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Geant4 Simulation (for FP420)

[in OSCAR(CMS) framework]

items:

- geometry description ($\Rightarrow$xml)
- multiple interactions **(MI)**
- multiple scattering **(MSC)**
- summary

Pocket geometry

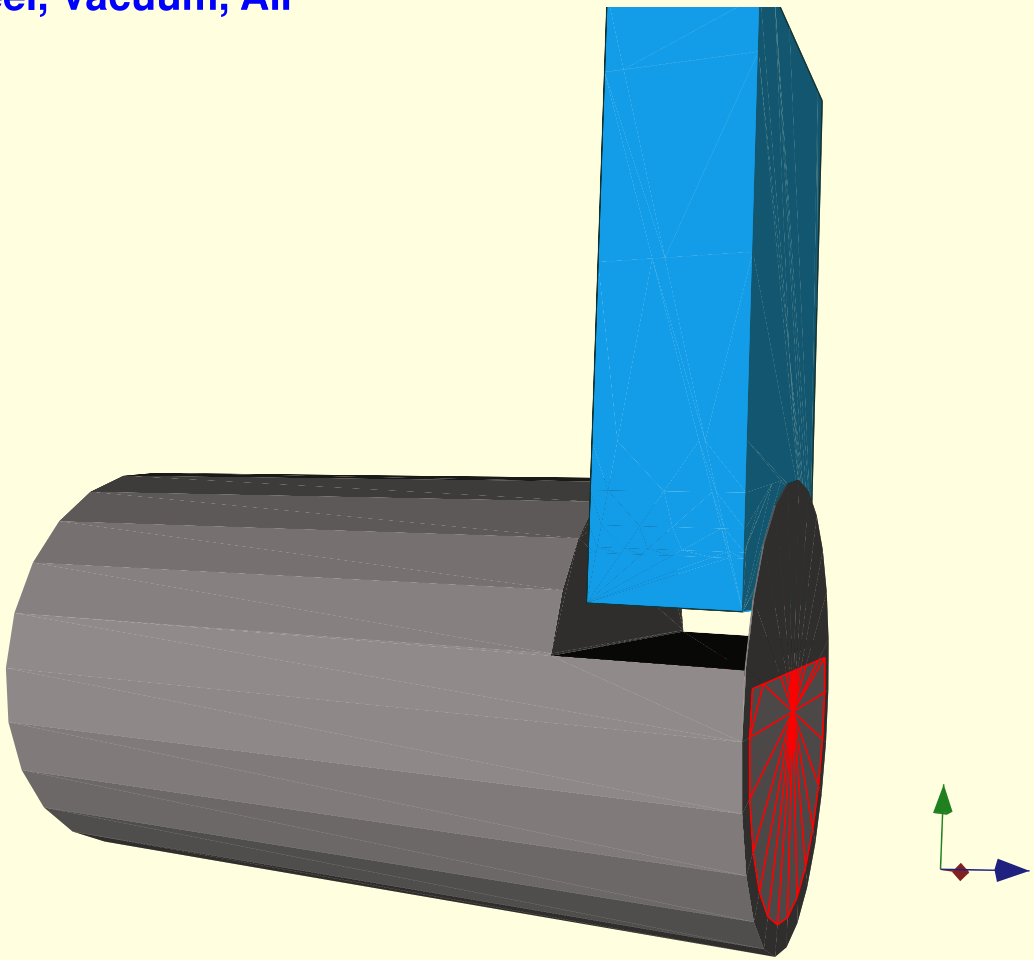
- subtraction Solid combine Tubs and Box solids

- materials: Stainless Steel, Vacuum, Air

- beam pipe (bp) radius: 40 mm
- bp unit length (bpul) : 2.8 m
- bp wall thickness (bpt) : 5 mm
- bp pocket y-thickness (bppyt) : 3.5 mm
- pocket z-size: 30 mm
- y pocket shift: 10 mm
- y-gap(pocket - station): 2 mm
- window thickness (wt) : 0.25 mm

The configuration unit to be used for full geometry set up (with 3, 5, ...stations)

