CNGS Proton beam line: news since NBI2002

OUTLINE

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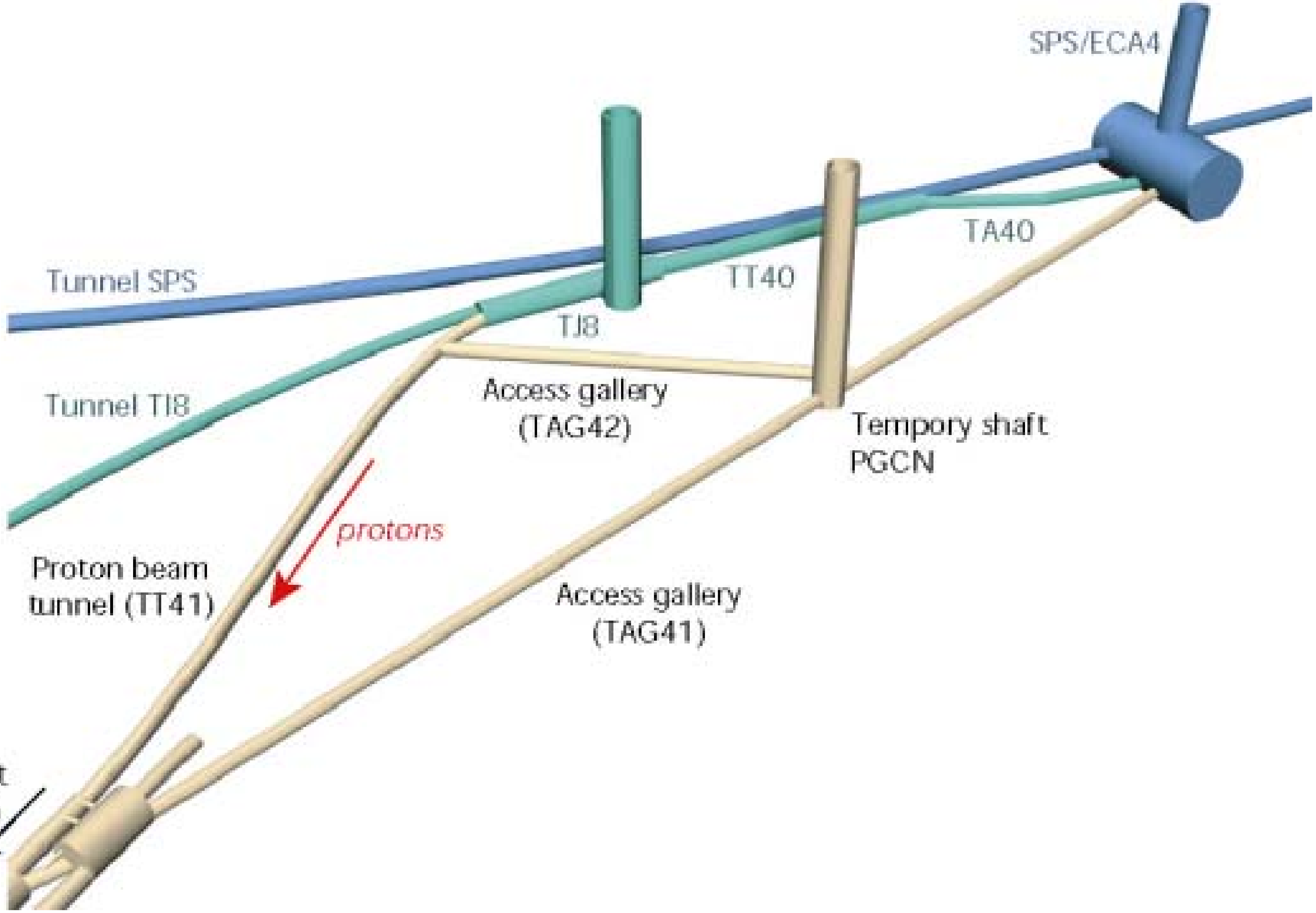
2. Beam optics
3. Trajectory correction scheme
4. Beam stability
5. Aperture checks
6. Need of a collimator
7. Summary

Overview


SPS/ECA4
TA40
Tunnel SPS
TT40
TJ8
Tunnel TI8
Access gallery
(TAG42)
Tempory shaft
PGCN
protons
Proton beam
tunnel (TT41)
Access gallery
(TAG41)
Target
(T40)

