CERN Neutrinos to Gran Sasso (CNGS): Results from Commissioning

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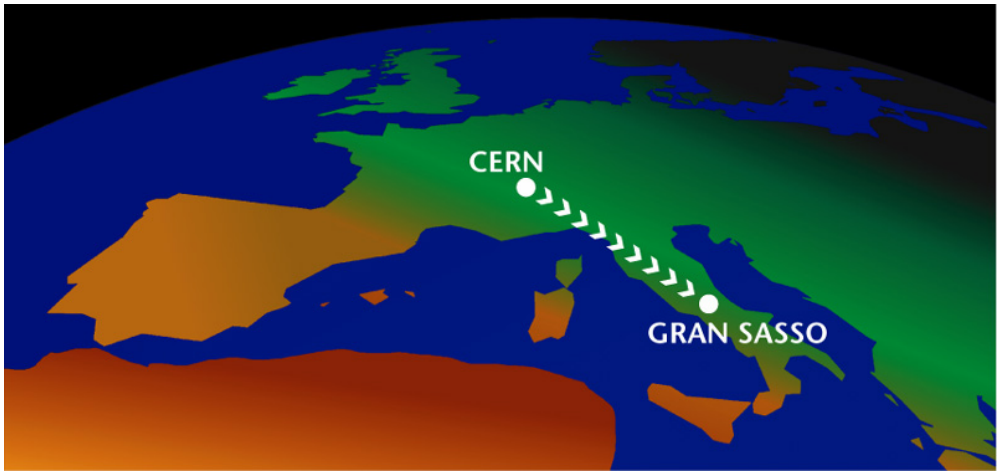
for the CNGS commissioning team

1. Project Overview
2. CNGS beam line
3. Results from commissioning

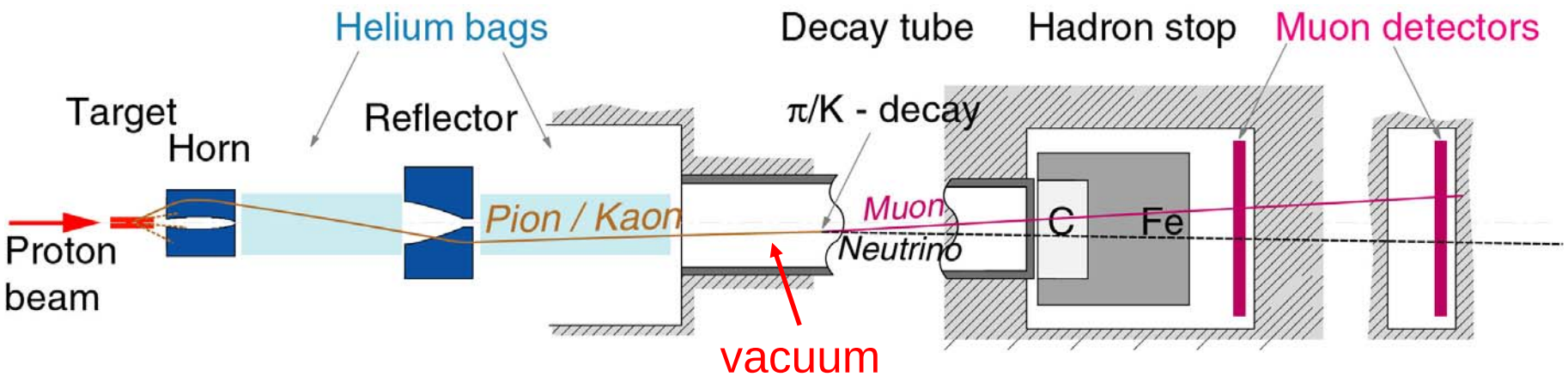
1. Project Overview

(see http://cern.ch/cngs)



send ν_μ beam
-> detect ν_τ appearance

700 m 100 m 1000m 67 m

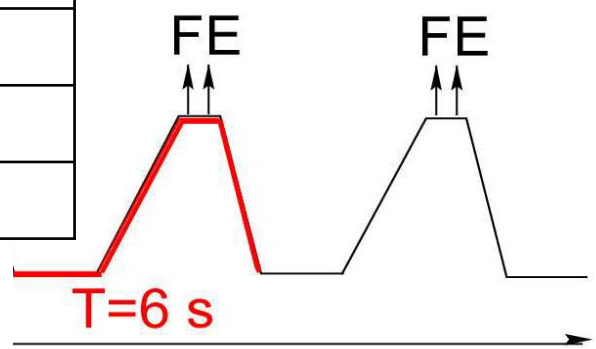


$p + C \rightarrow$ (interactions) $\rightarrow \pi^+, K^+, (\mu^+) \rightarrow$ (decay in flight) $\rightarrow \mu^+ + \nu_\mu$

