FP420 Collaboration Meeting
DESY 18th May, 2006

G4 simulation: where are we?

Marta Ruspa on behalf of Alexander Zokhin

Effect of multiple interactions and multiple scattering through pocket geometry

MI rate =

fraction of proton tracks which have an inelastic interaction anywhere along the path of the proton in the spectrometer before the last plane of the last station.

Beware: does not mean that the track is necessarily lost!

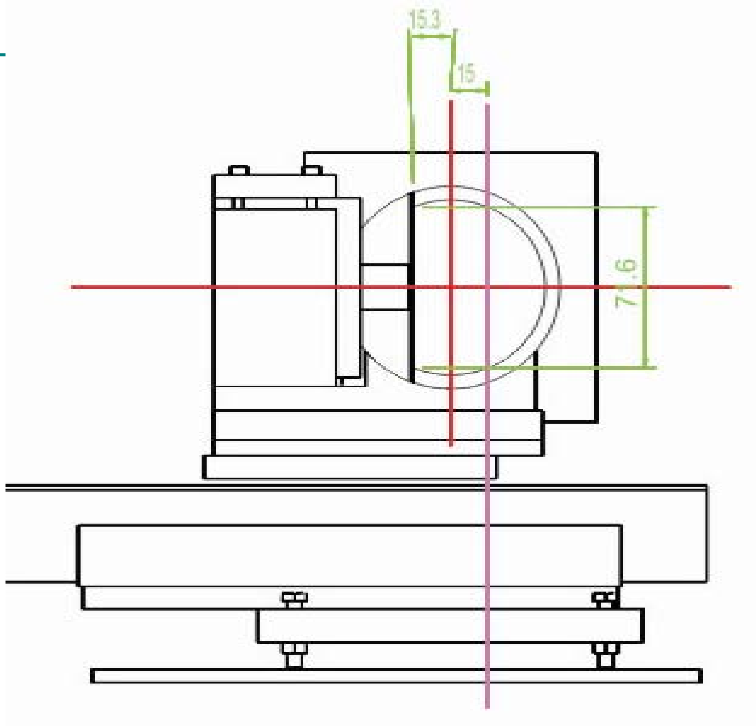
Mechanics options

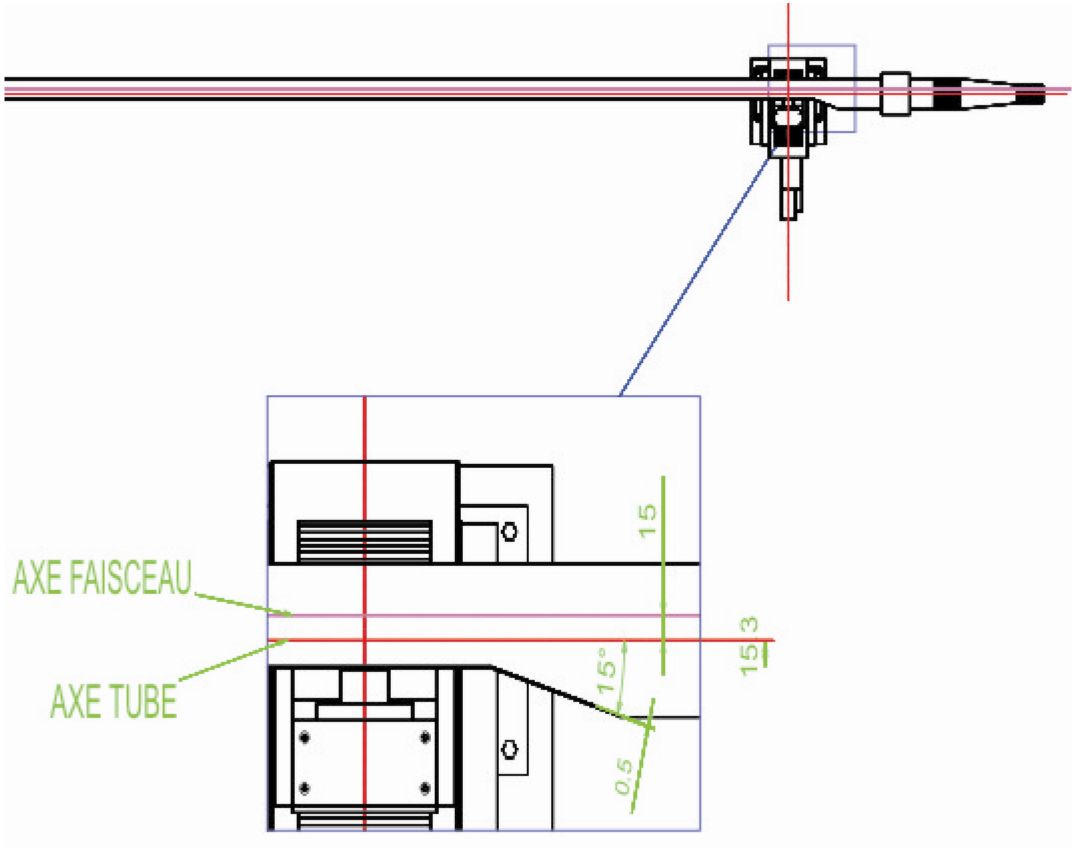
Mechanics options

- "long indent":
  7 m long indent, stainless steel window – thickness 0.5 mm

Mechanics options

Version I: 7m long indent





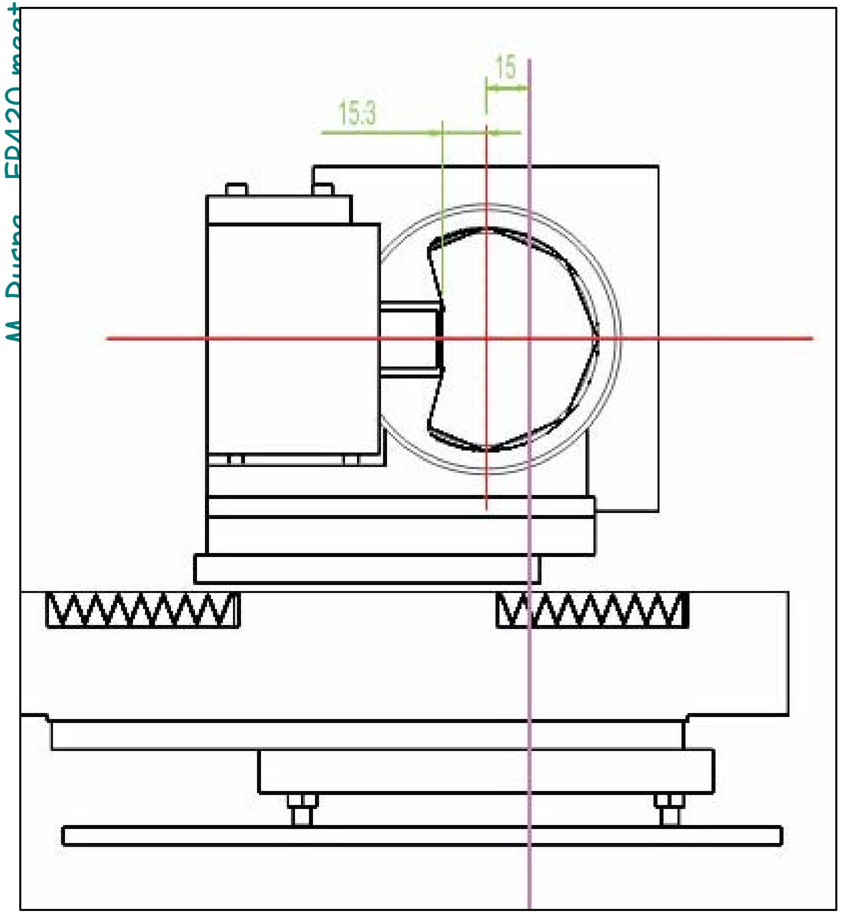
From Krzysztof

Mechanics options

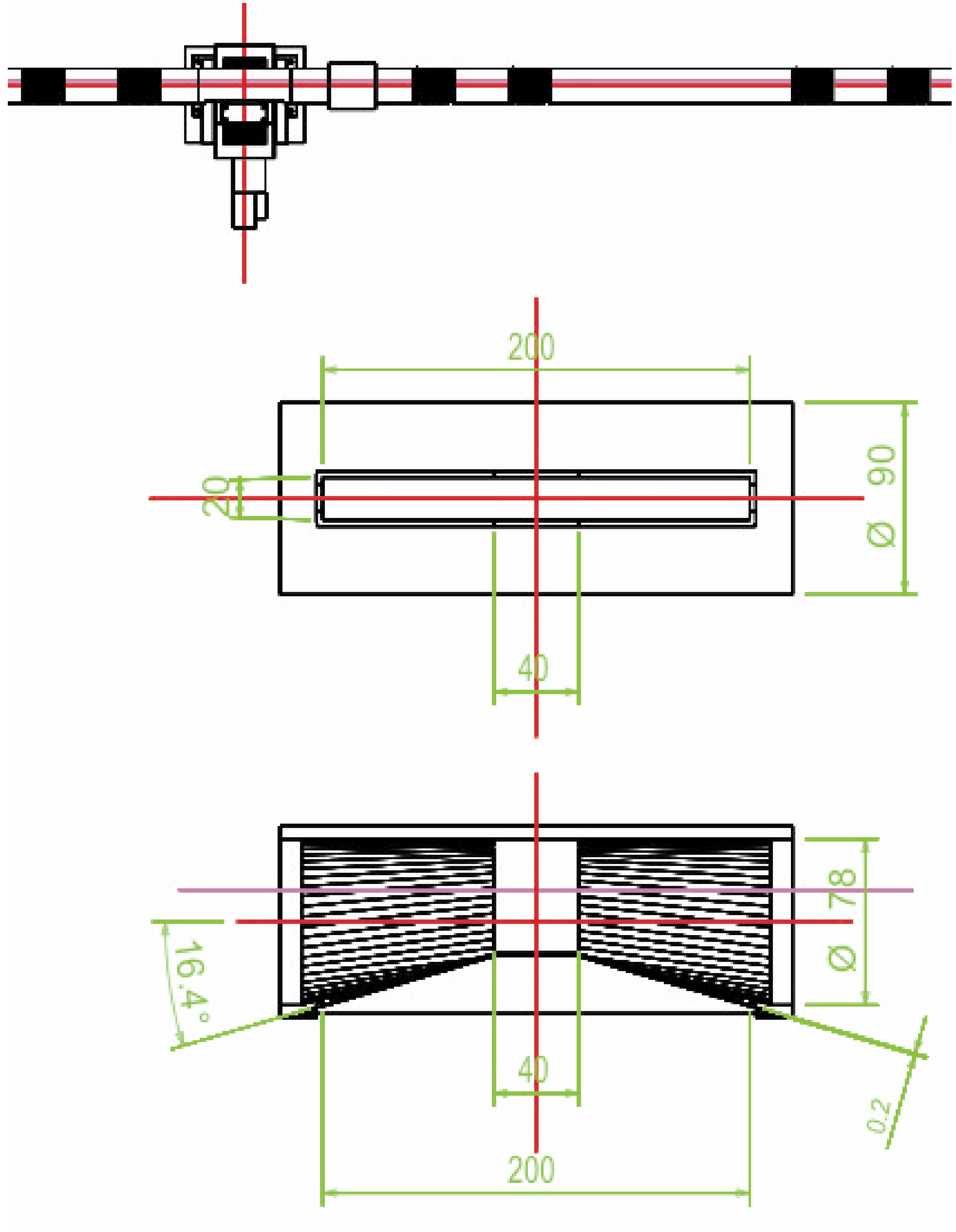
- "long indent":
  7 m long indent stainless steel window – thickness 0.5 mm
- "short pocket":
  4 x 40 mm long pockets, trapezoidal shape, stainless steel windows – thickness: 0.2 mm

Mechanics options

