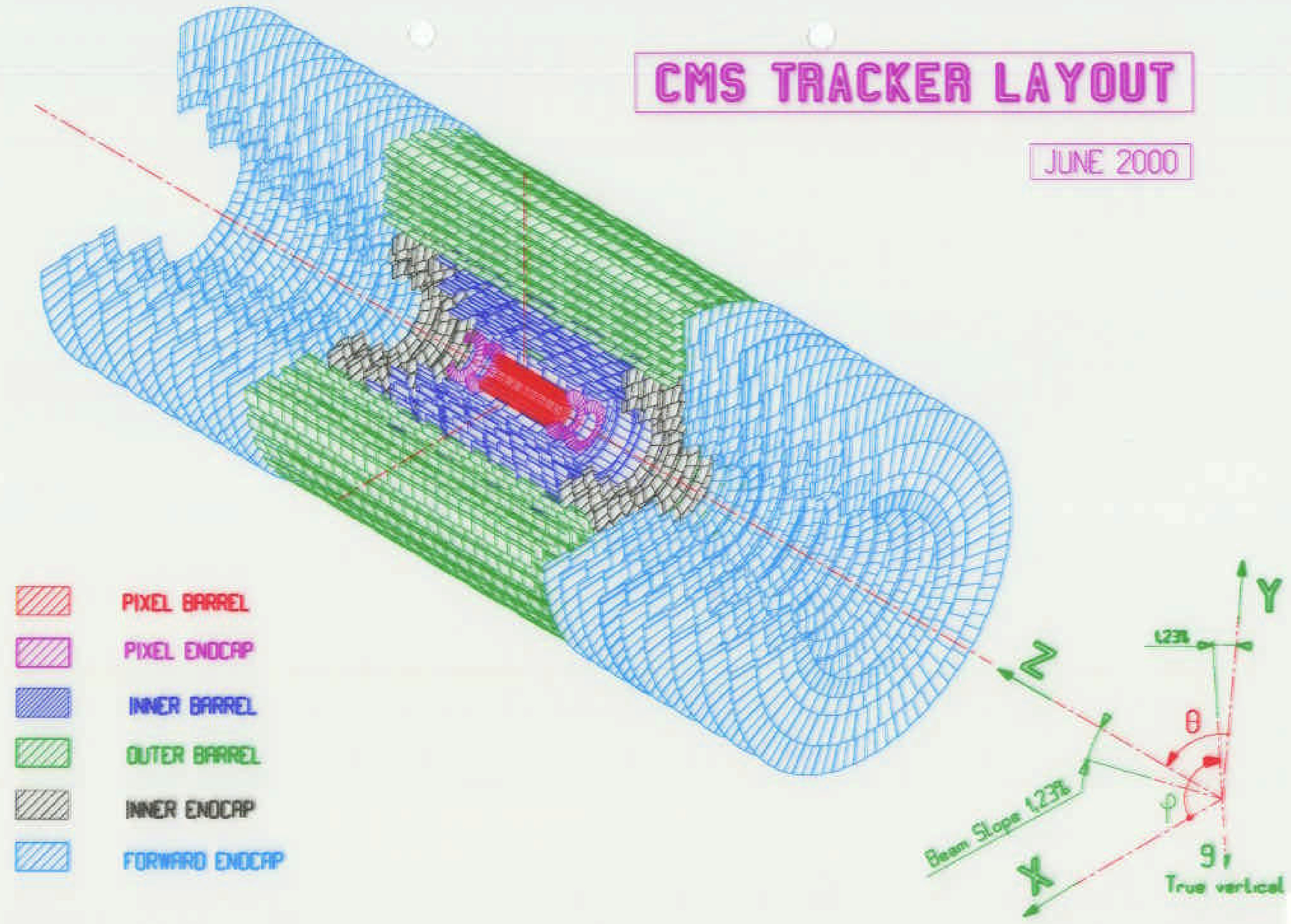
Primary charged particle densities integrating 20 minimum bias events:



Occupancy = $\Phi \times$ pitch $\times$ strip length.
Low (1 %) occupancy requires a maximum strip length of 10 cm at a radius = 20 cm.
This is relaxed at the outer radii. Increase of detector thickness to compensate higher noise due to longer strip length: $\frac{500}{320} \approx \frac{18}{10}$