⇒

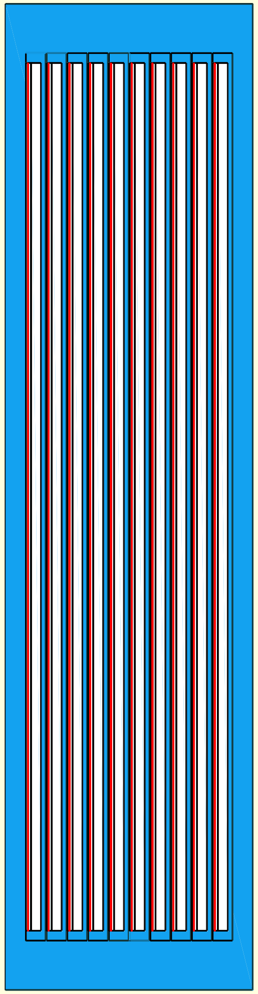


Station geometry

- few Planes (up to 10) per Station

- materials: Silicon, Boron Polyethylene.,Ceramic, Air,

- Station dimensions: 84 x 100 x 25 mm^3
- 1-st layer Si thickness: 0.200 mm
- bumpbouding thickness: 0.020 mm
- 2-nd layer Si thickness: 0.300 mm
- Ceramic thickness (ct) : 1.00 mm
- 2-layer-Si Plane dimensions: 80 x 98 x 2 mm^3
- Distance between centers of Planes: 2.5 mm
- Parameters in black brackets were varied in simulation studies



- One can generate events with interactions in the detector
- Analysis at aStep, EndOfTrack, EndOfEvent:

$\Downarrow$

Scan with protons

$\star$- **point of origin with 3 Stations**

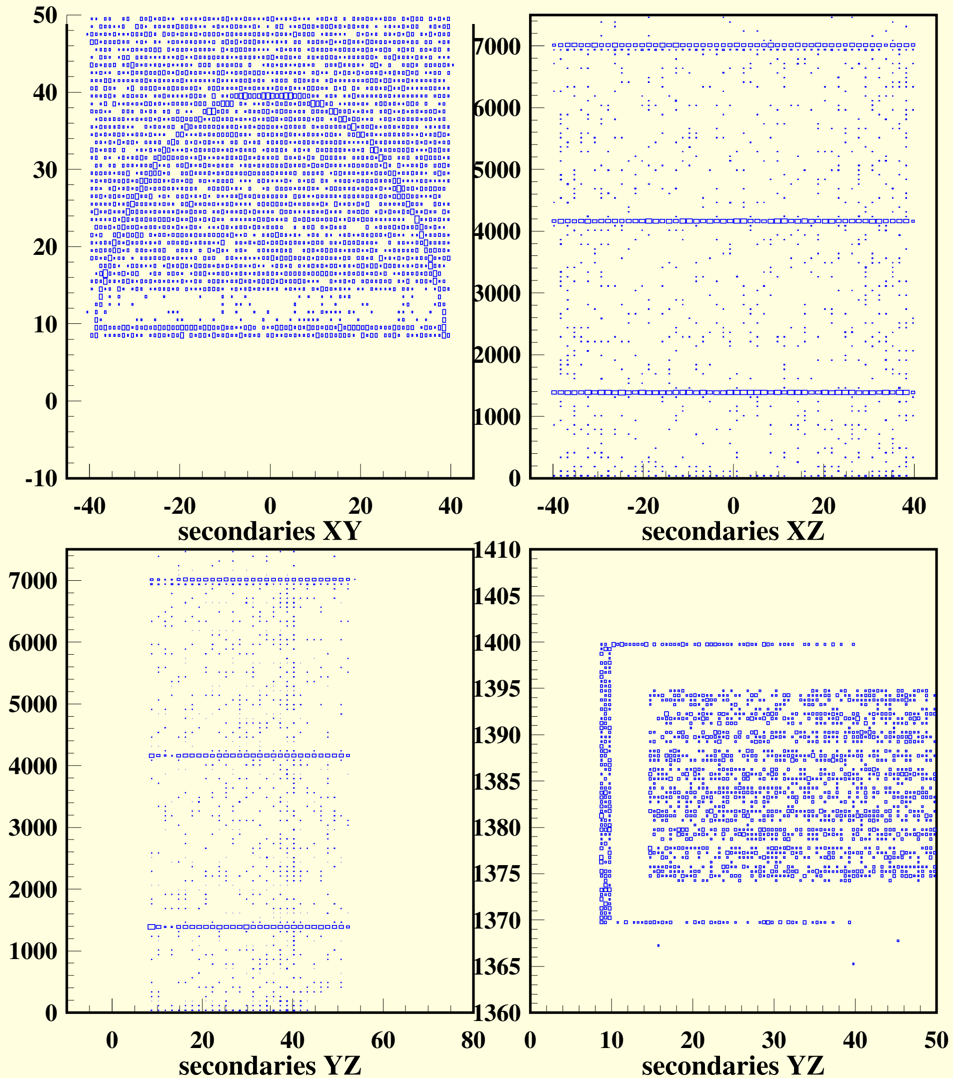
- eta: (8.8 $\div$ 11.4) $\simeq$ ($\tan(\theta)$: 120./420000. $\div$ 10./420000.)
- phi: 0 $\div$ 2 π
- Vertex: (-40. $\div$ +40., +8. $\div$ +50., 0.) mm
- P_p = 70 GeV , 50000 ev.