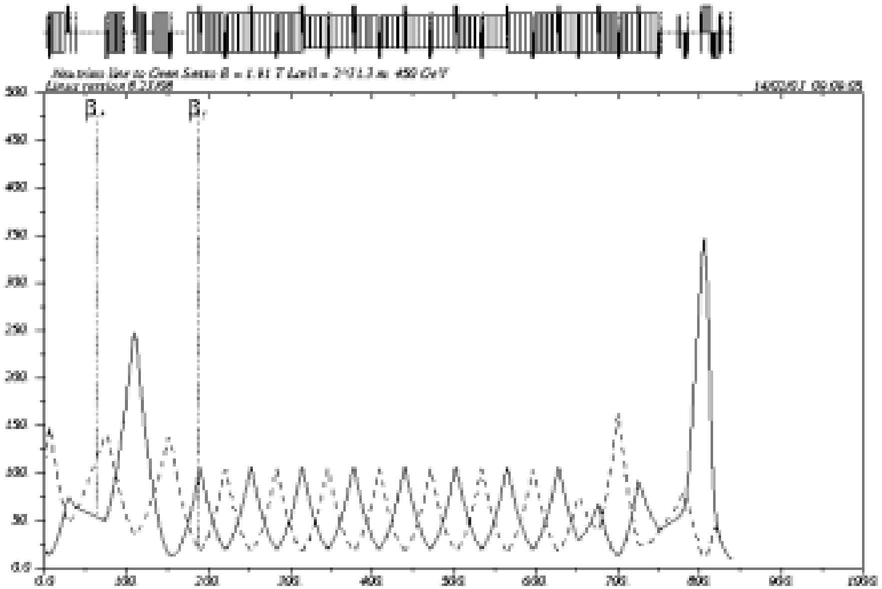
Nominal beam parameters

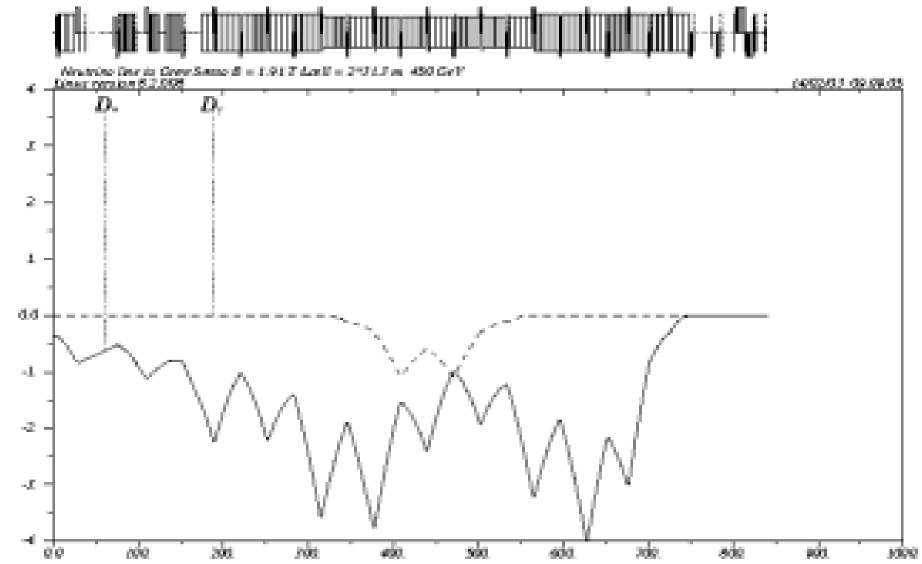
Beam parameters	Nominal CNGS beam
Nominal energy [GeV]	400
Normalized emittance [μm]	H=12 V=7
Emittance [μm]	H=0.028 V= 0.016
Momentum spread $\Delta p/p$	0.07 % +/- 20%
# extractions per cycle	2 separated by 50 ms
# of train per extraction	1
# of bunches per train	2100
Intensity per extraction [10^{13} p]	2.4
Bunch length [ns] (4σ)	2
r.m.s. bunch length [cm]	15
Bunch spacing [ns]	5
Train length [μs]	10.5

Upgrade phase: 3.5 10^{13} p

Optics at Target (1)

Nominal parameters :
- Beta at focus in both planes : 10 m
- σ_x , σ_y at 400 GeV [mm]: 0.53 / 0.4
- σ'_x, σ'_y at 400 GeV [mrad]: 0.05 / 0.4





Optics at Target (2)

- Round beams
- Increase σ

β_x[m]	2.5	10	20	30
σ_x[mm]	0.26	0.53	0.75	0.91
β_y [m]	2.5	10	20	30
σ_y [mm]	0.2	0.4	0.56	0.7

Going to 30 m: feasible but reaching the power supply limit and aperture limit (swapped power supplies)

Trajectory correction scheme (1)

AIM:

- Is the proposed scheme sufficient?
- Can we save some correctors or monitors?
- What happens if something goes wrong (w.r.t. faulty correctors or monitors)

Took into account:

Beam line errors (quad displacement, beam position monitor, dipole field and tilt, extraction from SPS)

Trajectory correction scheme (2)

2-in-3 scheme: 2 consecutive half cells per plane out of 3 are equipped with Beam Position Monitors (BPMs) and correctors.