2. CNGS beam line

Nominal beam parameters

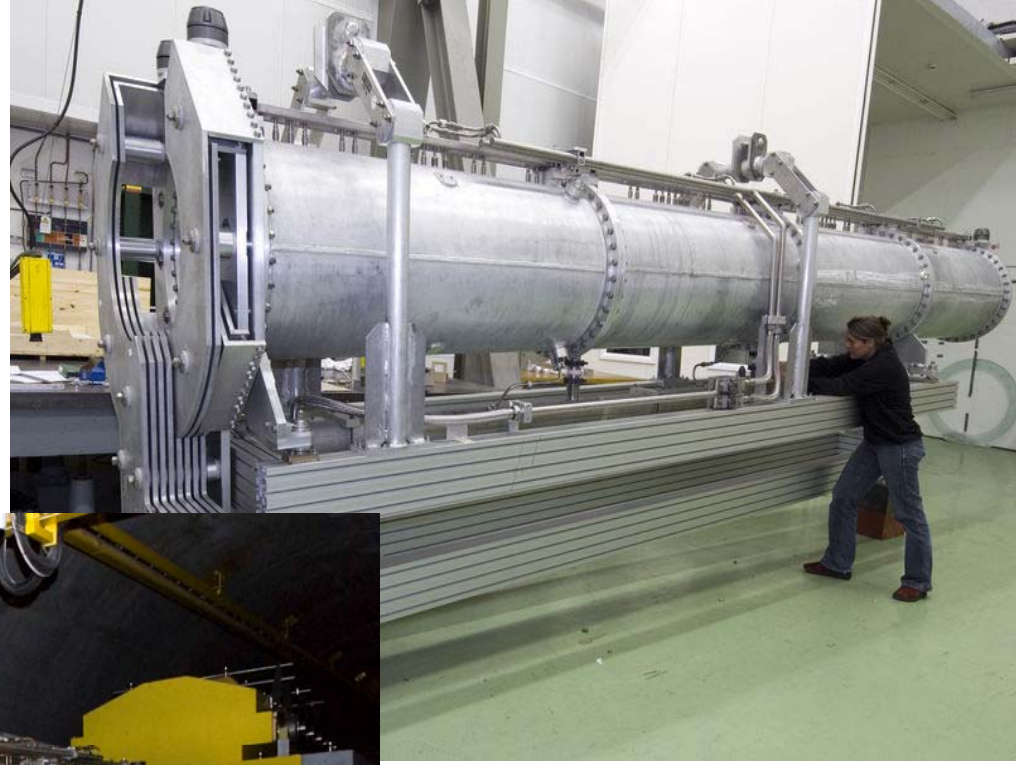
Beam Parameters	Nominal values
Normalised emittance [μm]	H=12 V=7
Physical emittance [nm]	H=28 V=16
Momentum spread Δp/p	0.07% ± 20%
Number of extractions per cycle	2 (50ms apart)
Batch length [μs]	10.5
Number of bunches per batch	2100
Intensity per extraction (protons)	$2.4\ 10^{13}$
Bunch length [ns] (4σ)	2
Bunch spacing [ns]	5
Beta at focus [m]	H=10 V=20
Beam sizes at 400 GeV [mm]	0.5