- to check the details of geometry: put bppt = 0.1mm, bppyt = 1.5mm to avoid too large !MI , wt = 0.5mm

Define the sign of !MI:

$$Z^{prim.track}_{lastpoint} > Z^{III-rdStation}_{position}$$

Starting points of secondaries

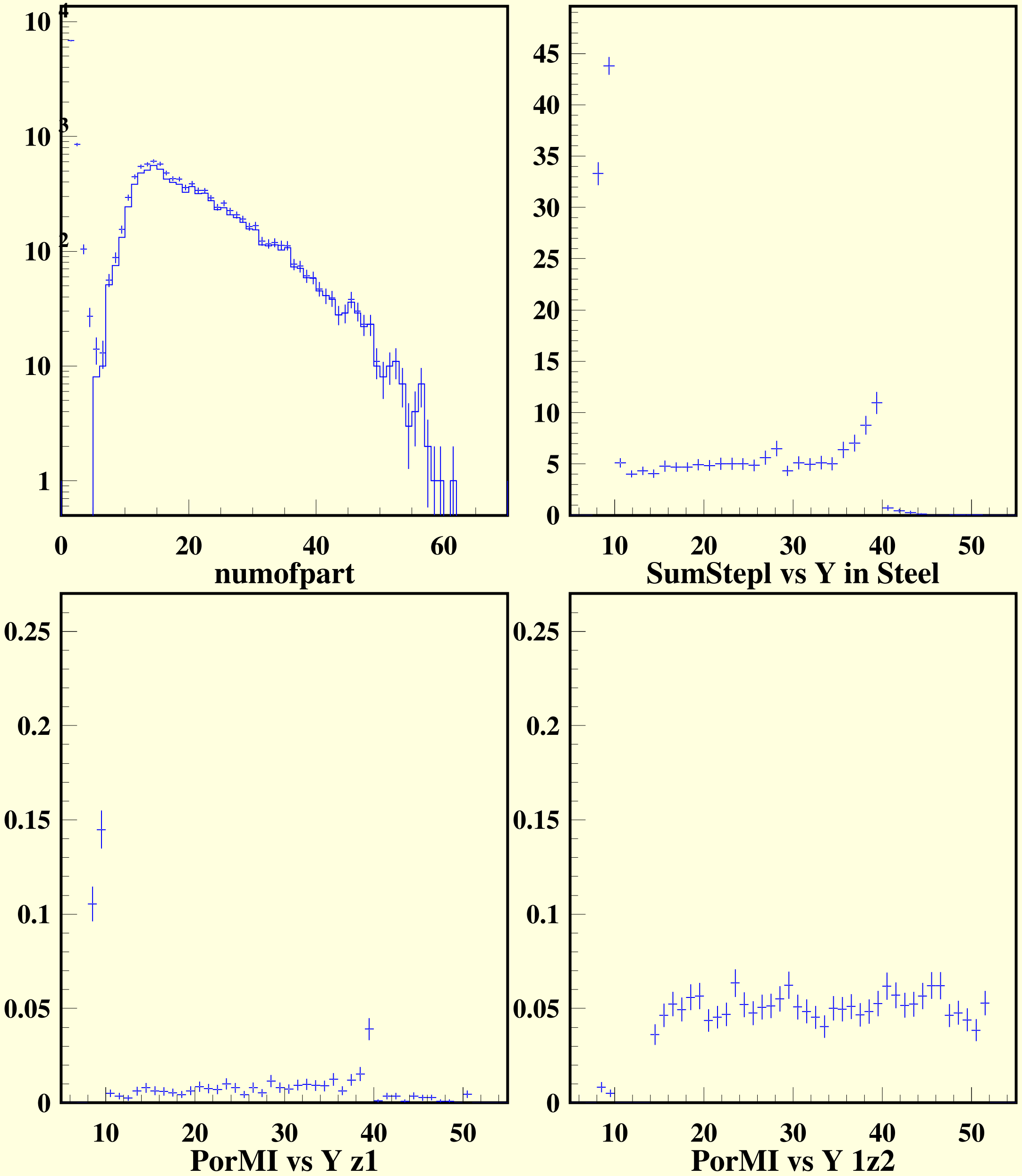


MI in proton scan

(still 70 GeV protons)

- check w/ number of secondary particles:
  $\Rightarrow$ strong correlation(histogram) w/ cut:
  $Z^{prim.track}_{lastpoint} < Z_{III-rdStation}$
- portion of **MI** vs. Y-vtx at $Z^{I-stStation}_{infront}$ and z range of I-st Station $\Longleftrightarrow$ track length in St.Steel vs. Y-vtx