Phase advance per cell: $\pi/2$

Produce π bumps which may not be visible as the trajectory is heavily under-sampled.
Problem worsen when some BPMs are malfunctioning

- Reading of the positions in both planes (X, Y) for all BPMs
- Add one BPM

Trajectory correction scheme (3)

Corrector strength and efficiency scrutinized

3000 trajectory corrections

Max. Strength for the new dipole correctors: 60 μrad

Two correctors were removed from the scheme

Use some bending magnets as additional correctors.

Trajectory correction scheme (4)

	RMS max	Trajectory max. (mm)
X before trajectory. Correction	3.57 (3.58)	10.98 (15.02)
X after trajectory correction	0.65 (0.65)	2.02 (2.68)
Y before trajectory. Correction	3.24 (3.20)	7.50 (8.02)
Y after trajectory correction	0.49 (0.62)	1.42 (2.52)

Reminder: max. trajectory excursion allowed: 4.3 mm

The proposed correction scheme is sufficient

Aperture checks (1)

AIM:

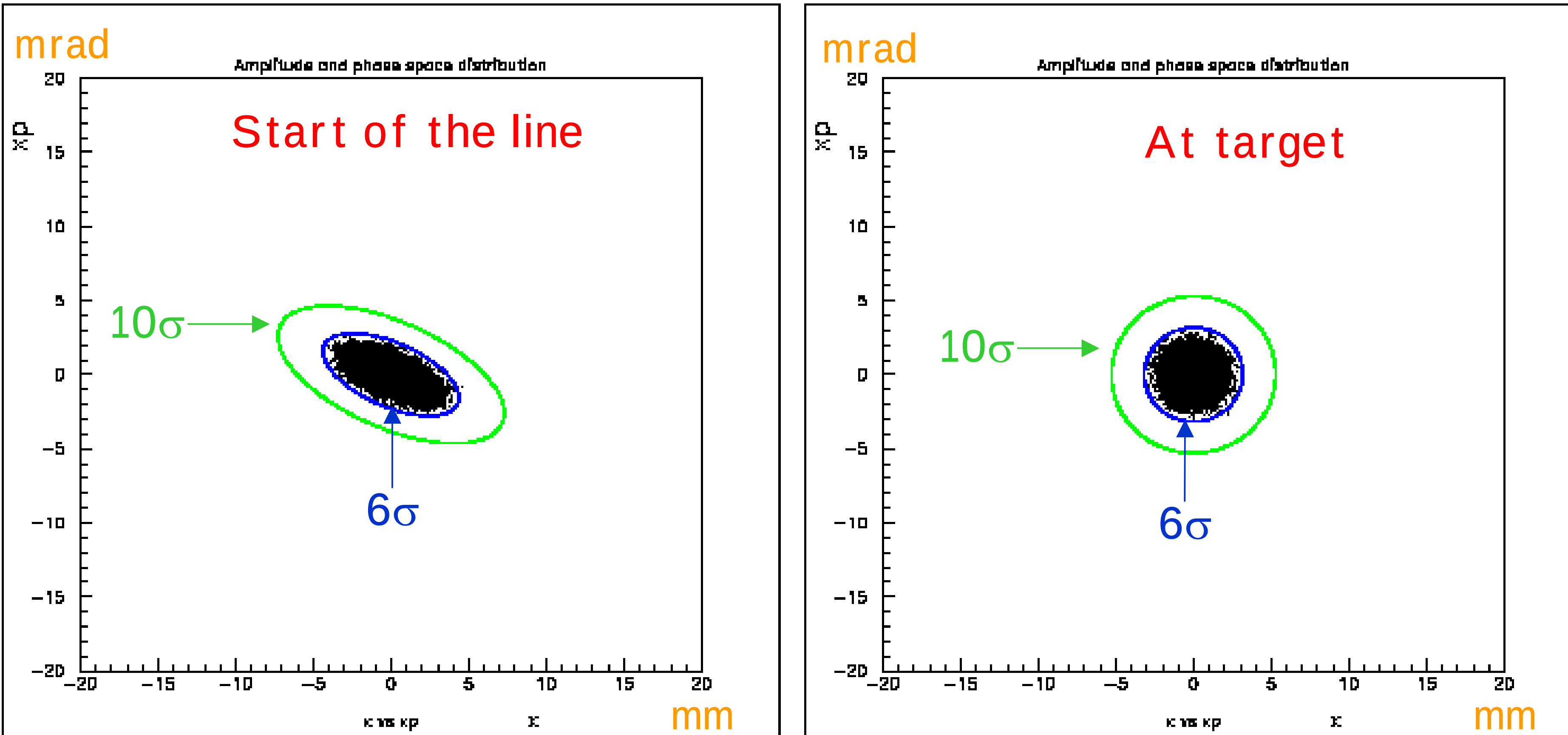
Investigate the aperture of the proton beam line