Version II: 4 short pockets



From Krzysztof

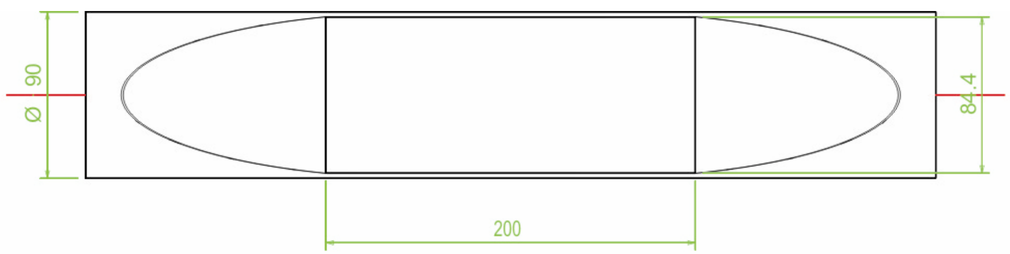


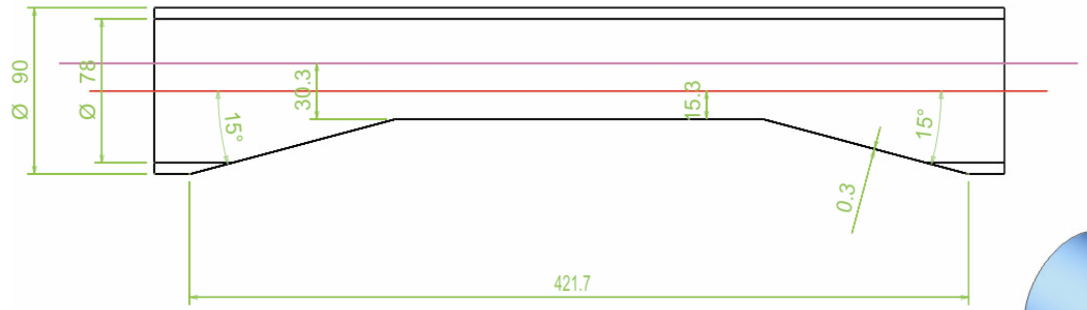
Mechanics options

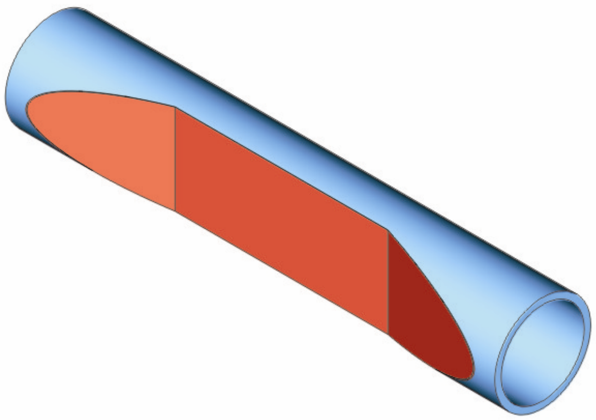
- "long indent":
  7 m long indent stainless steel window – thickness 0.5 mm
- "short pockets":
  4 x 40 mm long pockets, trapezoidal shape stainless steel windows – tickness: 0.2 mm
- "short rectangular pocket":
  4 x 40 mm long pockets, rectangular shape, stainless steel windows – tickness: 0.2 mm

Mechanics options

Version III: 4 long pockets







From Krzysztof

Mechanics options

- “long indent”:
  7 m long indent stainless steel window – thickness 0.5 mm

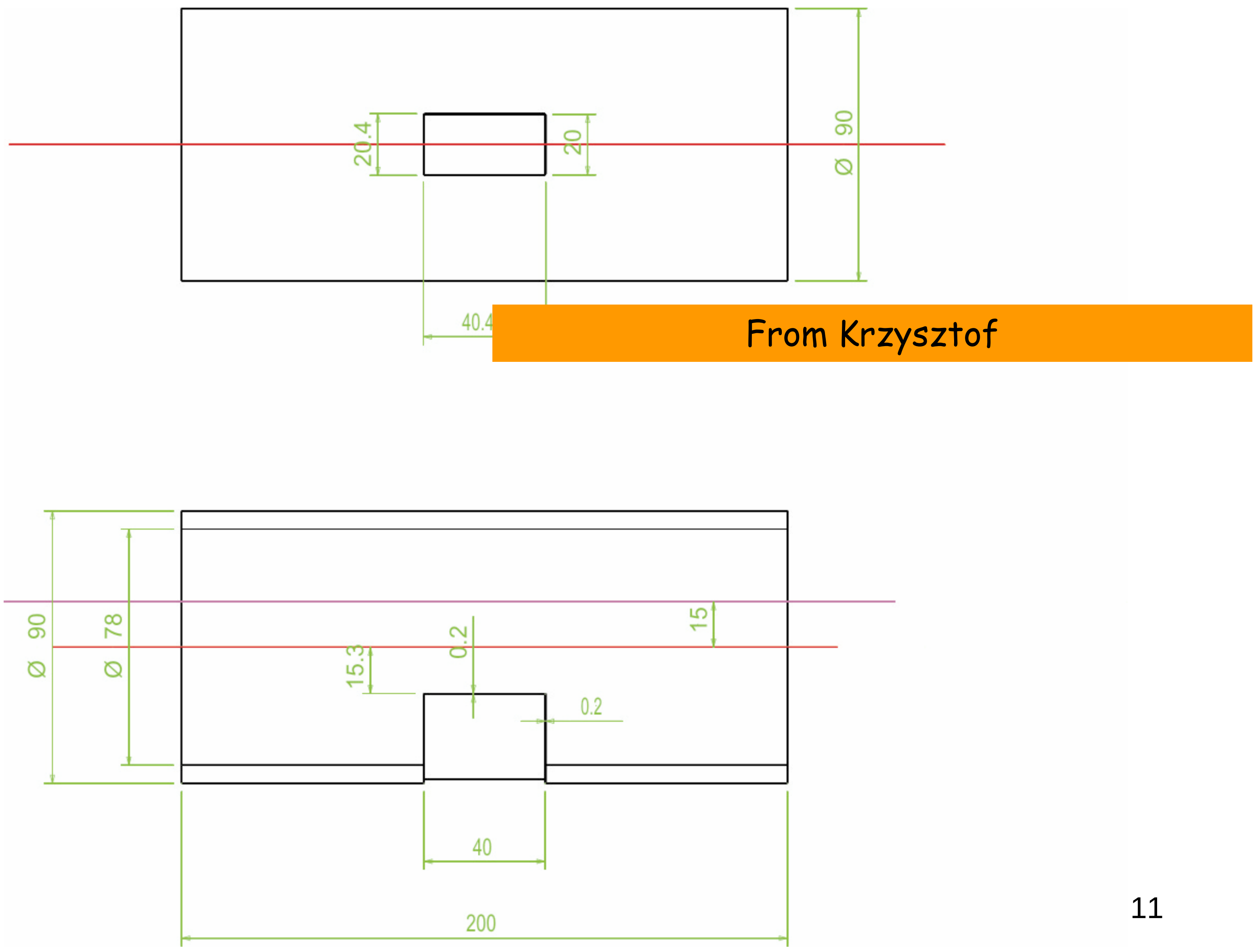
- “short pocket”:
  4 x 40 mm long pockets, trapezoidal shape stainless steel windows – tickness: 0.2 mm

- “short rectangular pocket”:
  4 x 40 mm long pockets, rectangular shape stainless steel windows – tickness: 0.2 mm

- “long pocket”:
  4 x 200 mm long pockets, trapezoidal shape, stainless steel windows – tickness: 0.3 mm