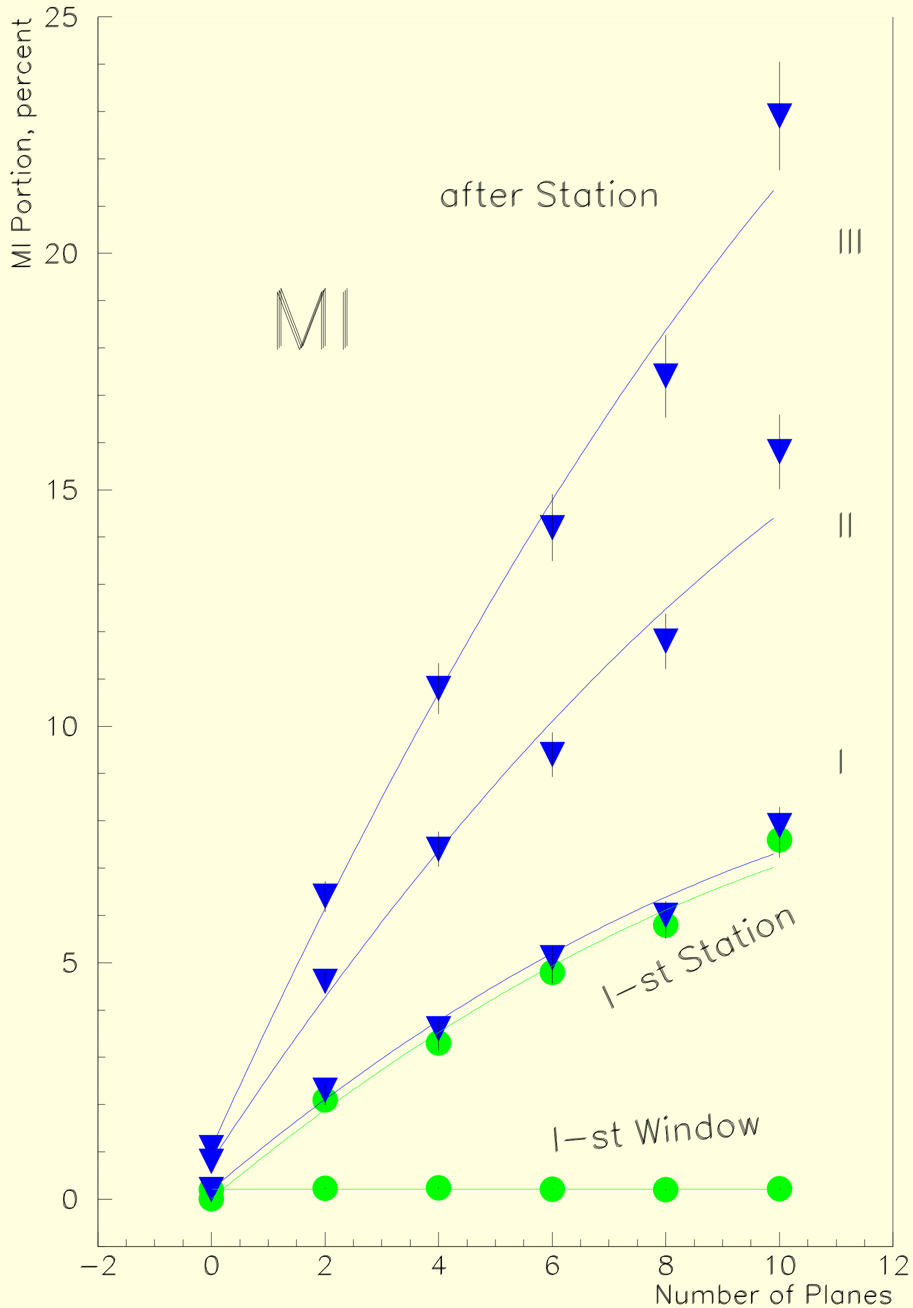
start real job with
P_p = 7 TeV,
vertex(0.,20.,0.),
2500 ev. / point,
wt = 0.25 mm,
bpt = 0.01 mm,
bppyt = 3.5 mm



MI as function of ♯ Planes

- strong rise vs. ♯ Planes
- portion of MI w/ 10 Planes is
  $\simeq$ 20 %
- portion of MI w/ 6 Planes is
  $\simeq$ 15 %
- contribution of 250 μm St.Steel Window is negligible($\sim$0.2%)

check last statement ...