Target

Courtesy of L. Bruno and D. Grenier

Horn and Reflector



length: 6.5 m
diameter: 70 cm
weight: 1500 kg

Pulsed devices:
150kA / 180 kA
water-cooled:
distributed nozzles

Courtesy of A. Pardons

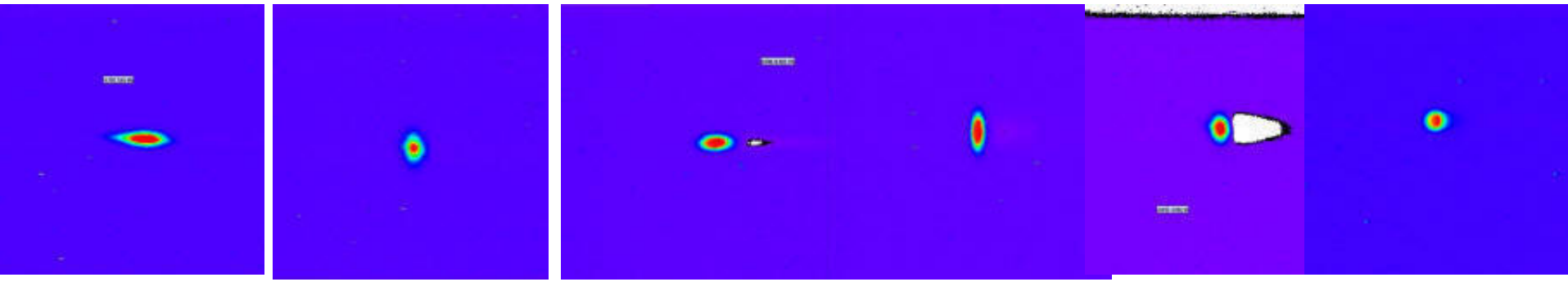
3. Commissioning

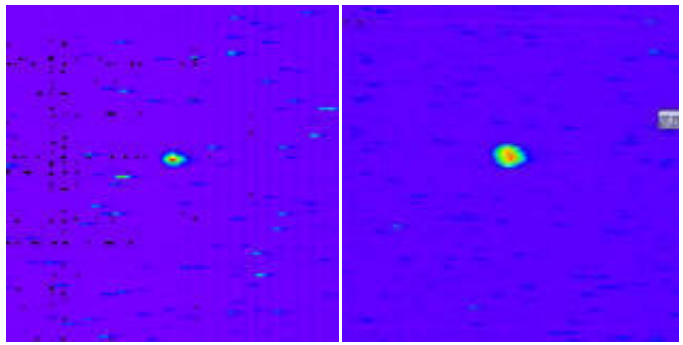
Importance of complete hardware commissioning and dry runs
(as if beam but without beam)

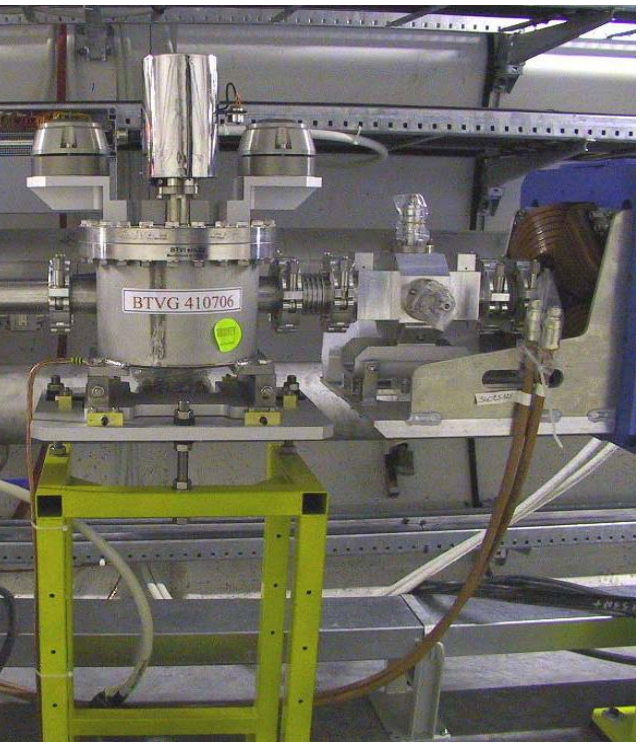
- Hardware commissioning Feb. – April 2006
  - Beam instrumentations
  - Power supplies
  - Magnets (polarities)
  - Vacuum system
- "Dry runs" April – May 2006
  - Timing
  - Controls
  - Interlocks
  - Beam permit
  - Magnets (current & polarities)
- Commissioning with beam 2006: weeks 28, 30 and 33
  - Upper limit of protons of 1×10^{17} for the 3 weeks.