CMS TRACKER LAYOUT

JUNE 2000



Perspective view of the tracker layout

Pixel detector:

pixel size = $150\mu m \times 150\mu m$;

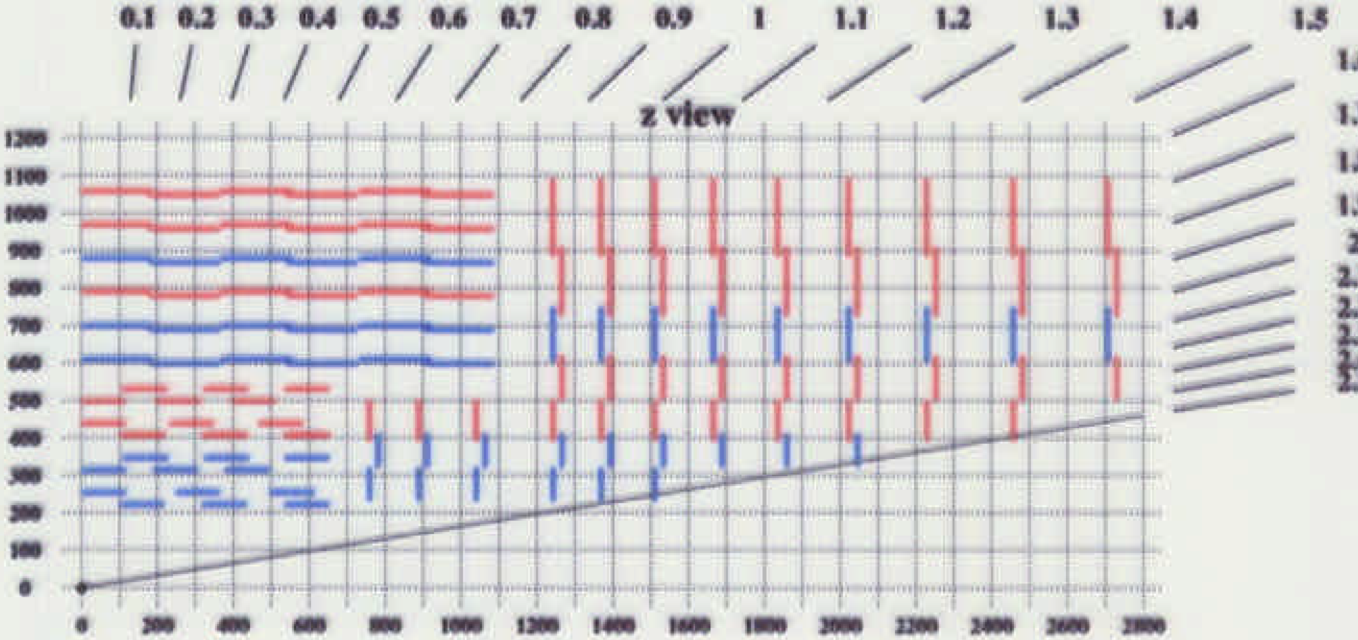
2 to 3 layers in the barrel

at a radius of 4, 7 and 11 cm;

2 end-cap disks on each side.

50×10^6 channels.

Layout of the silicon strip detector (SST) (1)



- Red lines indicate single-sided layers (5 layers in the barrel). Blue lines indicate stereo layers with detectors mounted back-to-back ((5 layers in the barrel). Stereo angle = 100 mrad.
- On each side: 3 mini-end-cap disks and 9 large end-cap disks.
- The CMS SST detectors;
  two different thicknesses: 320 μm thick for r $<$ 60 cm and 500 μm thick in the outer region.
- Detectors (from 6" wafers) contain one (thin) or two (thick) daisy-chained silicon sensors.
- Read-out with APV25 in deep sub-micron technology; 128 channels/APV.