Mechanics options

Version IV: 4 short rectangular pockets

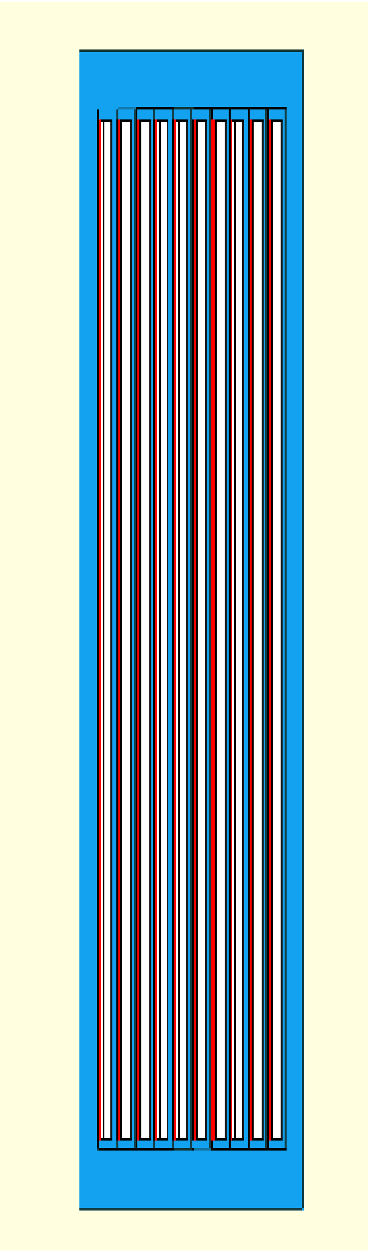


Baseline detector geometry

Sequence of single planes with 1mm air in between.

Single plane unit:

- station dimensions: 84 x 100 x 25 mm^3
- 1st layer Si thickness: 0.200 mm
- bumpbonding thickness: 0.020 mm
- 2nd layer Si thickness: 0.300 mm
- ceramics thickness: 1.00 mm
- 2nd layer Si plane dimensions: 80 x 98 x 2 mm^3



Results: multiple interaction rate

MI portion, $\%(IP)_{MI}$

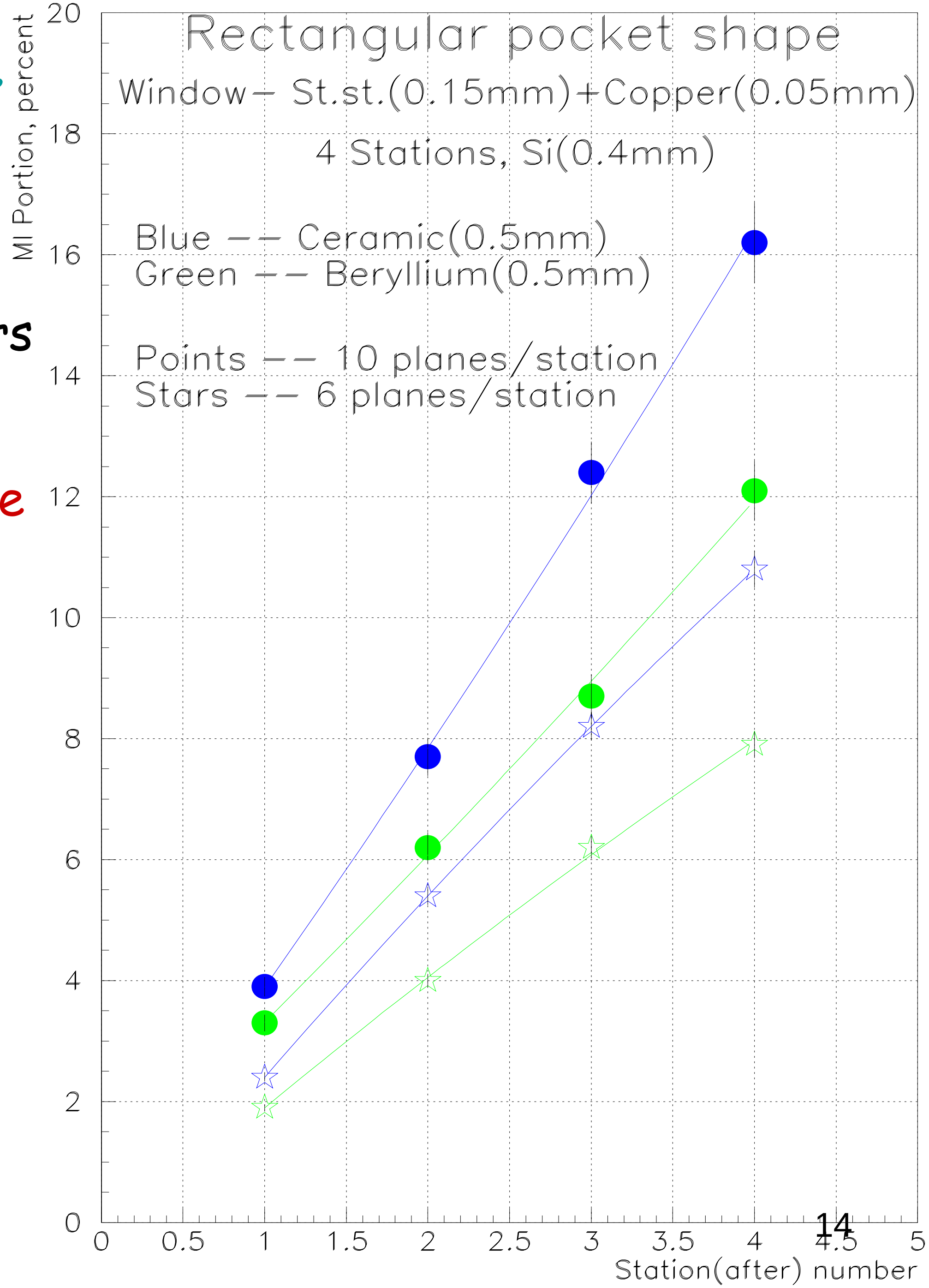
set up	7m long indent	4 short pockets	4 long pockets	4 short rectangular pockets
variant	1	2	3	4
6 Planes	20.7±0.4	24.1±0.5	27.3±0.5	20.4±0.4
10 Planes	28.6±0.5	31.7±0.6	35.0±0.6	28.1±0.5

- Contribution to MI total rate of 250 µm stainless steel window ~ 0.24%
  (we can have as many as we want!)
- Contribution to MI total rate of 1 mm ceramics ~ 0.5%
  (for 10 planes and 4 stations → 20%)
- Contribution to MI total rate of 1 silicon plane ~ 0.2%

From ceramics to Be

- Single plane unit: 2 silicon layers with thickness 0.2 mm each

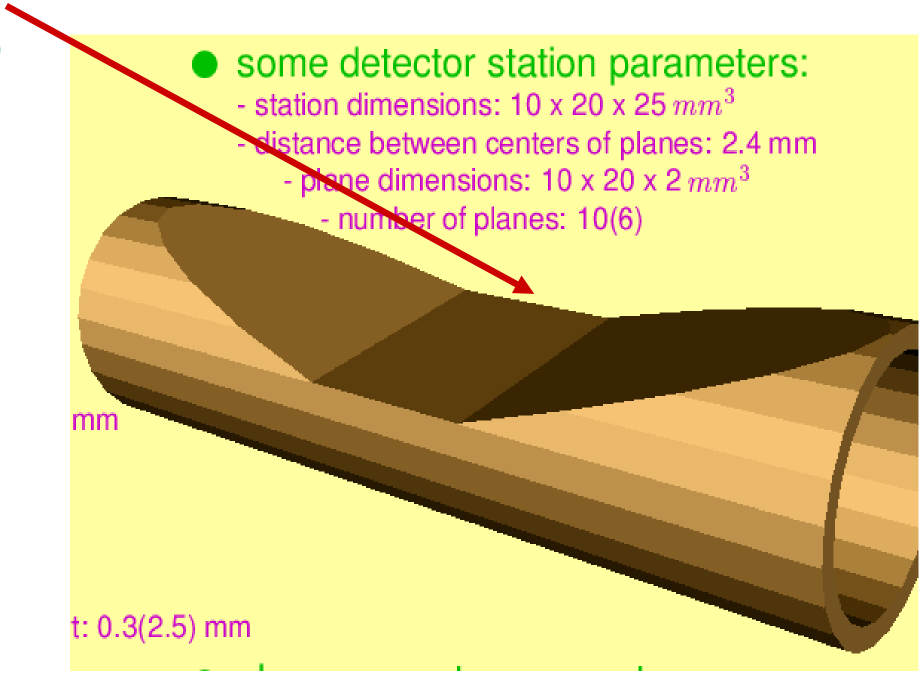
→ at most MI rate 16% after the 4th station



Results: multiple scattering

→ Relative uncertainty on track momentum due to multiple scattering negligible

Effect of multiple interactions of halo protons with the pocket bottom



Effect of multiple interactions of halo protons with the pocket bottom

- Halo protons may interact with the pocket bottom and generate secondaries which may end up in the detector
- These extra tracks may be easy to spot because they obviously have a wrong vertex
- In the following quantify:
  - probability that a secondary from a halo proton in the pocket bottom is generated
  - rate of potentially lost events

- N.B.: rate of halo protons so far unknown (will be soon available from N. Mokhof)

Effect of multiple interactions of halo protons with the pocket bottom

Protons generated in front of flat pocket part.

→ e.g. for 3 stations: MI rate ~ 40%

- One can argue like this: one secondary crosses the planes of one station under large θ: for events with only one secondary there is hope to distinguish tracks from IP from background tracks. Let us call a "good case" an event with ≤ 1 secondary track.

- Furthermore one can assume that a track can be reconstructed using 2 and not all stations.