Method:

- Generate 100 000 particles according to Gaussian distribution to follow the contour of the emittance ellipse
- Populate tails of distribution

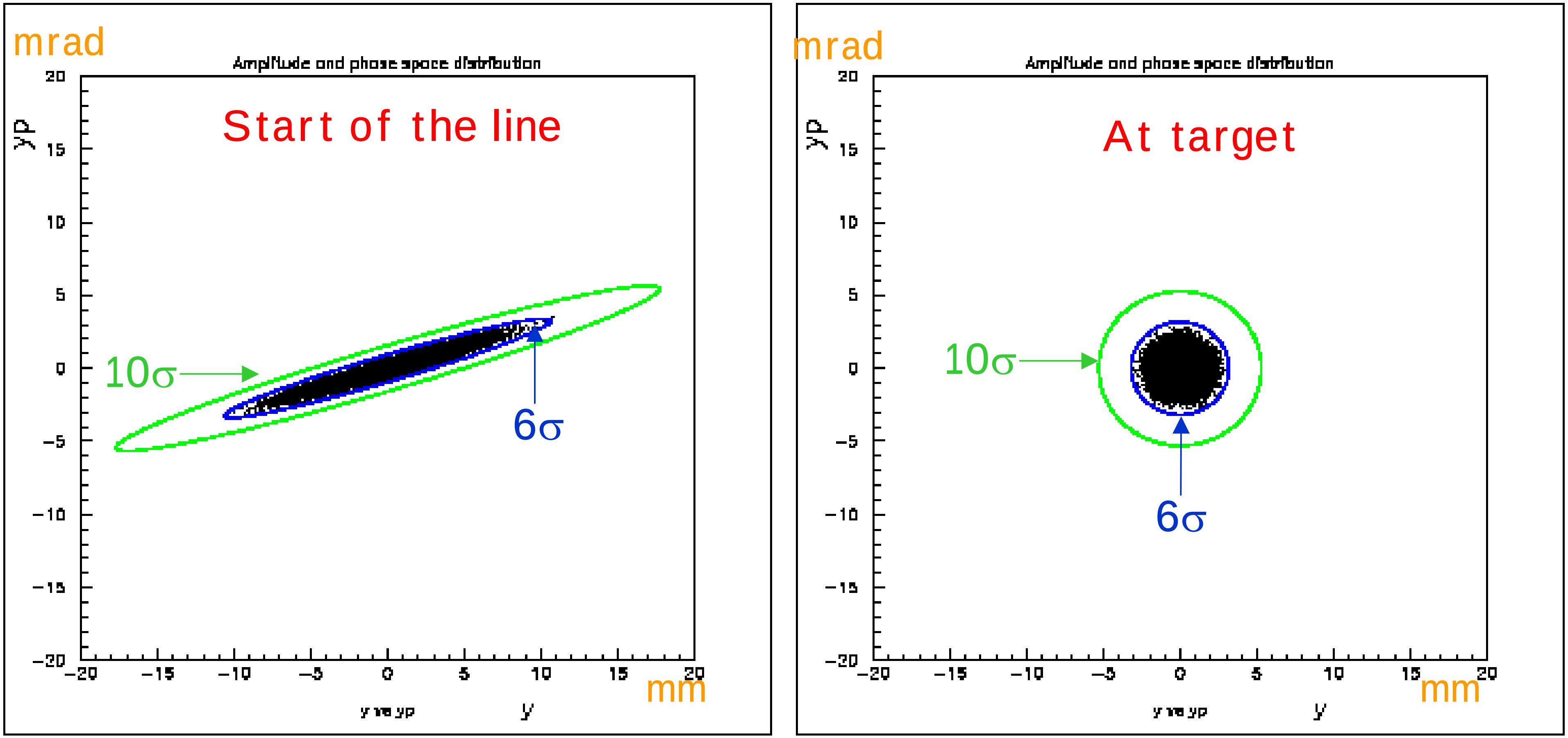
Aperture checks (2)

Horizontal phase space



Aperture checks (3)

Vertical phase space



Aperture checks (4)

Fraction of particles lost for different aperture misalignments and momentum offsets.