Layout of the silicon strip detector (SST) (1)

CMS SST detectors continued:

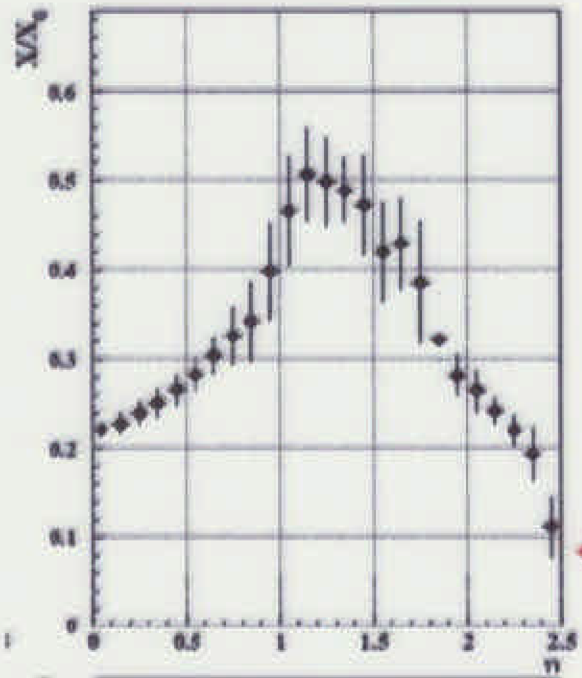
7,888 single-sided and 4032 double-sided
→ 15,952 single-sided equivalent modules.
10×10^6 **strips = electronic channels**
78,256 APV chips.

Comparison of some silicon detectors:

experiment	nb. of detectors	nb. of channels	silicon area [m^2]
CMS	15.95 k	10×10^6	223
ATLAS	16.0/2 k	6.15×10^6	60
AMS 2	2.3 k	196 k	6.5
D0 2		793 k	4.7
CDF SVX II	720	405 k	1.9
Babar		140 k	0.95
Aleph	144	95 k	0.49
L3	96	86 k	0.23

From L3 to CMS:
⟹ increase of silicon area by
3 orders of magnitude!!!

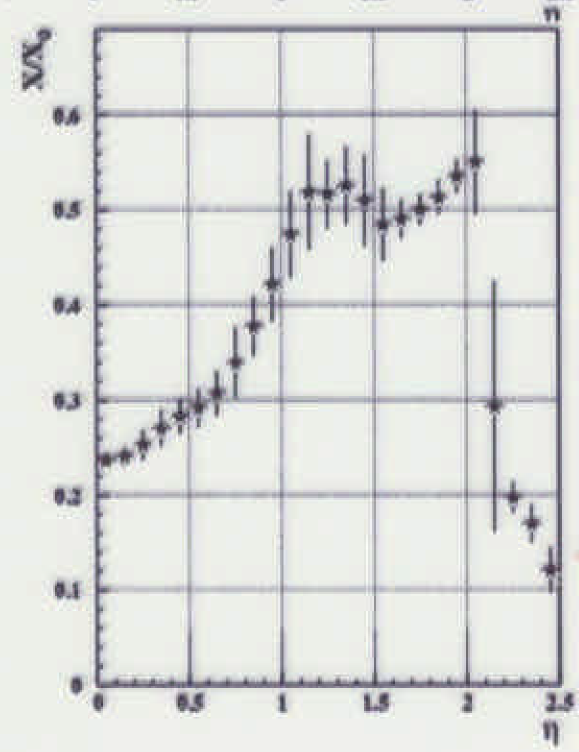
Material Budget



Radiation length of the SST as a function of rapidity.