Proton beam along the 8 screens of transfer line

1st shot down proton beam line: beam is already well centered



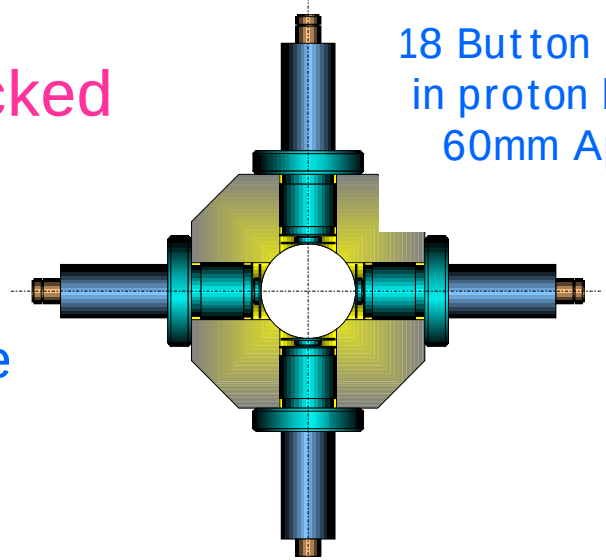




Screens:
75 μm carbon
12 μm titanium

Courtesy of E. Bravin, G. Burtin

Beam position monitors (BPM) checked



18 Button Electrode
in proton beam line
60mm Aperture

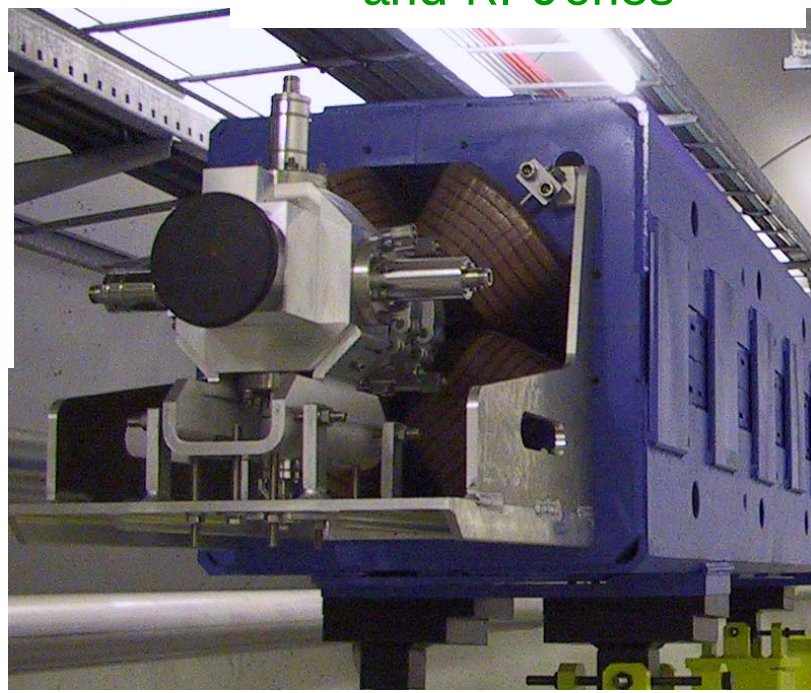
2 batch lengths

2μs, for I~2x10^{11}
Trigger at 1μs, 400ns gate

10.5μs for I>2x10^{12}
Trigger at 1μs, 8μs gate
or trigger at 2μs, 400ns gate

Courtesy of T. Bogey
and R. Jones

source	*rms uncertainty*	*tolerance*
BPM (global accuracy)	0.25 mm	± 0.5 mm
Alignment	0.20 mm	± 0.4 mm
Total	0.32 mm	± 0.6 mm