What is the rate of halo protons with > 1 secondary track in at least two stations, i.e. of halo protons that would potentially lead to event losses?

→e.g. for 3 stations: $\%(\text{halo})_{loss} = 25\%$

N.B.: 40% of halo protons have MI, but only 25% lead to event loss under the above assumptions.

Effect of multiple interactions of halo protons with the pocket bottom

Let us assume that the number of halo protons is a fraction 0<k<1 of the number of protons from IP

We compute the fraction of events potentially lost:

$\%(IP)_{MI}$ = n_protons$(IP)_{MI}$/n_protons$(IP)_{tot}$
n_protons(halo)= k n_protons(IP), with 0< k < 1 portion of events with halo proton contamination

$\%_{losses}$= (n_protons$(IP)_{MI}$ + n_protons$(halo)_{loss}$)/ n_protons$(IP)_{tot}$ =
= $\%(IP)_{MI}$ + $\%(halo)_{loss}$ · n_protons$(halo)_{tot}$ / n_protons$(IP)_{tot}$ =
= $\%(IP)_{MI}$ + k $\%(halo)_{loss}$

Results: multiple interactions of halo protons with the pocket bottom

Total losses, $\%_{losses}$

set up	7m long indent	4 short pockets	4 long pockets	4 short rectangular pockets
6 Planes	21÷71	24÷56	27÷77	20÷53
10 Planes	29÷79	32÷64	35÷85	28÷61

variants 1 & 3 do not work due to high contamination of halo protons
variants 2 & 4 can be used but need to reduce st.st. z-size (16→12cm)

Summary

- From the point of view of multiple interactions the only critical thickness in the detector package is that of ceramics
- The effect of multiple scattering on the momentum resolution is negligible
- The option which exhibits the least multiple interaction effect and which is least sensitive to halo protons is that of "4 short rectangular pockets"

Outlook

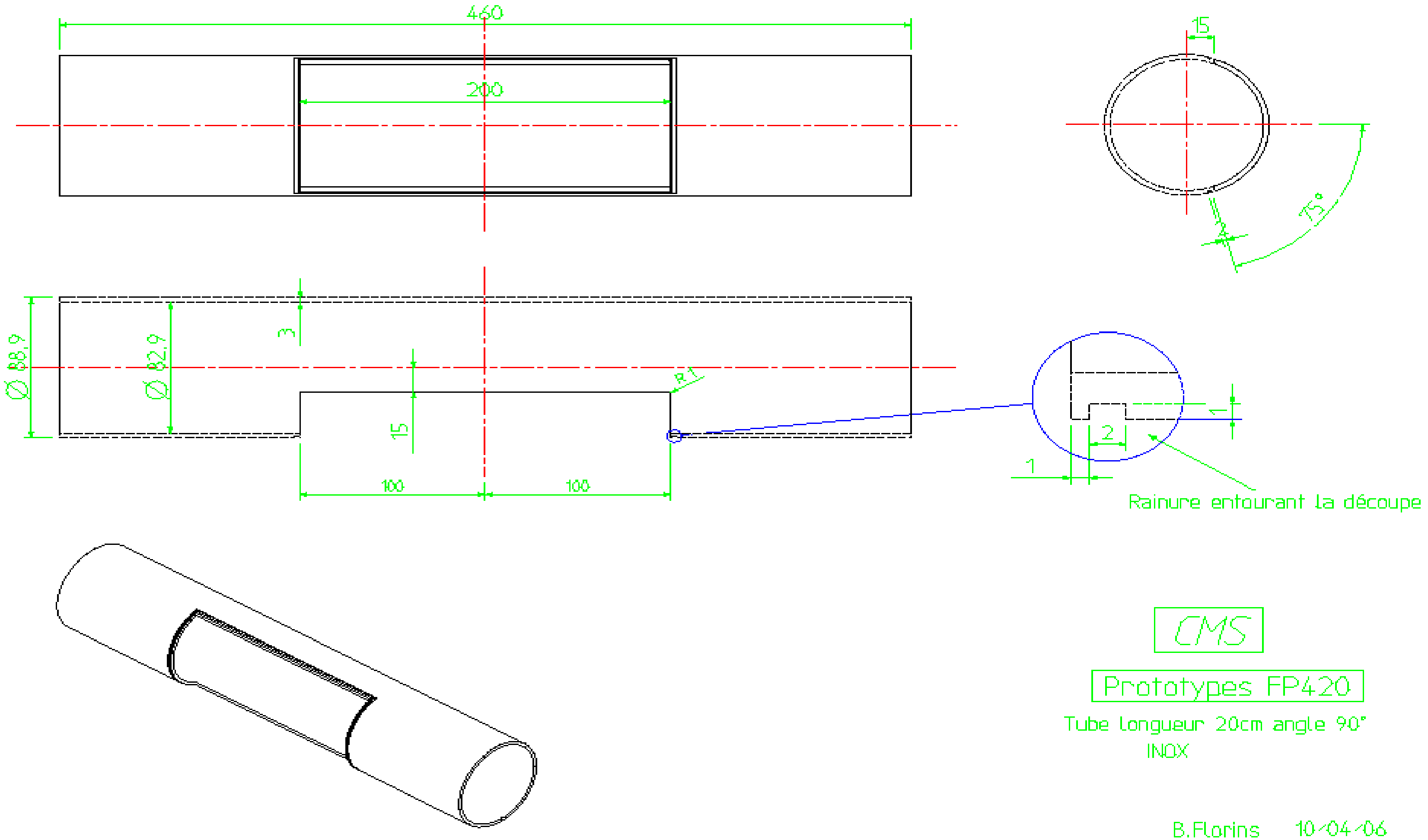
Estimated time to implement reconstruction algorithms: 2 months, starting from middle of September

Background from N. Mokhof for FP420 location: will re-run from middle of June

From Mimmo et al. (20/04)