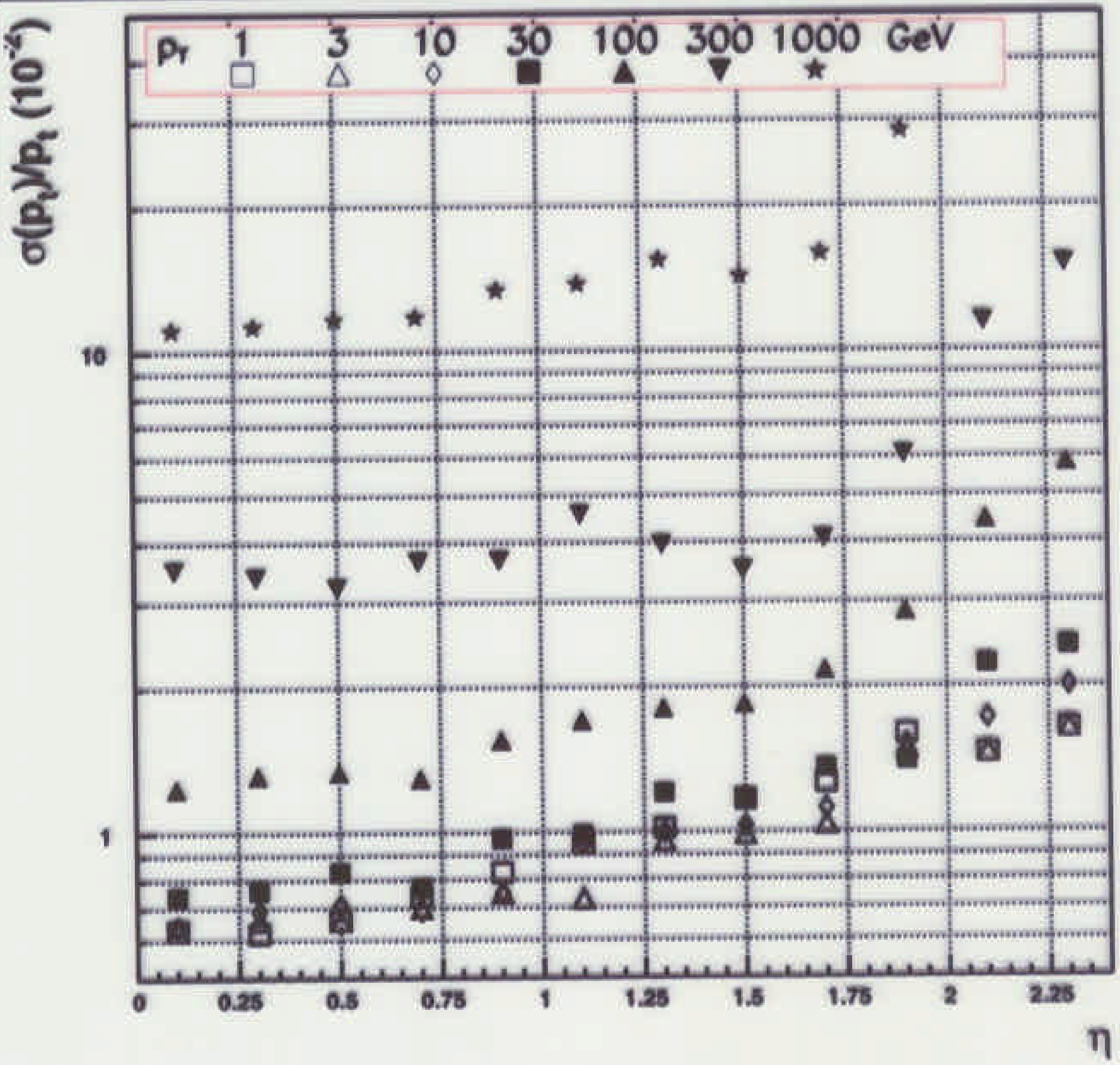
Material outside the tracker volume not included