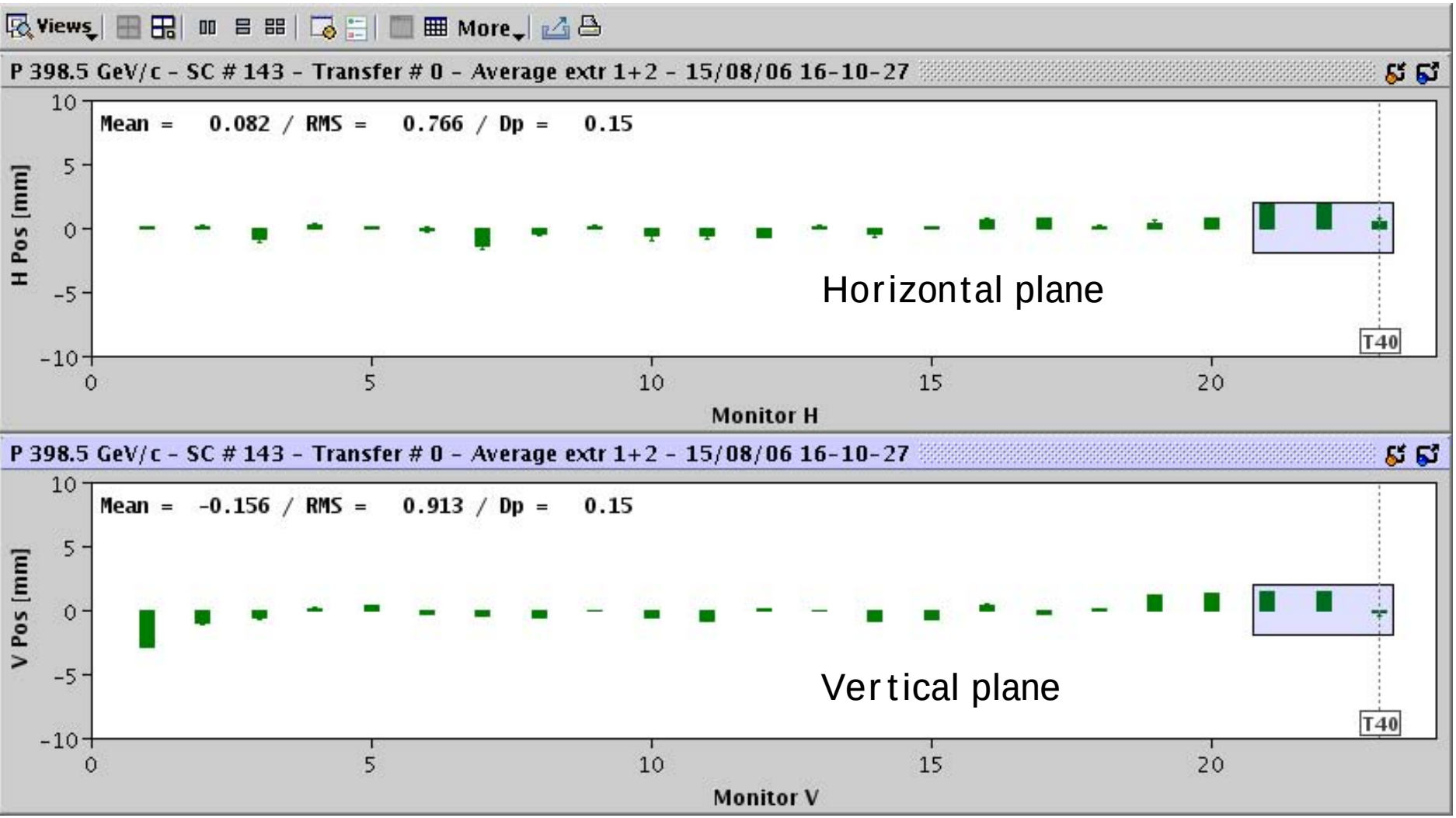


System is very sensitive
to batch structure and intensity.
However for nominal beam
parameters, system is reliable.