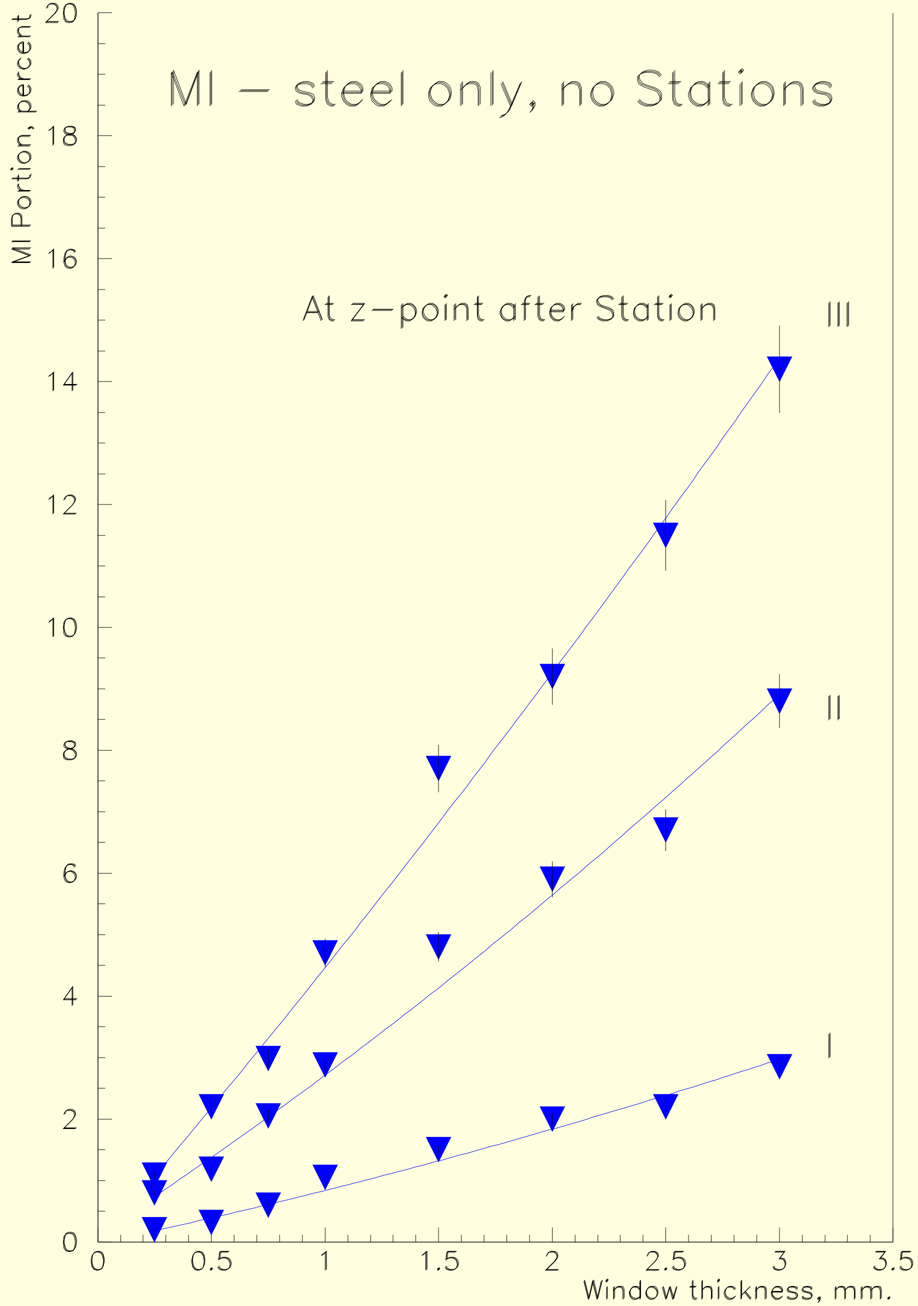
MI as function of wt

- strong rise vs. wt

- contribution of 250 μm wt
  to MI is $\simeq$ 1.2 %

- contribution of 1 mm wt
  to MI is $\simeq$ 4 %

check MI contribution
for Ceramic ...