100000 particles tracked

For nominal parameters, no particle losses are observed.

Losses occur for larger aperture misalignments or larger momentum offsets

Beam stability at the target (1)

AIM:

Investigate the beam spot stability at the target
→ Target resistance to non-centered beam

Took into account:

Beam line imperfections (quad displacement, beam position monitor, main dipole field and tilt, extraction, power supply precision)

Type of error	Error magnitude	Horizontal σ_x at target (mm)	Horizontal σ'_x at target (μrad)
Magnet errors	As defined	0.12 mm	11 μrad
Horizontal extraction angle	10 μrad r.m.s.	0.11mm	5 μrad
Horizontal extraction position	0.5 mm r.m.s.	0.32 mm	21 μrad
Extraction angle and position	As above	0.34 mm	21 μrad
Magnet and extraction errors	As above	0.36 mm	22 μrad
Nominal beam size [r.m.s.]		0.53 mm	53 μrad
Effective beam size [r.m.s.]		0.64 mm	57 μrad

Beam stability at the target (3)

Horizontal plane spot size is dominated by extraction errors

Vertical beam spot size is not increased, vertical beam position is determined by trajectory errors.

Overall beam stability at the target (4)

Injection and magnet errors (horizontal σ at target)	0.36 mm
Total BPM rms incertainty	0.32 mm (?)
Target overall precision	0.30 mm (?)
Total:	~0.60 mm

For β=10 m, nominal σ_{beam} = 0.53 mm

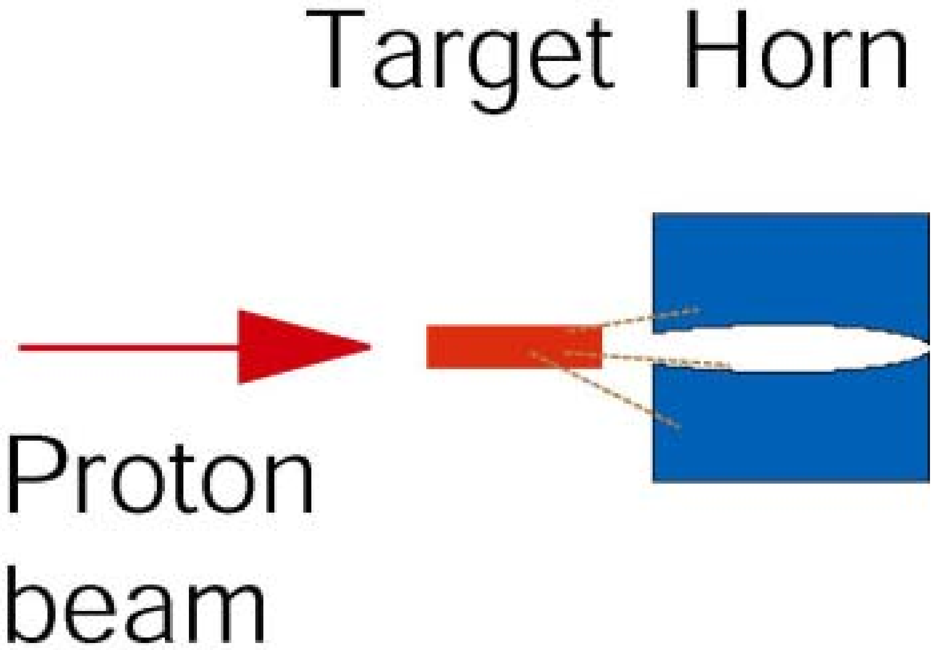
On target first 2 rods (5 mm diameter) :