3 new proposal, apparently very similar but different in details

- Window inclination: 90^o
- Stainless steel window: 0.3 mm



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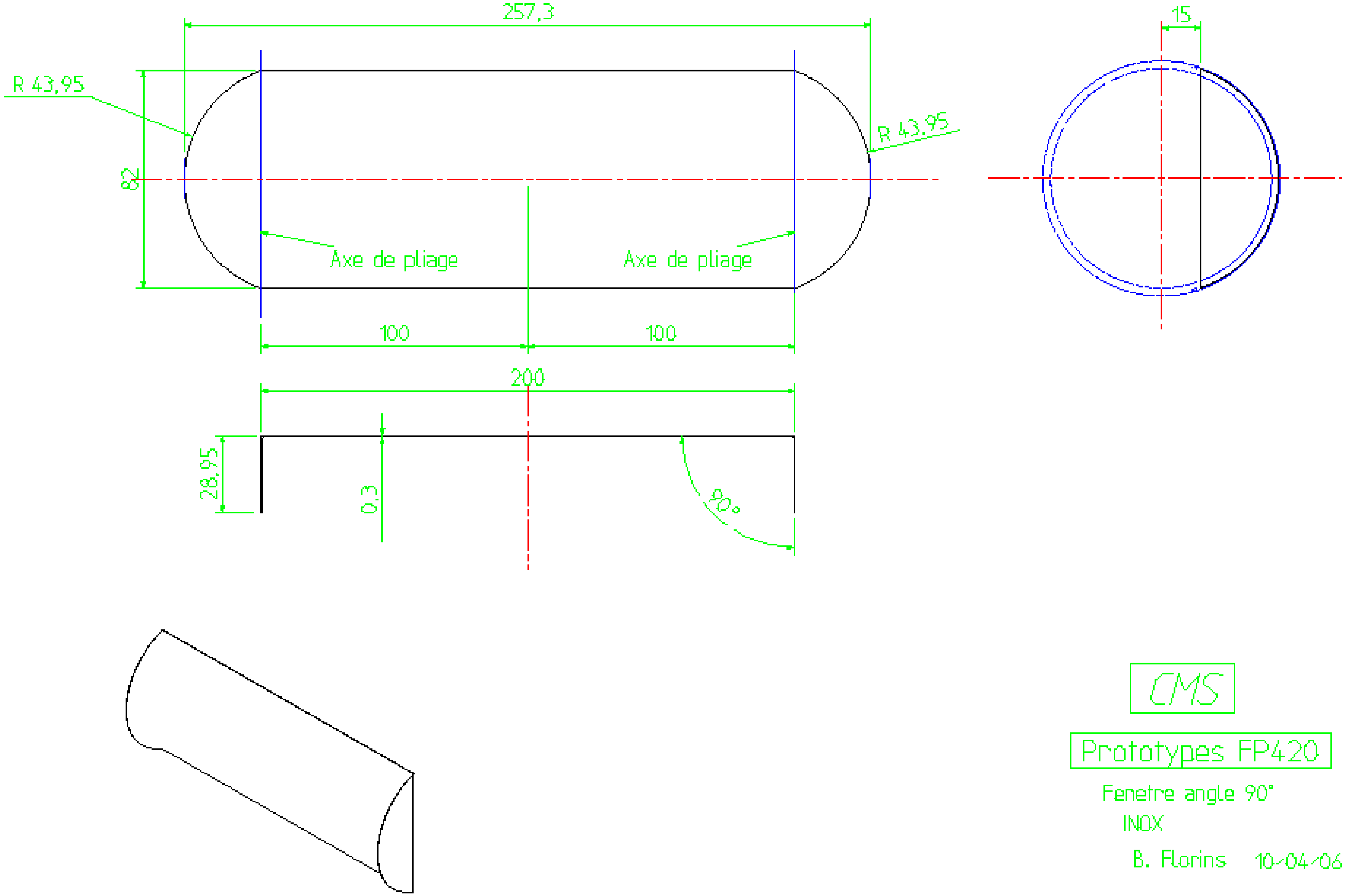
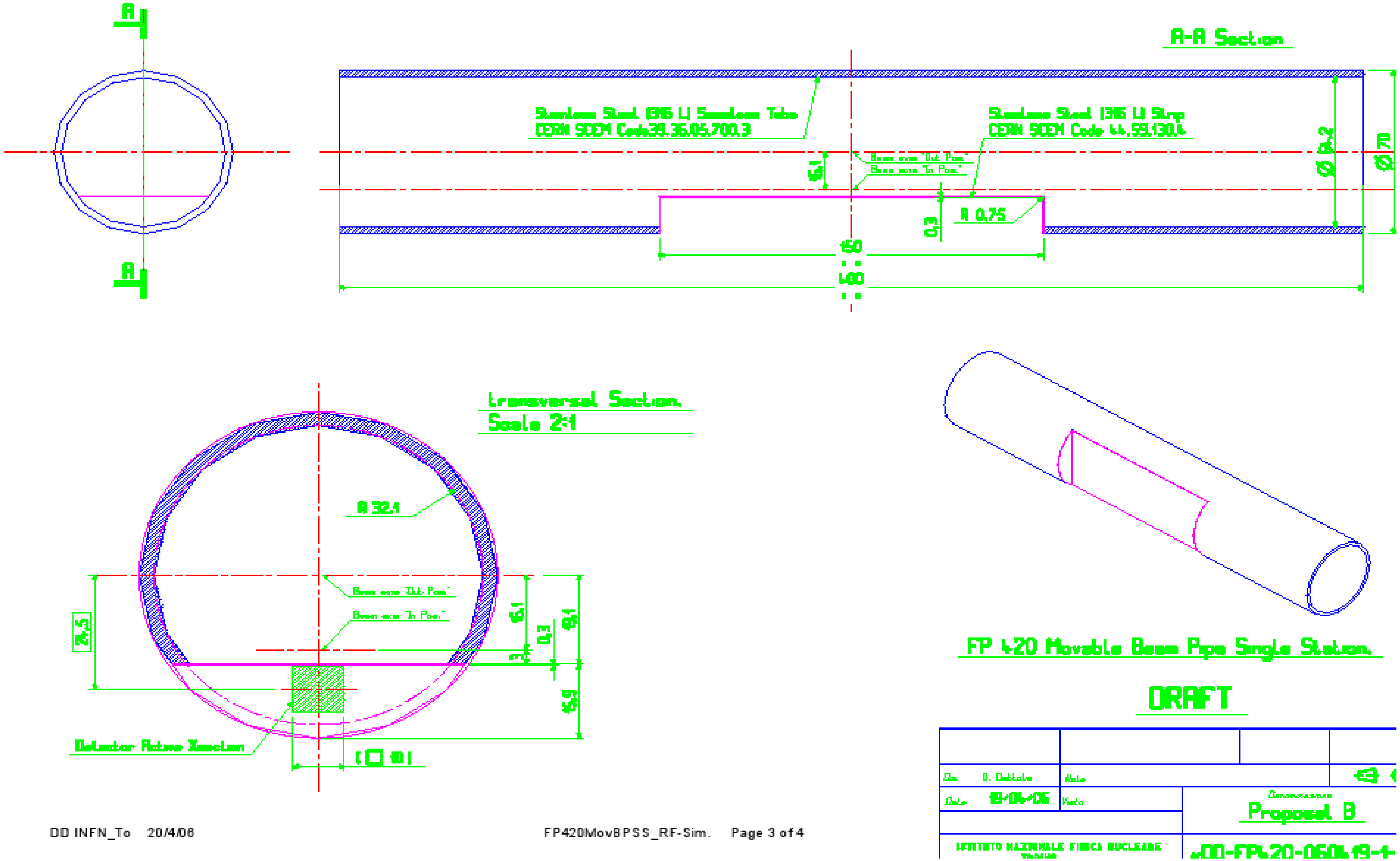
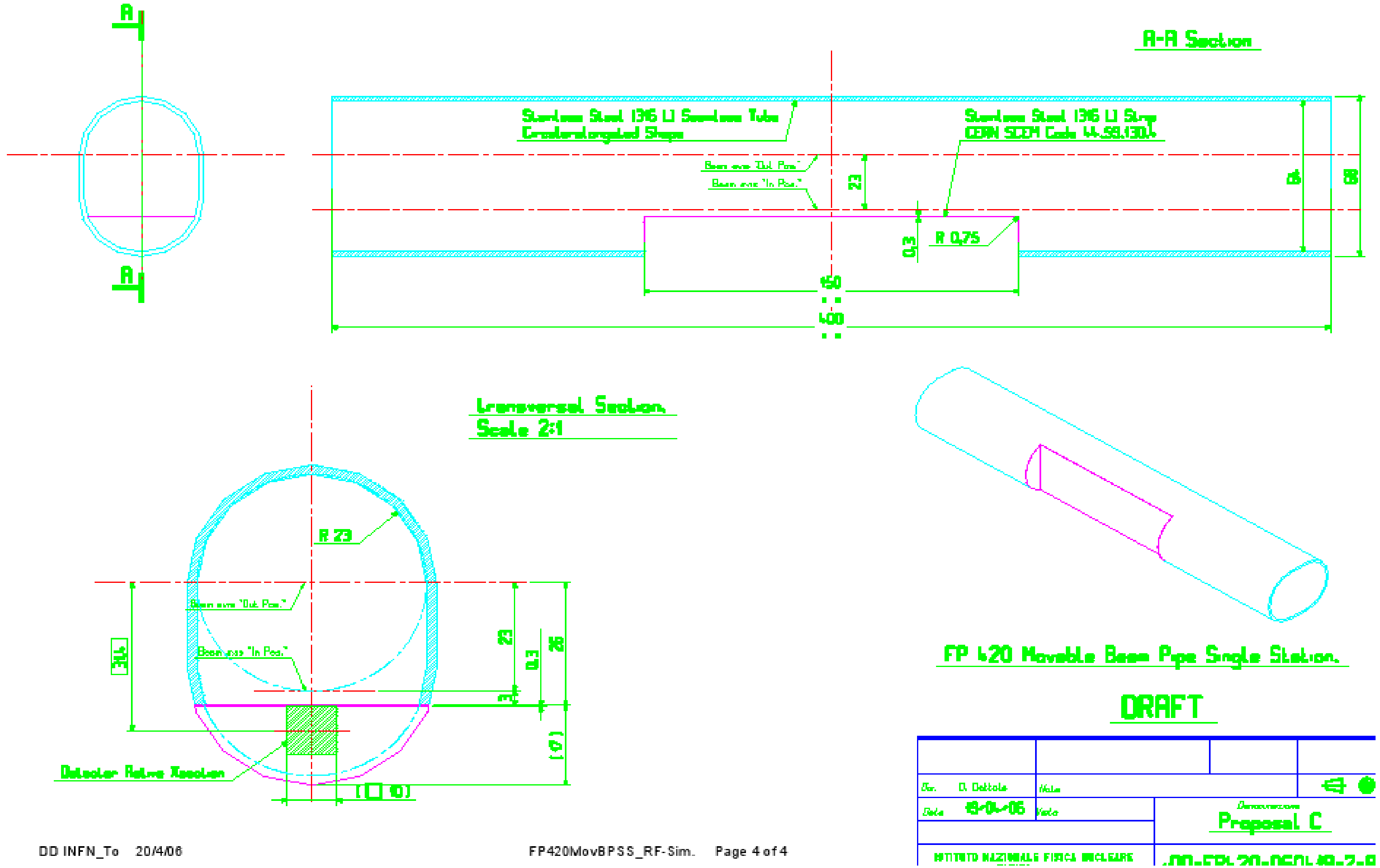
FP420MovBPSS_RF-Sim. Page 1 of 4



257,3
15
R 43,95
R 43,95
82
Axe de pliage
Axe de pliage
100
100
200
28,95
0,3
90°
CMS
Prototypes FP420
Fenetre angle 90°
INOX
B. Florins 10-04-06


A-A Section
Transversal Section
Scale 2:1
R 32.1
FP 420 Movable Beam Pipe Single Station
DRAFT
Proposal B


A-A Section
Transversal Section
Scale 2:1
Detector Active Xsection
R 23
R 0,75
FP 420 Movable Beam Pipe Single Station
DRAFT
Proposal C

From Mimmo et al. (20/04)

3 new proposal, apparently very similar but different in details

- Window inclination: 90°
- Stainless steel window: 0.3 mm

Comment from Sasha:

"…I do not see essential peculiarity with respect to our previous pocket configurations which can have specific influence on multiple interactions (MI) and scattering (MSC). For these 3 proposal there are changes on tube radius/thickness and its shape (ellipse/circle)…"

Beam line simulation

MAD input to G4

BDSIM (Beam Delivery System sIMulation - developer: Grahame Blair): from Rob Appleby

particles inside beampipe → direct implementation of equations of motion

particles enter matter → G4

developed for ILC beam delivery system, but easy to track and study protons (according to Rob)

protons/background in input, any desired starting distribution of particles

easily adaptable to an hadron machine: LHC lattice should be converted into BDSIM format, close to MAD