Malika Meddahi
for the CNGS commissioning team

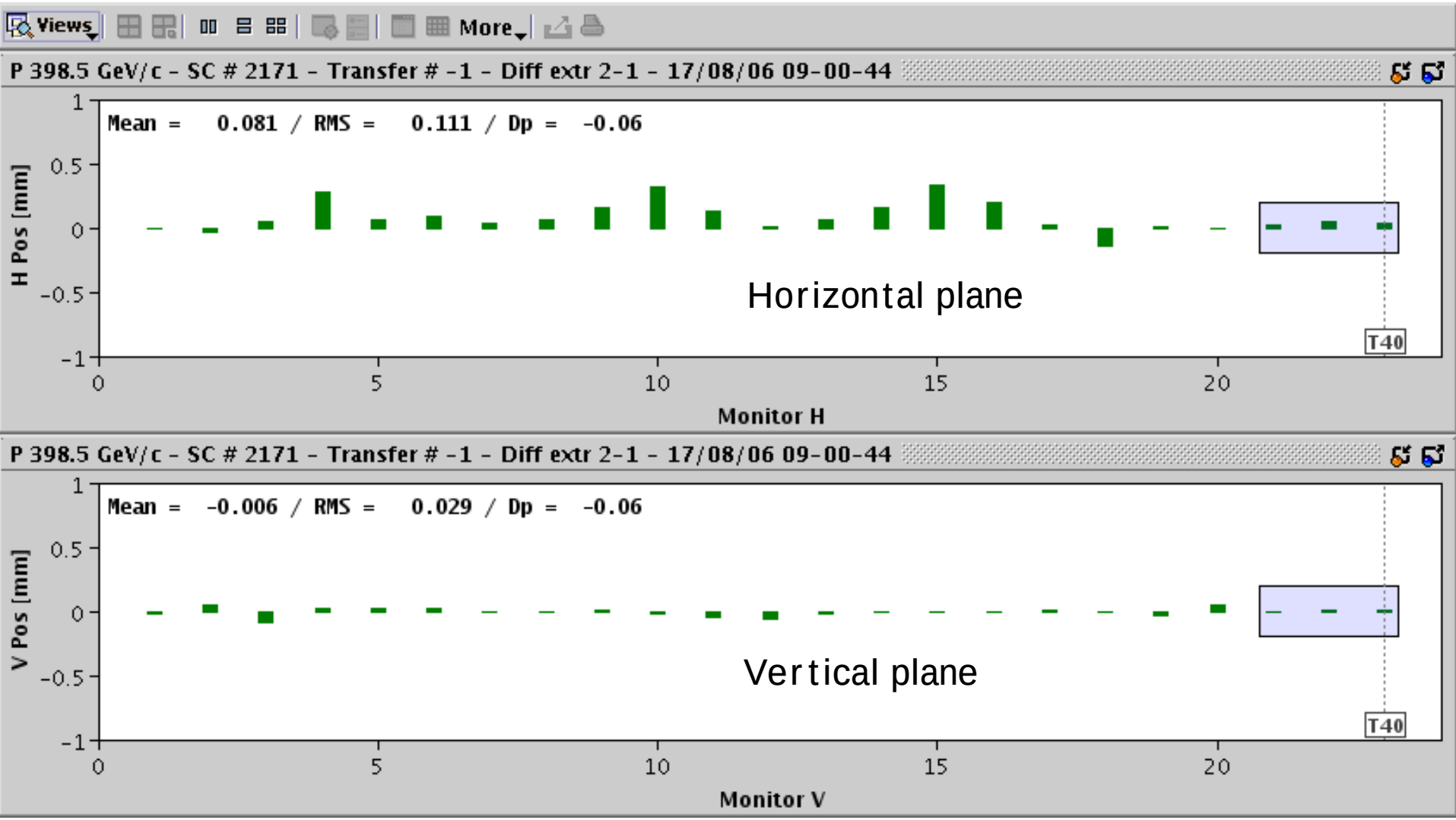
Trajectory along beam line

2 extractions, ~ 10^{13} protons per batch



Trajectory difference between the 2 extractions on BPMs