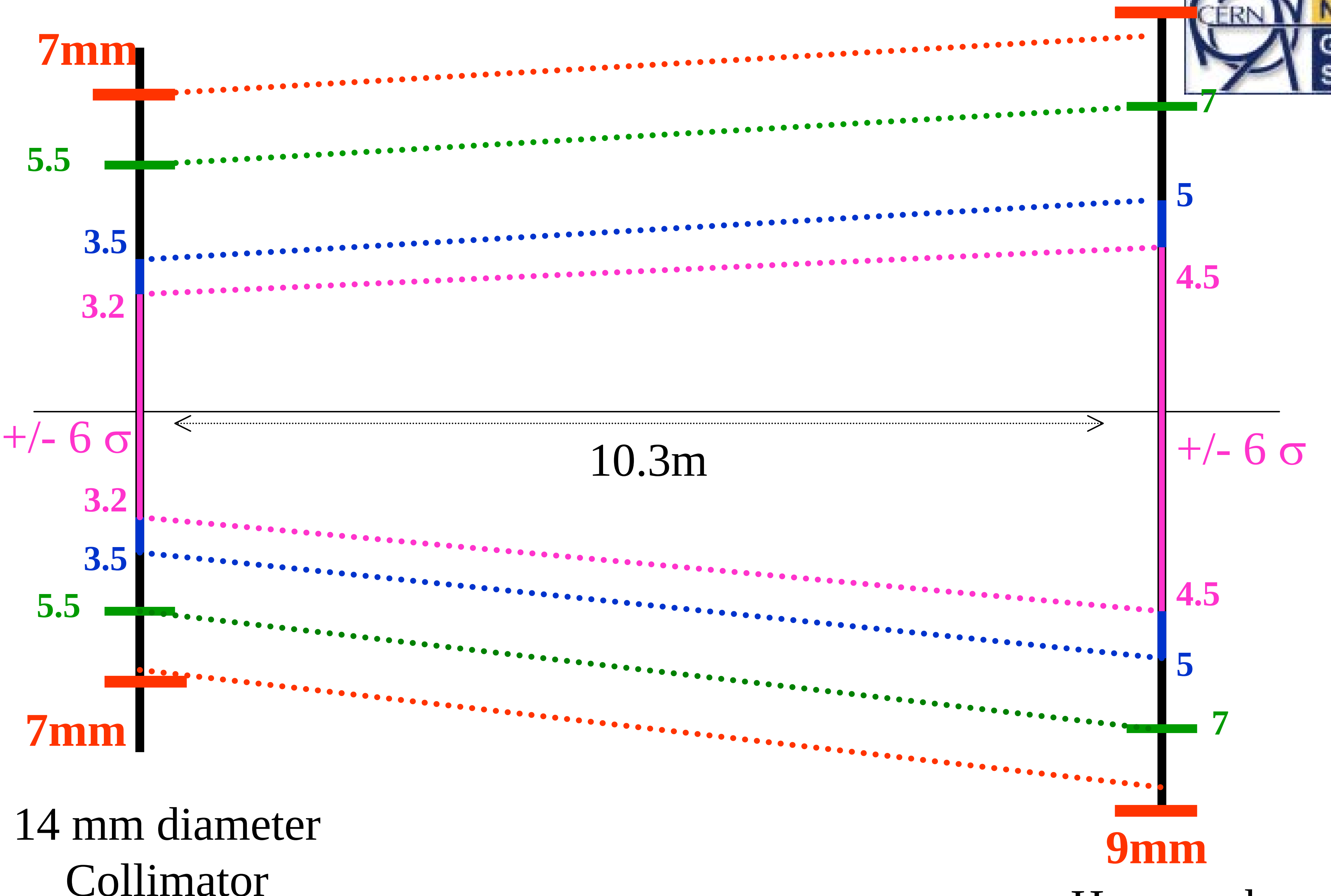
$2.5 \text{ mm} - (3\sigma_{beam} + 0.6\text{mm}) = 0.31 \text{ mm}$

On target following rods (4 mm diameter) :

$2.0 \text{ mm} - (3\sigma_{beam} + 0.6\text{mm}) = -0.19\text{mm}$

Need of a collimator (1)




9mm
7mm
7
5.5
5
3.5
4.5
3.2
+/- 6 σ
10.3m
+/- 6 σ
3.2
3.5
4.5
5.5
5
7
7mm
9mm
14 mm diameter
Collimator
Horn neck

Summary

Beam dynamics studies confirmed earlier preliminary studies.

Results on trajectory corrections, apertures studies, beam stabilities, need of a collimator to protect the horn neck.

Proton beam line “on schedule”

General services:	October 2004 to July 2005
Equipment:	August 2005 to January 2006
Cold check-out:	Feb-March 2006
Test with beam:	April 2006