Background simulation

MARS15 (developer: Nikolai Mokhof):
from Michele

all elements included

generator: DPMJET

→ energy and momentum distribution of all particles at any desired
depth

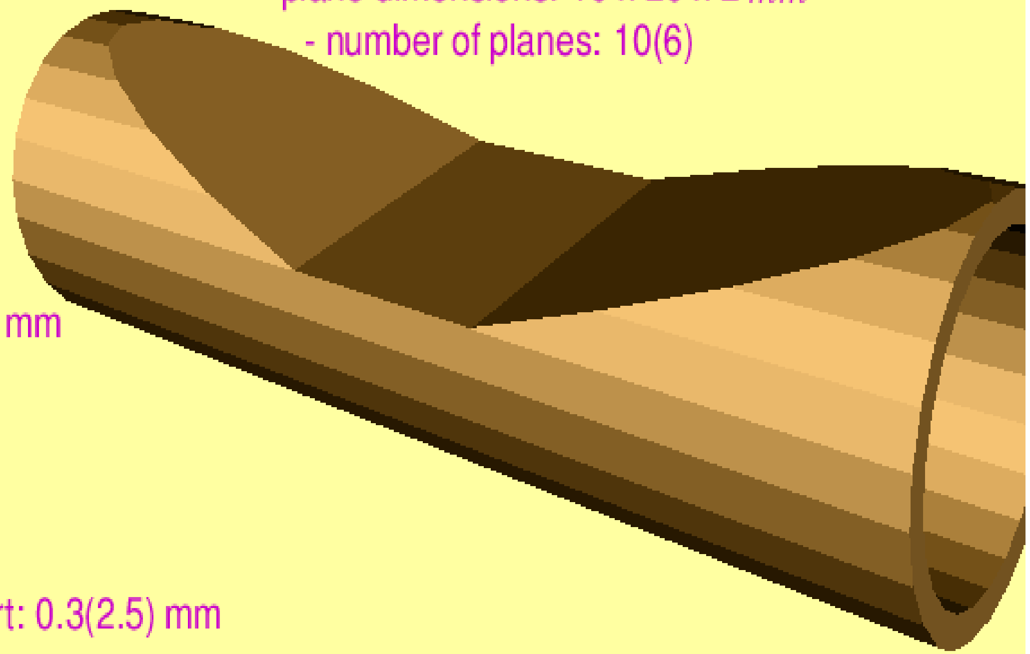
Pocket geometry

- general parameters:
  - beam pipe (bp) radius: 40 mm
  - bp unit length (bpul): 2.8(4.0) m
  - z-size of flat pocket part(zfpp): 30 mm
  - window slope: 15^0
- copper coating:
  - bp wall thickness: 0.1 mm
  - y-thickness of flat pocket part: 0.1(0.5) mm
  - window thickness (cowt) : 0.1 mm
- stainless steel material:
  - bp wall thickness: 5 mm
  - y-thickness of flat horizontal pocket part: 0.3(2.5) mm
  - window thickness(sswt) : 0.25 mm

Geometry XML files verified through visualization

have a look on **MI** & **MSC** for updated set up

- some detector station parameters:
  - station dimensions: 10 x 20 x 25 mm^3
  - distance between centers of planes: 2.4 mm
    - plane dimensions: 10 x 20 x 2 mm^3
      - number of planes: 10(6)

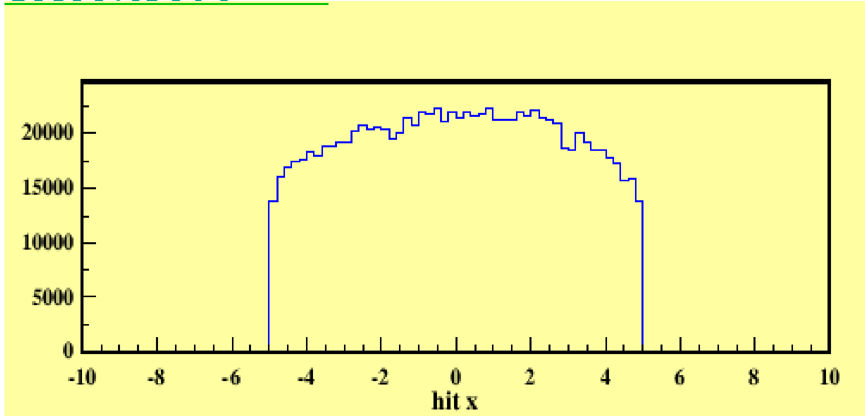


- plane geometry parameters:
  - 1-st layer Si thickness: 0.200 mm
  - glue thickness: 0.020 mm
  - 2-nd layer Si thickness: 0.300 mm
  - ceramic thickness : 1.00 mm

Multiple interactions from halo protons going through horizontal part of pocket

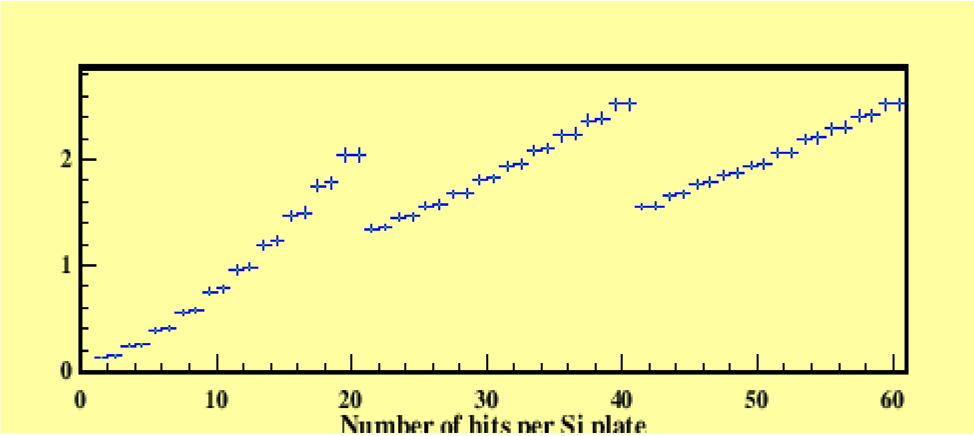
Protons generated in front of flat pocket part.

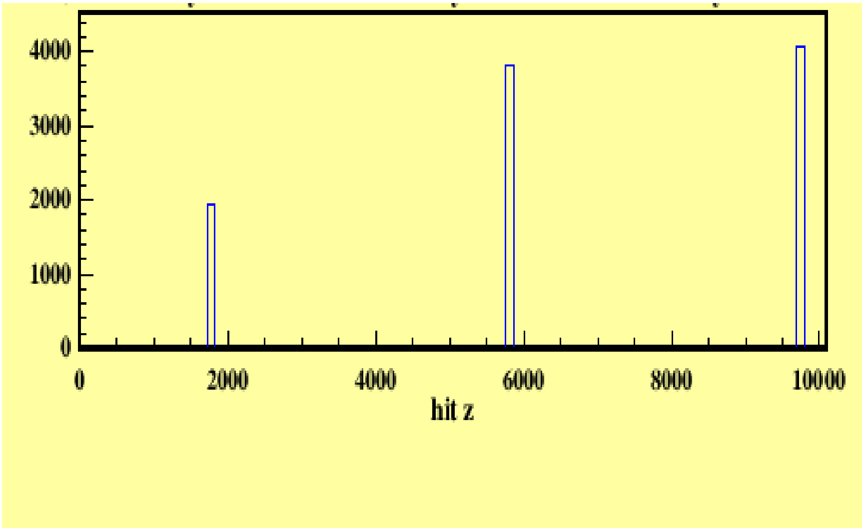
→ MI rate ~ 40%



Detector acceptance in X between -5 and +5 mm

How many secondaries go in the detector?





→ MI hit rate per plane ~ 35% for 2nd station and ~55% for 3rd station

$rate(IP)_{MI}$ = $n\_protons(IP)_{MI}$/$n\_protons(IP)_{tot}$

$rate(halo)_{loss}$ = $n\_protons(halo)_{loss}$/$n\_protons(halo)_{tot}$

n_protons(halo)= k n_protons(IP)

with 0< k < 1 portion of events with halo proton contamination

k=0: no contamination

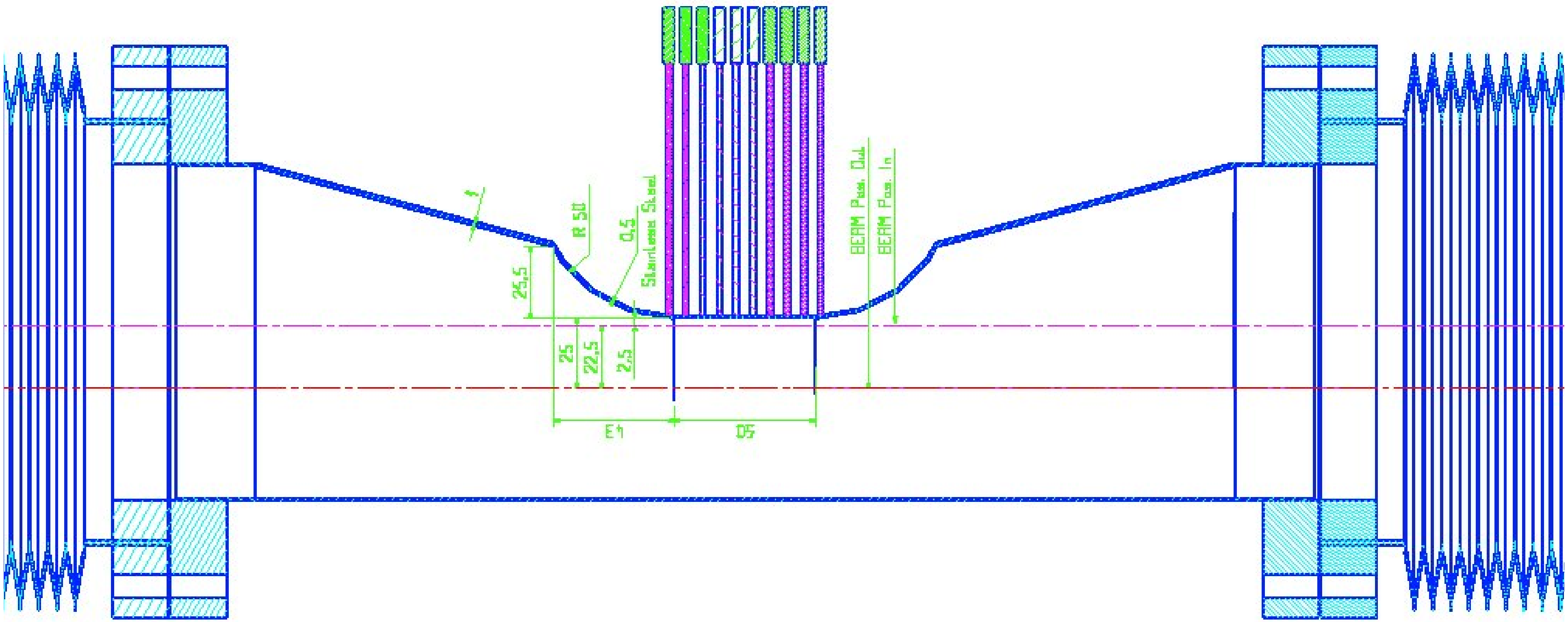
k=1 every proton from IP is accompanied by a second bgd proton