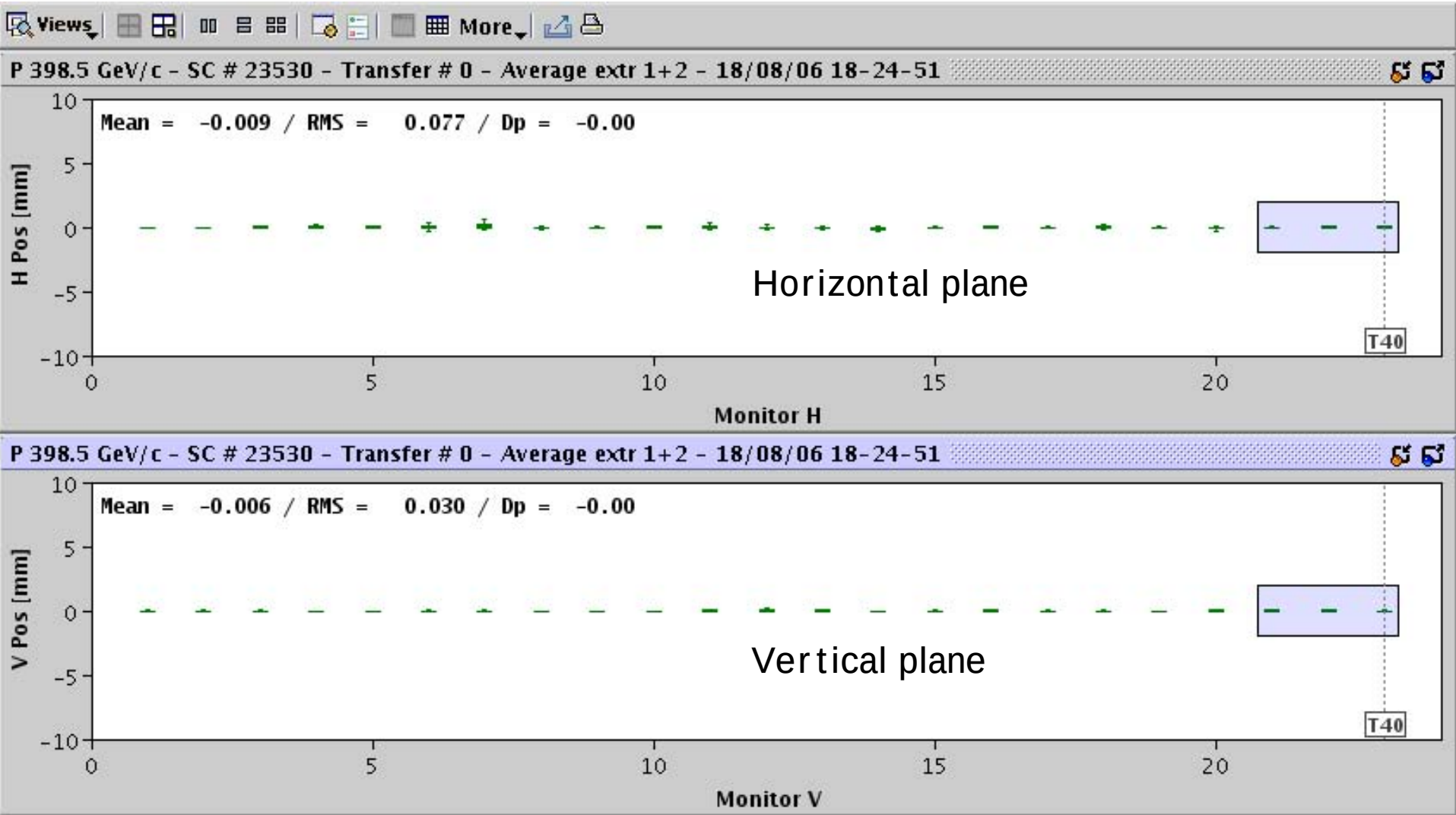
Energy difference of 6×10^{-5}



Interpolation to Target Elements

Target	Type	Corr.	X	X' [urad]	Y	Y' [urad]	Show	History
T40	Left-Left	☑	0.002	-5.76	-0.012	-13.43	☐	☐