Present layout



Layout used in the full simulation

$\frac{\sigma_p}{p}$ Performance

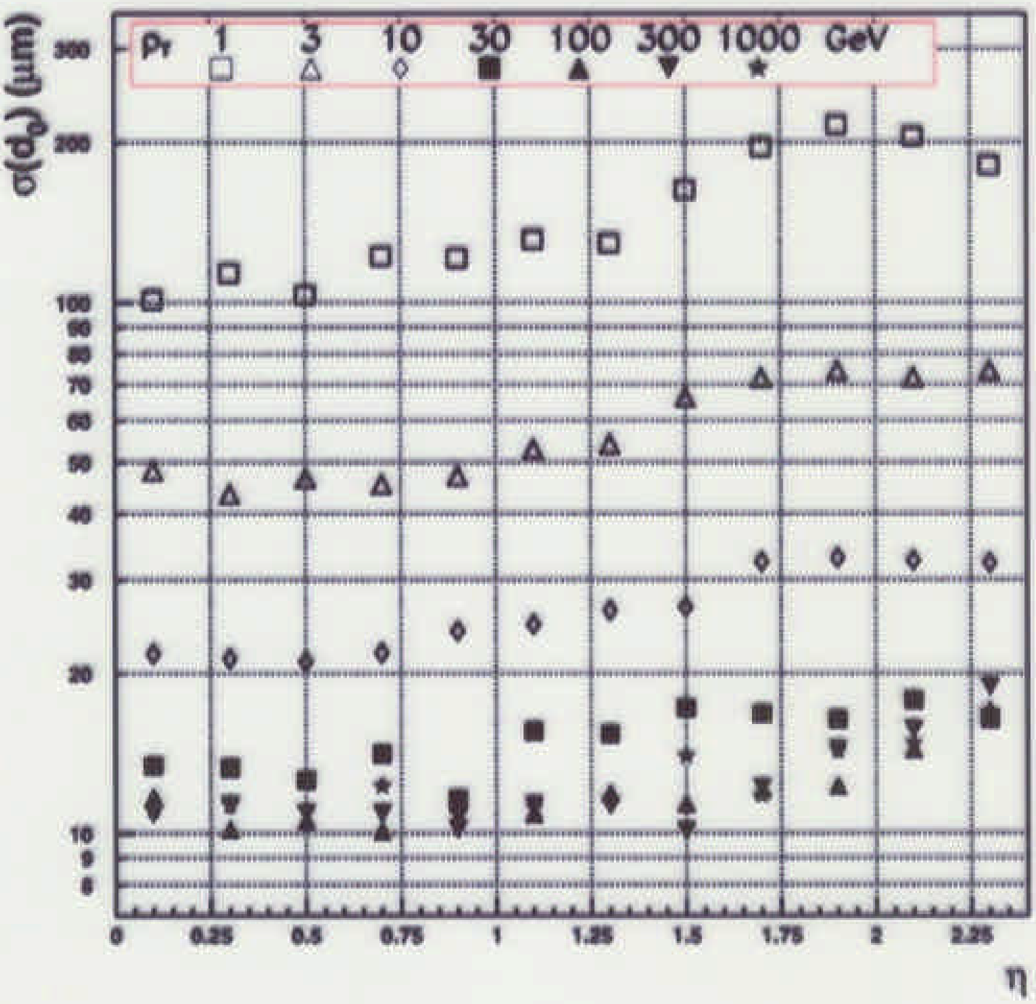


Expect $\frac{\sigma_p}{p} = 13\ \%$ at 1 TeV from analytic calculation: 12 layers with a digital spatial resolution (σ_x = pitch/$\sqrt{12}$):

$$\frac{\sigma_p}{p} = \frac{\sigma_x \cdot p}{0.3 \cdot B \cdot L^2}\sqrt{\frac{720}{N_{plane}+4}}$$