$rate_{losses}$= ($n\_protons(IP)_{MI}$ + $n\_protons(halo)_{loss}$)/ $n\_protons(IP)_{tot}$ =

= $rate(IP)_{MI}$ + $rate(halo)_{loss}$ · $n\_protons(halo)_{tot}$ / $n\_protons(IP)_{tot}$ =

= $rate(IP)_{MI}$ + k $rate(halo)_{loss}$

Mechanics options input to G4



From Mimmo

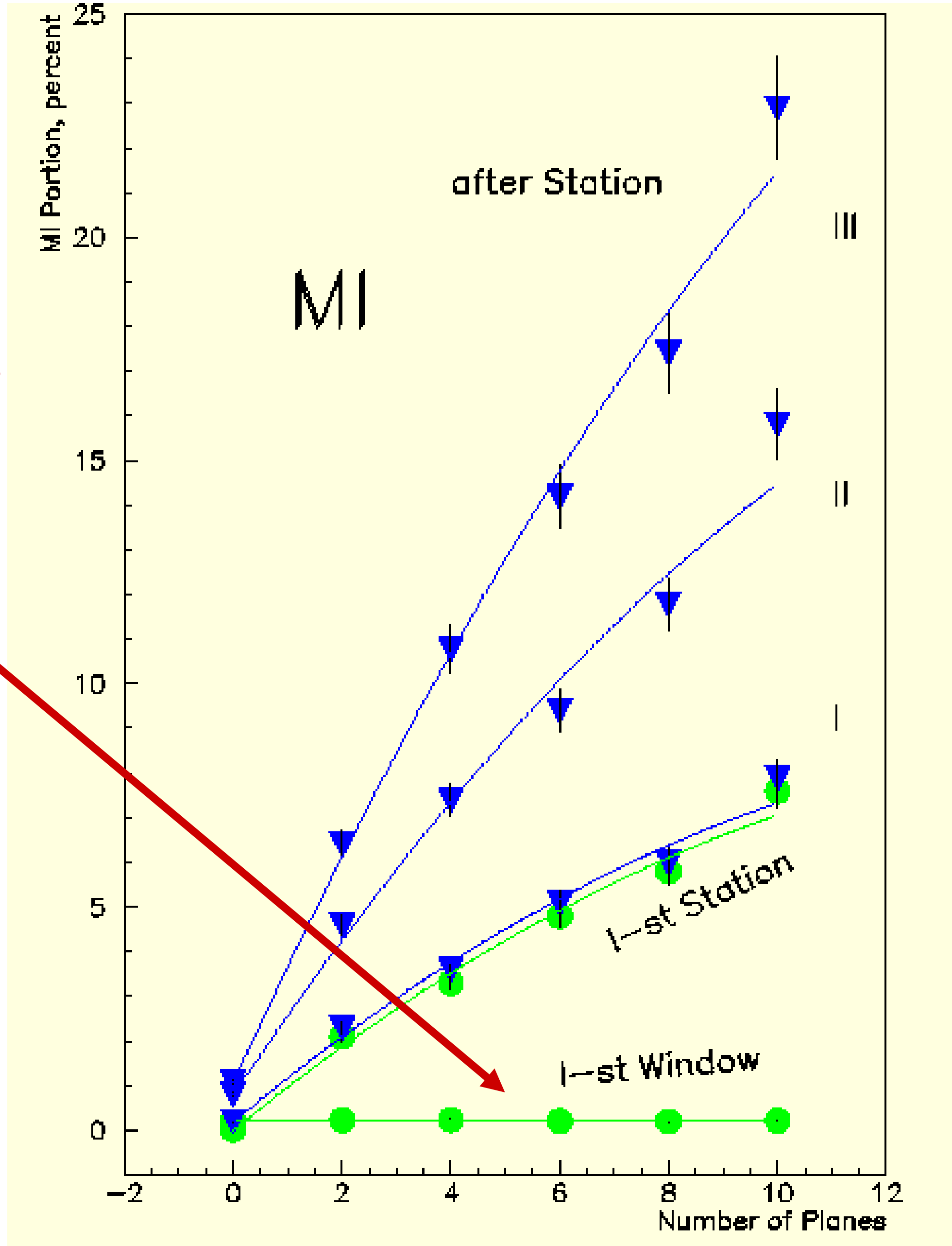
Multiple interactions vs # planes

- 3 stations, 2.8 m interdistance

→ MI rate with 10 planes ~ 20%

→ MI rate with 6 planes ~ 15%

→ Contribution of 250 μm stainless steel window negligible

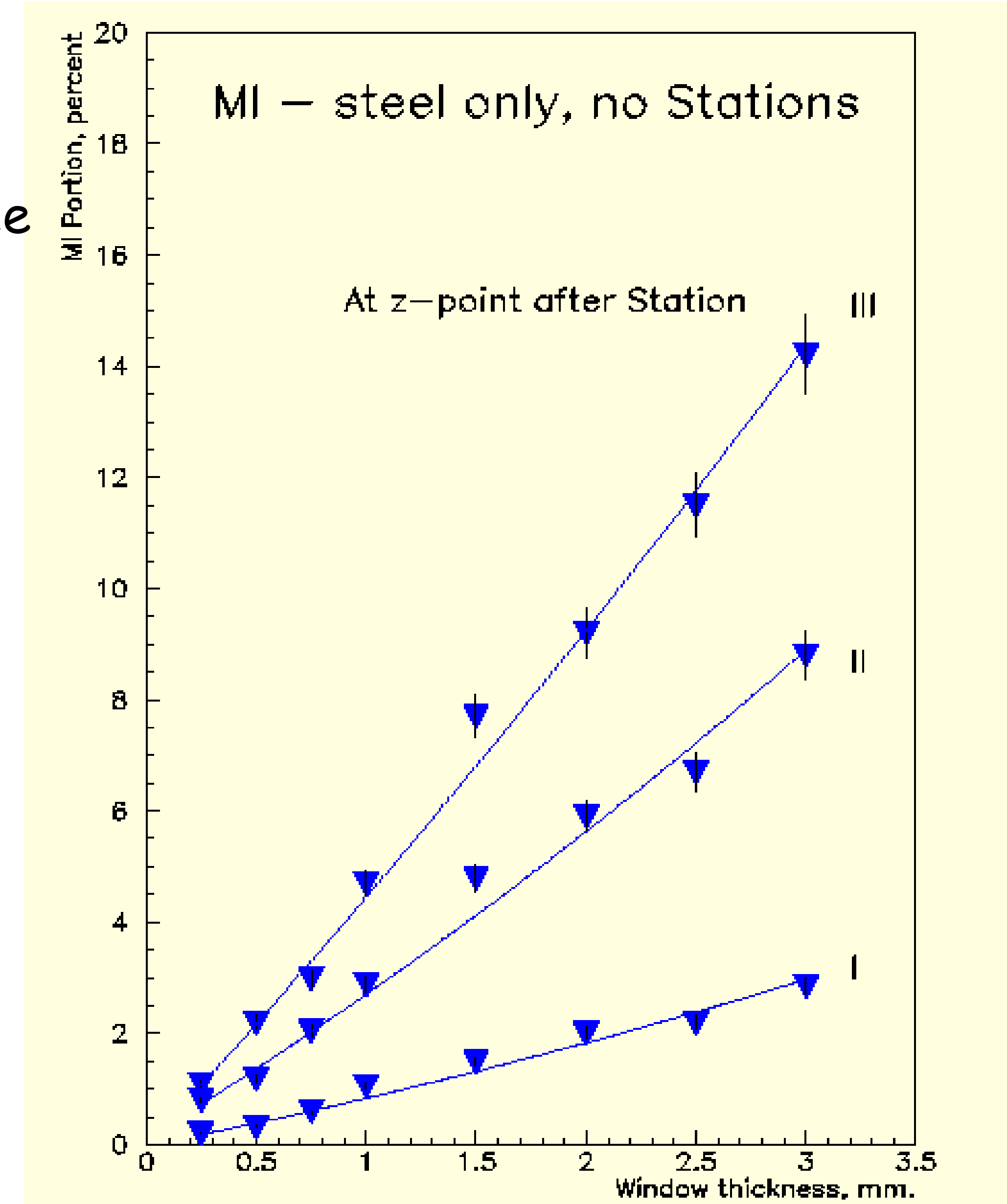


Multiple interactions vs window thickness

- 3 stations, 2.8 m interdistance

→ Contribution of 250 μm stainless steel window ~ 1.2%

→ Contribution of 1 mm stainless steel window ~ 4%

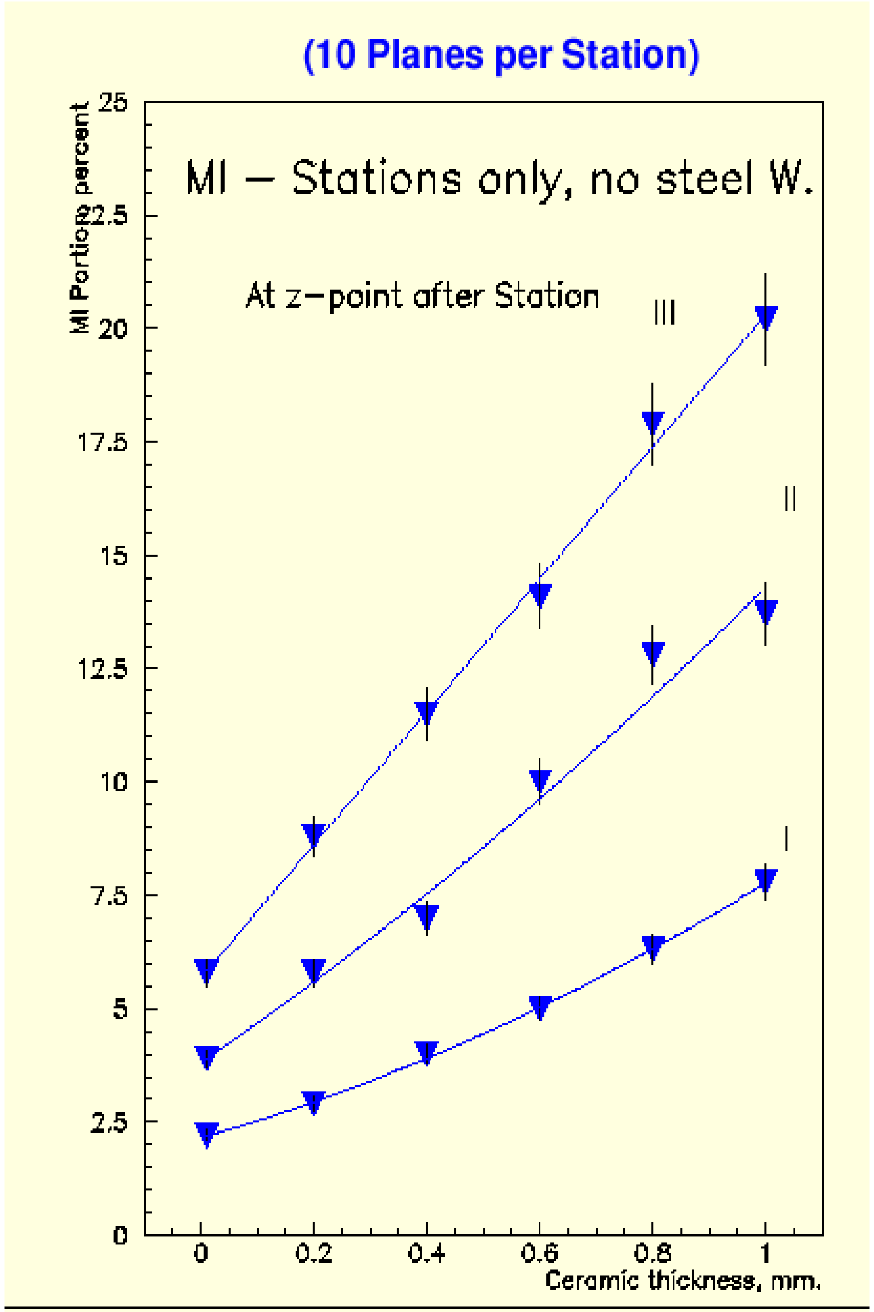


Multiple interactions vs ceramic thickness

10μm ceramic thickness → Si only:

→ contribution of Si < 6%

→ Contribution of 1 mm ceramic ~ 15%



Multiple interactions vs ceramic thickness & number of planes

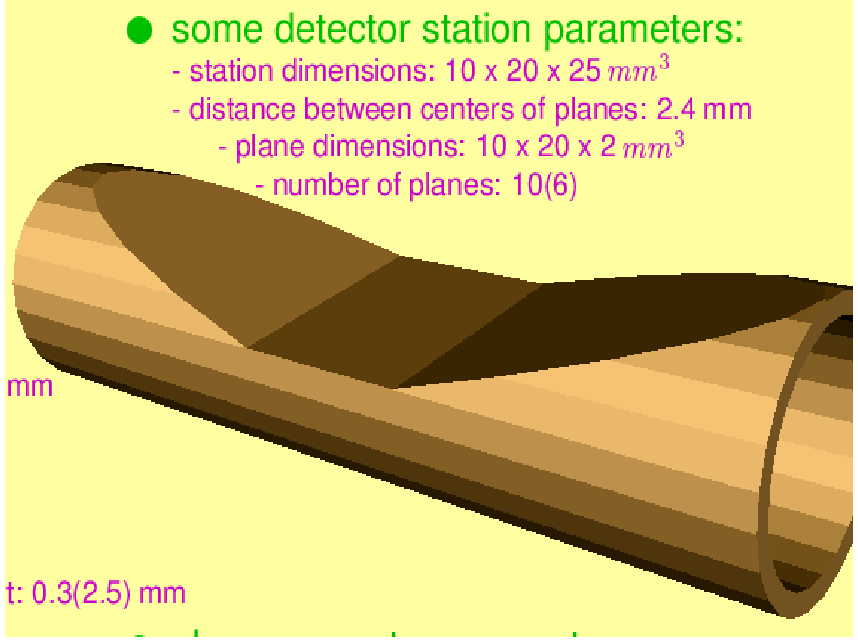
- 3 stations, 2.8 m interdistance
- Stainless steel window: 250 μm

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

ct = ceramic thickness

Trapezoidal pocket

- Beam pipe radius: 40mm
- Beam pipe thickness: 5 mm
- Cu deposit thickness: 0.1 mm
- 3 stations, 2.8 m interdistance
- Horizontal pocket part:
  y = 0.4 mm (st.st. + Cu), z=30 mm
- Window inclination: 15°



MI rate

Multiple scattering: σ^{XY} [μm], deviation of track from primary direction at z of Si planes for 2nd and 3rd