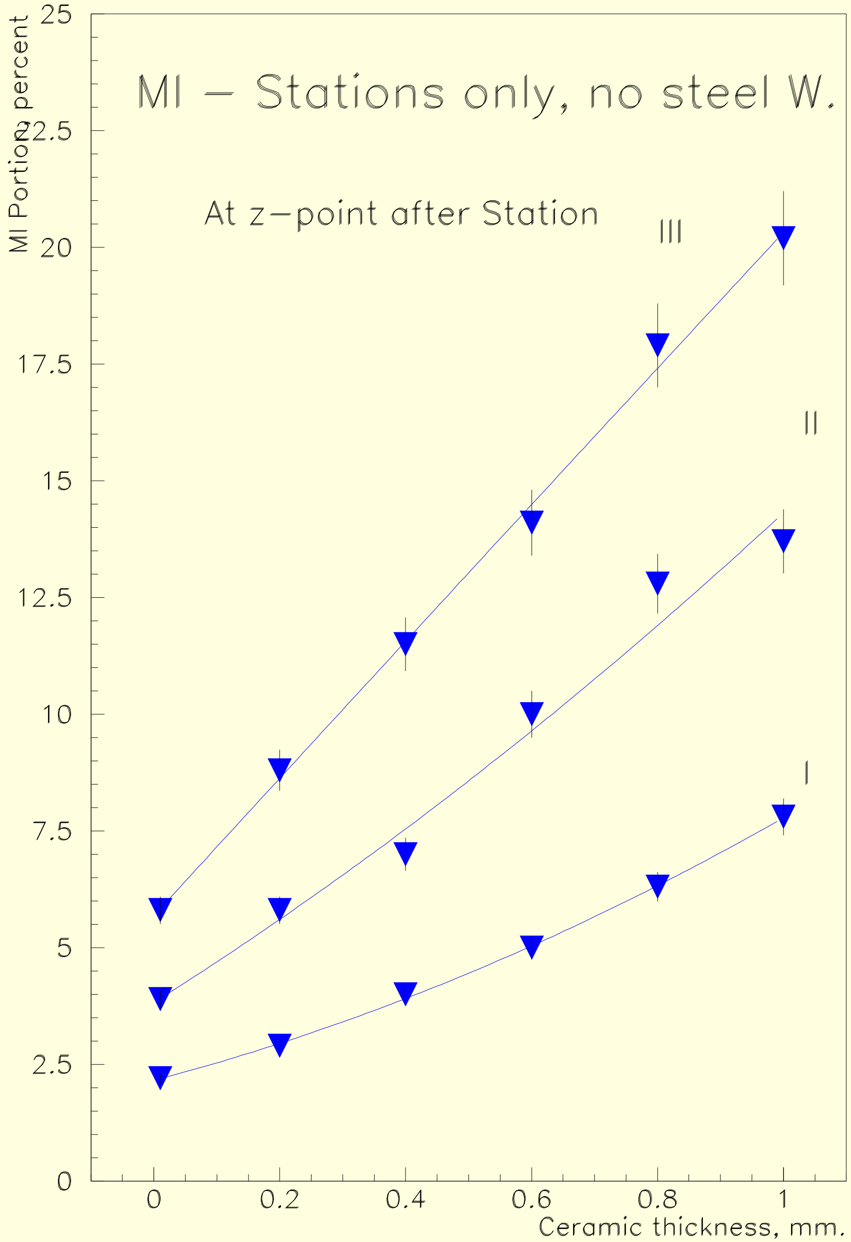


MI as function of ct

(1 mm ct is foreseen as default)

- strong rise vs. ct
- at 10μm ct there is just Silicon contribution to MI $\Longrightarrow \leq 6\ \%$
- pure Ceramic contribution of $1mm$ thickness $\sim$ 15 %
  (reminder: w/ 10 Planes and 3 Stations, overall Ceramic thickness is 3 cm)

(10 Planes per Station)



One can do estimation of **MI** portion for different number of Planes and ct keeping fixed the number of Stations = 3 and wt=250μm

Estimation of MI portions(%) with 3 Stations

ct, mm	2 Planes	4 Planes	6 Planes	10 Planes
0.4	4.4	6.7	9.1	11.5
0.6	5.2	8.2	11.2	14.5
0.8	6.0	9.6	13.3	17.5
1.0	6.5	10.5	14.5	20.5

- example of calculation for 4 Planes and ct=0.6 mm:

14.5% *((10.5-1.2)% / (20.5-1.2)%) + 1.2% = 8.2 %

(14.5% *((10.5-1.2)% / (20.5-1.2)%) + 4.0% = 11.0 % $\Leftarrow$ wt=1mm)