pitch = 100 μ m, B = 4 T, L = 1.1 m

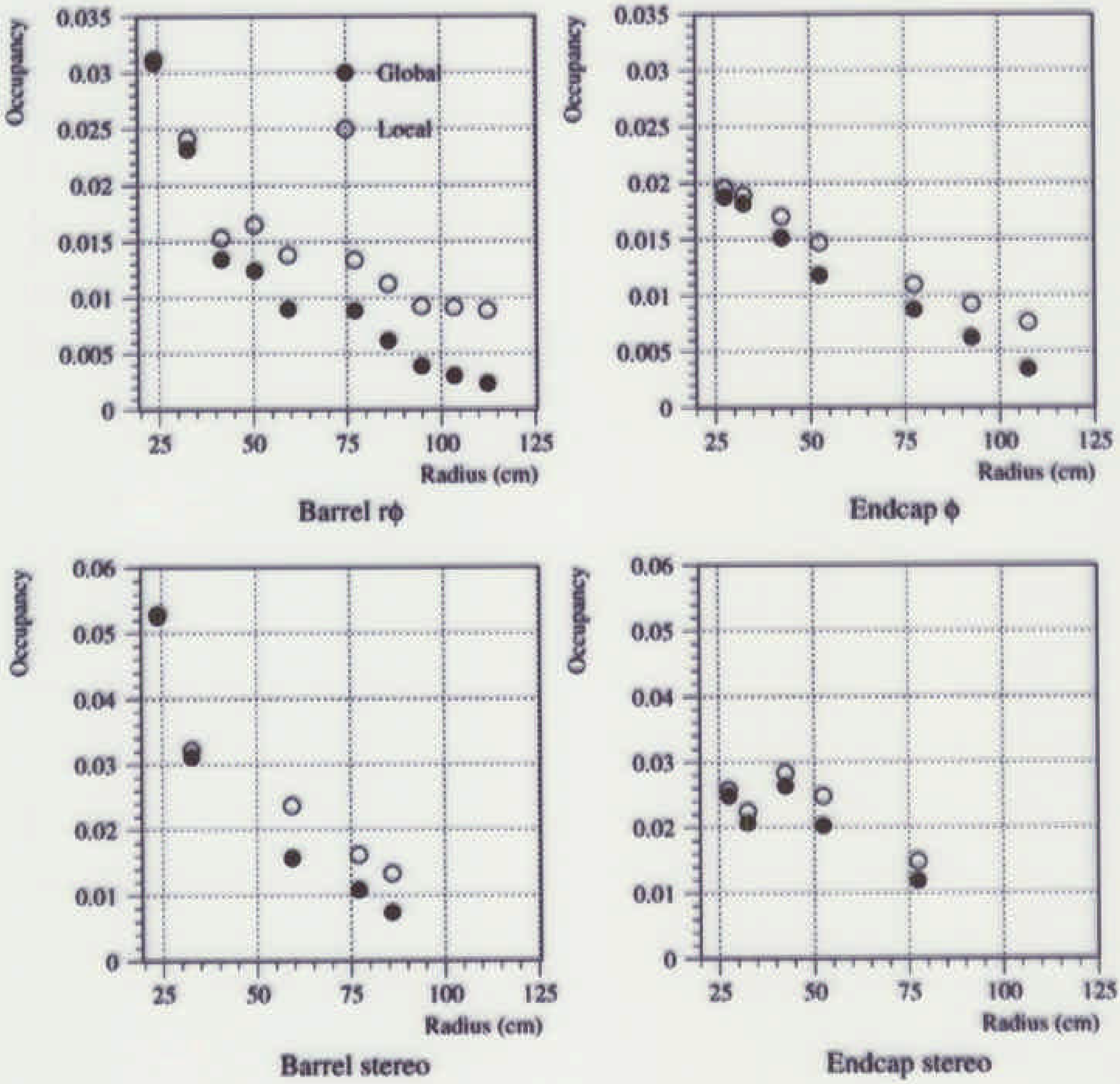
Impact Parameter Performance



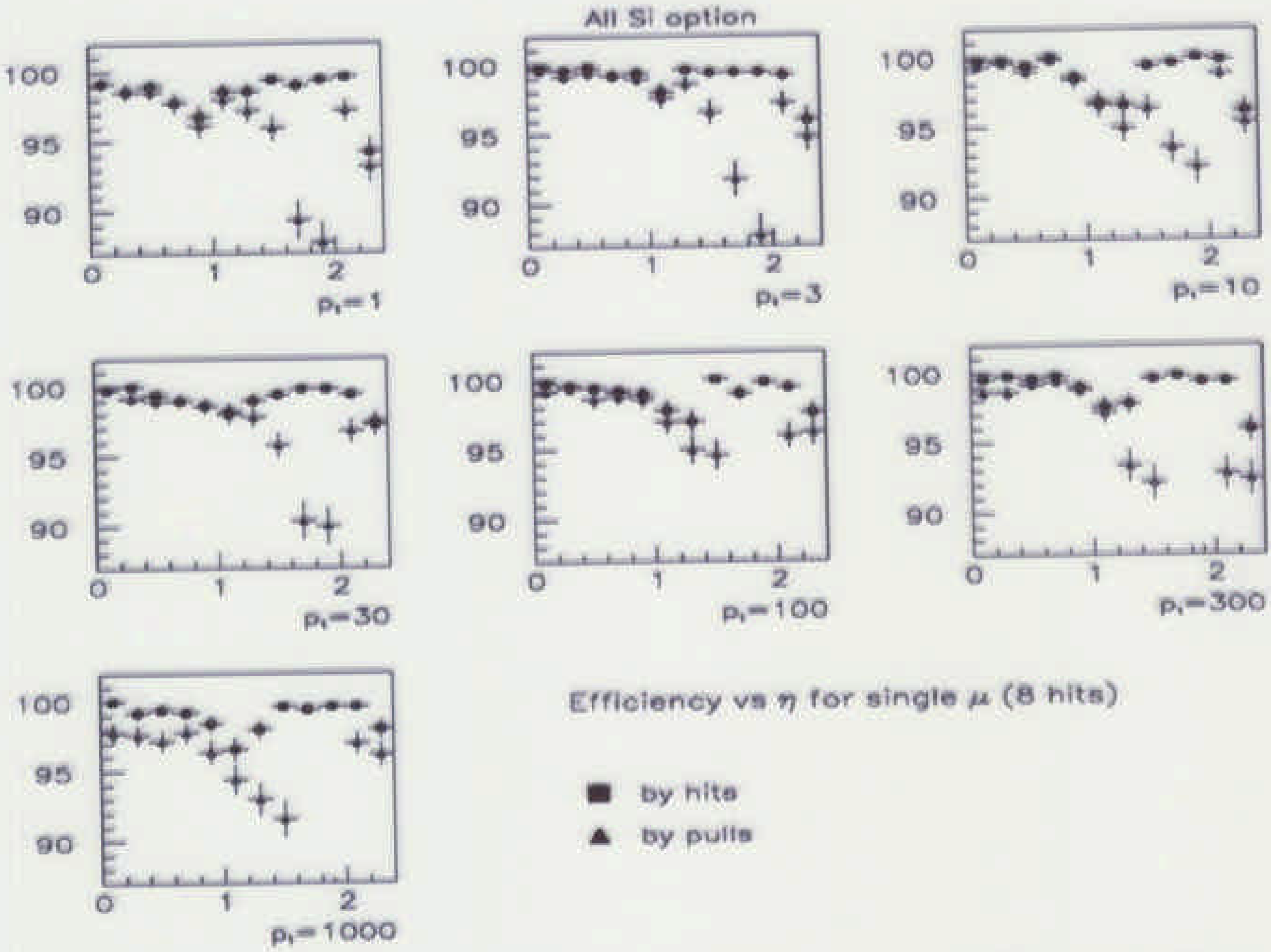
Transverse impact parameter resolution dominated by multiple scattering for low and by measurement in innermost pixel layer (4cm) for high momentum tracks.

$\sigma(d_0) < 30\ \mu$m for p $\geq$ 10 GeV.

Occupancy


Occupancy
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Global
Local
25
50
75
100
125
Radius (cm)
Barrel rϕ
Endcap ϕ
0.06
0.05
0.04
0.03
0.02
0.01
Barrel stereo
Endcap stereo

Efficiency



Efficiency(%) in jets: $\eta < 0.7$ $1.2 < \eta < 1.6$

ghost fraction(%) $p_t > 2$ Gev/c

	$\eta < 0.7$	$1.2 < \eta < 1.6$
At least 6 reg.hits	93.7 +/- 0.6 0.26 +/- 0.09	91.6 +/- 0.6 0.10 +/- 0.07
At least 8 reg.hits	88.3 +/- 0.9 0.06 +/- 0.06	86.8 +/- 0.8 0.10+/-0.07

main loss due to interaction of particle in the tracker material

Schedule and Conclusions

1. Preproduction of 200 SST modules at the end of 2000
2. Production of SST modules:
   from mid 2001 till end 2003
   by 3 "consortia":
   Central Europe, INFN and USA.
3. 4th quarter of 2004: commissioning by CERN and INFN; installation at CERN.

- Availability of 6" wafer technology allows to build a homogeneous, fast detector.
- Compensation of increase in noise due to larger surface by thicker detectors.
- 0.25 μm electronics at reduced price and better performance w.r.t. previous technologies.
- Automated assembly possible.
- The CMS all-silicon detector will have excellent performance.