Set up	6 planes	10 planes	6 planes		10 planes	
			2nd	3rd	2nd	3rd
Stainless steel only	16.9 +- 0.4	23.9 +- 0.6	2.6	5.8	3.0	6.8
+ copper deposit	17.2 +- 0.4	24.4 +- 0.6	2.8	6.4	3.1	7.2

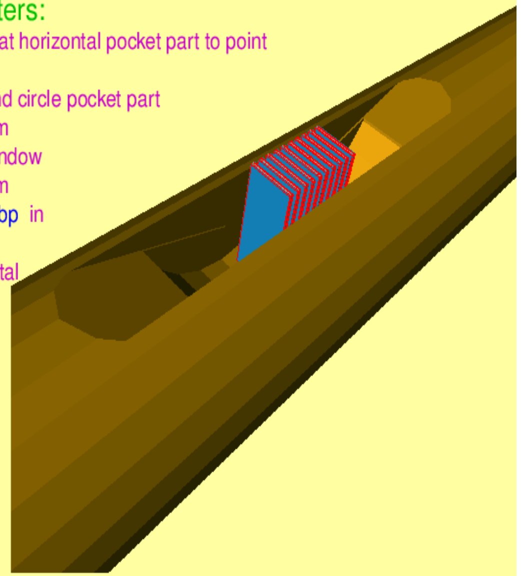
Relative uncertainty on track momentum : $(\Delta p/p) \sim tg\,\theta \sim 10^{-6}$

Circular pocket

- Beam pipe radius: 33.35 mm
- Beam pipe thickness: 5 mm
- Cu deposit thickness: 0.1 mm
- Window inclination: 15°

→ MI rate ~ 30%

- update and new parameters:
  - distance(in Y) from bottom of flat horizontal pocket part to point of window slope begin: 25.5 mm
  - bp thickness in range of flat and circle pocket part (Copper-St.Steel): 0.1mm/0.4mm
  - bp thickness of 15^0 inclined window (Copper-St.Steel): 0.1mm/0.9mm
  - (Copper-St.Steel) thickness of bp in pocket region: 0.1mm/1.75mm
  - gap between top of flat horizontal part of pocket and detector bottom: 0.2 mm
  - (Copper-St.Steel) x-thickness of pocket walls: 0.1mm/0.4mm
  - x-dimension of pocket: 30 mm
  - y-distance to center: 2.5 mm
  - zfpp: 50 mm
  - bp radius: 33.35 mm
  - bpul: 2.5
  - 4 stations
  - radius of window: 50 mm

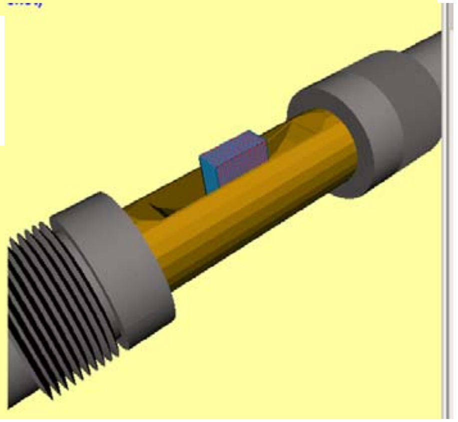


MSC: $\sigma^{X(Y)}_{deviation}, \mu m$

I	II	III	IV
0.02	2.4	5.5	9.3

$$(\Delta P/P)_{msc} \sim tg\theta_{msc} \sim 10^{-6}$$

$$\sigma_X^{IP-vtx} = \sigma_Y^{IP-vtx} = 310\mu m \sim 0.3mm$$



- Stainless steel: 1% in 1mm
- Ceramic: 15% in 3 cm → 0.5% in 1 mm
- Silicon: 6% in 30 planes, 500 μm for each each, 15 mm in total
  → 0.4% in 1 mm