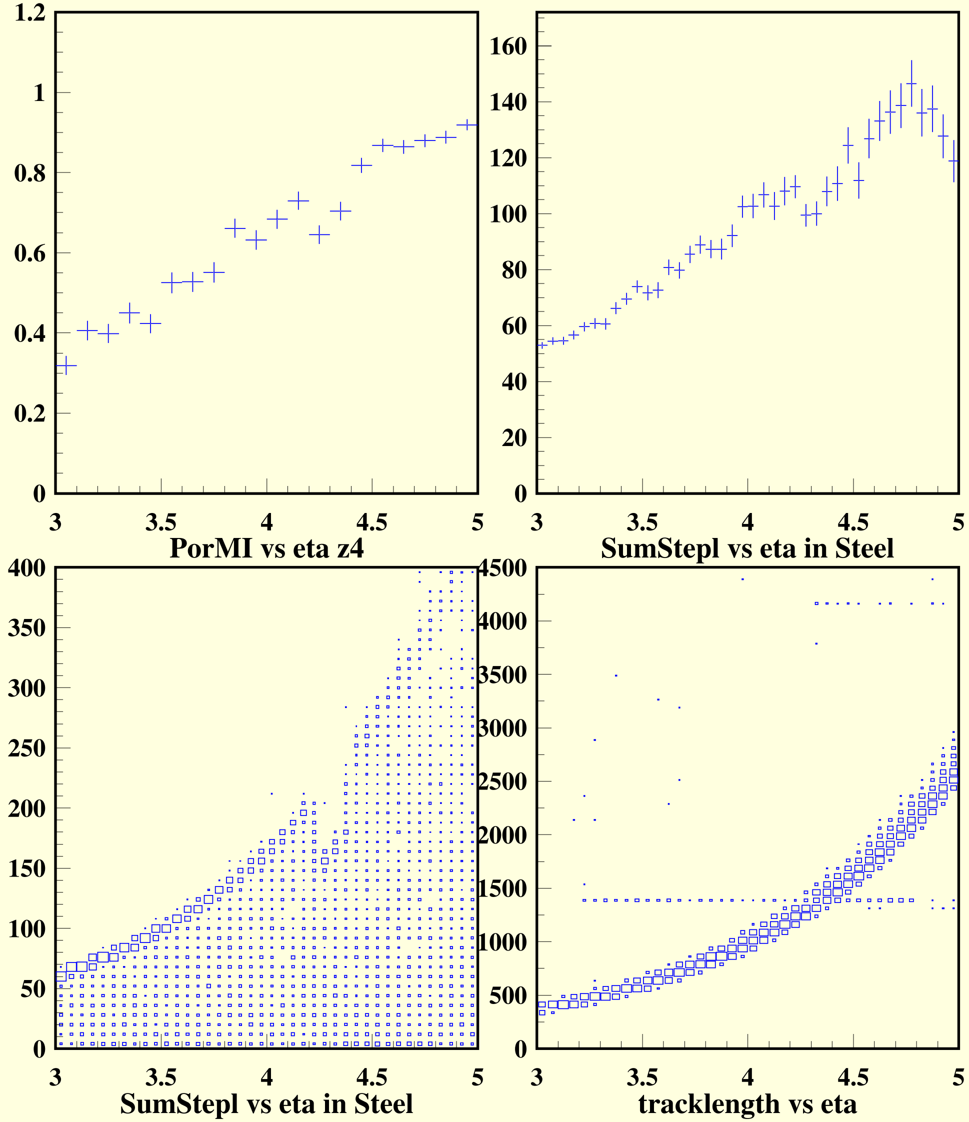
Reminder: each plane include 2 Si layes (0.3 + 0.2 mm)

Exercise with protons going through steel

realistic (bpt) & (bppyt): 6 mm and 3.5 mm accordingly

- eta: (3. ÷ 5.) $\simeq$ ($\tan(\theta)$: 120./1400. ÷ 10./1400.), phi: π
- Vertex: (0., 0., 0.) mm, P_p = 70 GeV , 10000 ev.

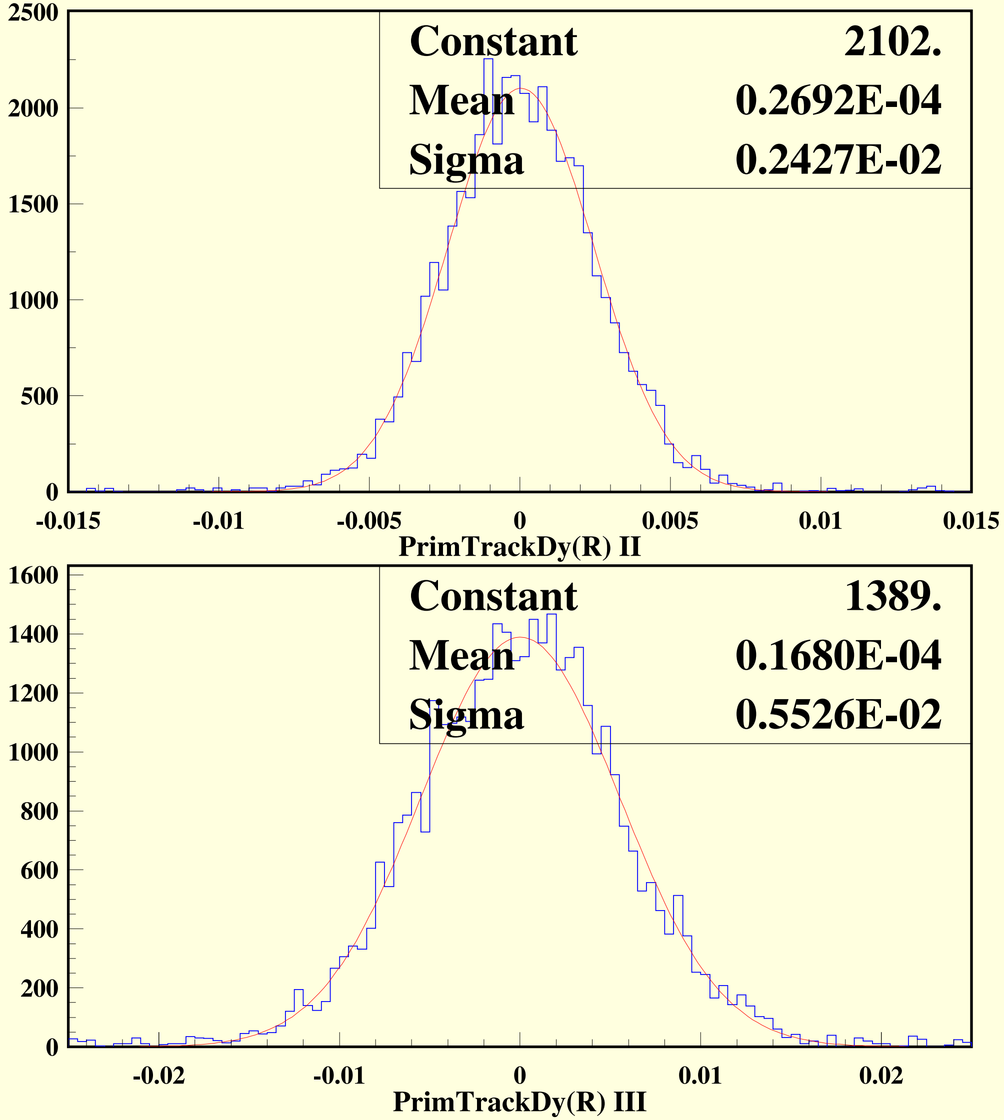
$\sim$ 65 % of **MI** for I-st Station position



Effect of MSC

10(6) Planes

- eta: (8.8 ÷ 11.4), phi: 0 ÷ 2 π, vertex(0.,20.,0.), P_p = 7 TeV, 5000 ev., distance between I-st and last Station
  2·bpul = 5.6 m
- Plots:
  Y(X) - deviation of track from primary direction at z of Si plates(last step inside every Si media) for II-nd and III-rd Stations
- For I-st Station: $\sigma_{deviation} \sim$ 0.001 μm
  For II-nd Station: $\sigma_d \sim$ 2.4(2.0) μm
  For III-rd Station: $\sigma_d \sim$ 5.5(4.5) μm
- Corresponding deviations for 2·bpul = 8.0 m:
  σ_{II} = 3.6(2.8)μm, σ_{III} = 7.9(6.3)μm
  (Using hits: σ_{II} = 3.8μm, σ_{III} = 8.5μm)



estimation of $\perp$ uncertainty of IP position:
$\sigma \sim$ 150(125) μm

(Z/z) * $\sqrt{(\Sigma(D_i)/n)}$

Summary

- **The version of G4-simulation of FP420 is prepared (pure simulation: no digitization & reconstruction).**
- **The study of MI effects for different geometry parameters was presented.**
- **The influence of MSC on position resolution was estimated.**
- **The things to do:**
- **short term - simulation:**

  - implementation of more realistic geometry set up, materials, rotation matrices
  - NumberingScheme, production cuts
  - SensitiveDetector: class of SimHitsCollection $\Longrightarrow$ studies with hits

  SimHitsCollection provide input information for signal simulation

  $\Downarrow$

- **long term - provide digitization & reconstruction to have complete MC:**
  - charge collection:
  - SimHitsCollection: entrance and exit points, E_{dep}
  - divide track segment into 10 μm long sub-sgm.
  - take into account Landau fluctuations in thin material layers:
    assign a fraction of energy for each sub-sgm.
  - drift in magnetic field (Lorentz angle)
  - charge collected by every strip, a list of hit strips
  - add the noise contribution
  - convert the charge into an integer number(ADC digitization)
  - strip zero suppression
  - cluster(set of adjacent strips) finding algorithm
  - precise hit position reconstruction
  - track reconstruction