Beam position stability onto the target over 3 first days:~50 μm rms



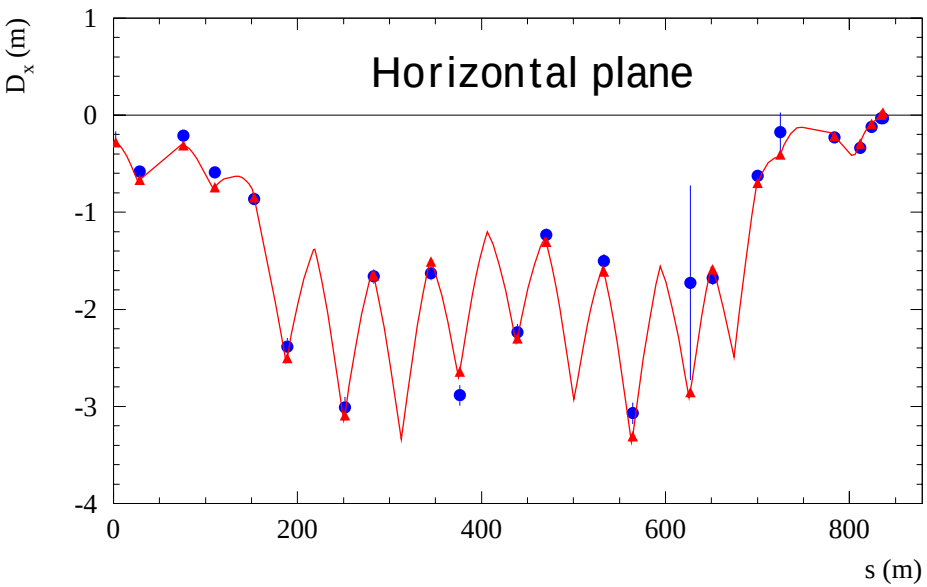
Optics checks

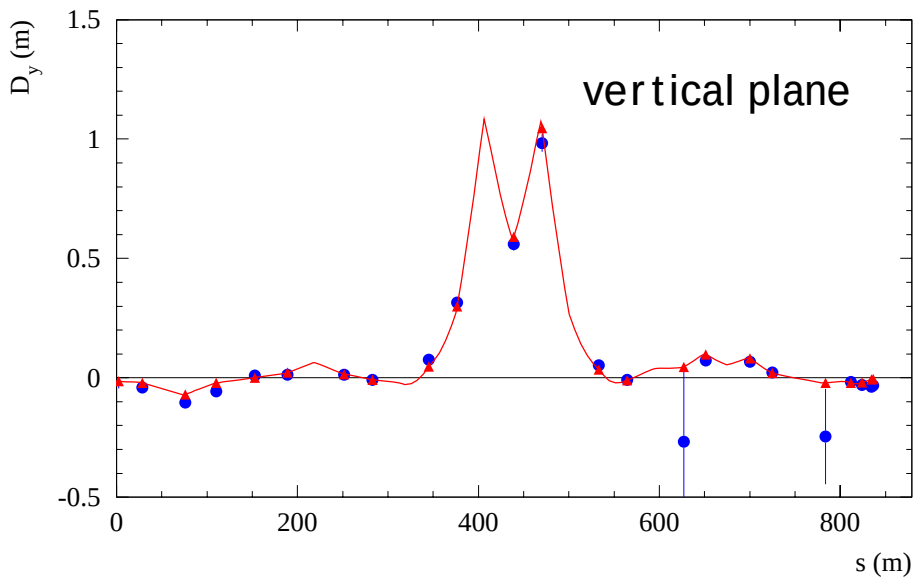
Good agreement with theory

Beta beat of less than 10%

"Beam stability and Optics studies of the CNGS transfer line" by J. Wenninger et al, **AB-Note-2007-008 OP**

Dispersion measurements





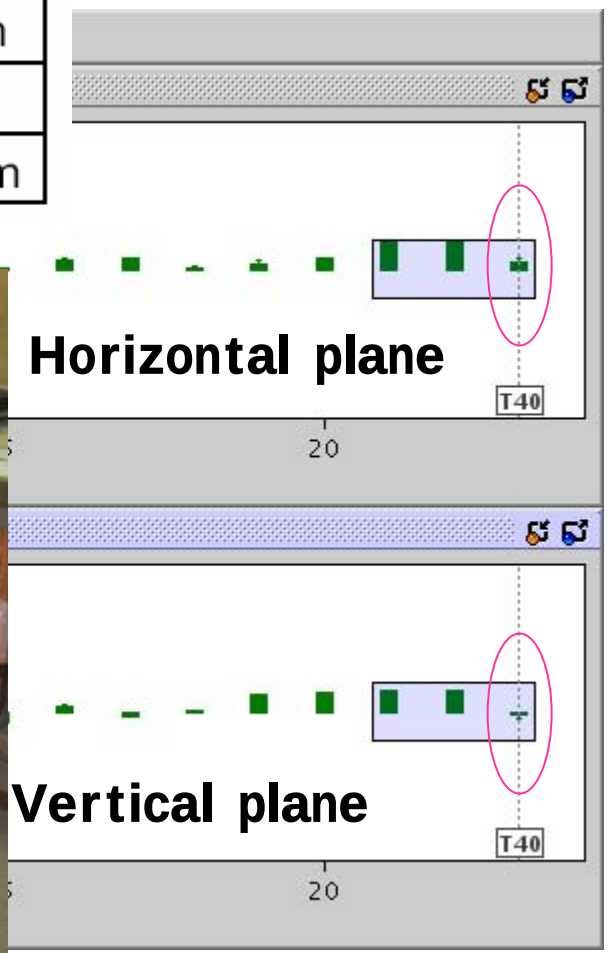
Courtesy of J. Wenninger

Special beam position monitor on target table:

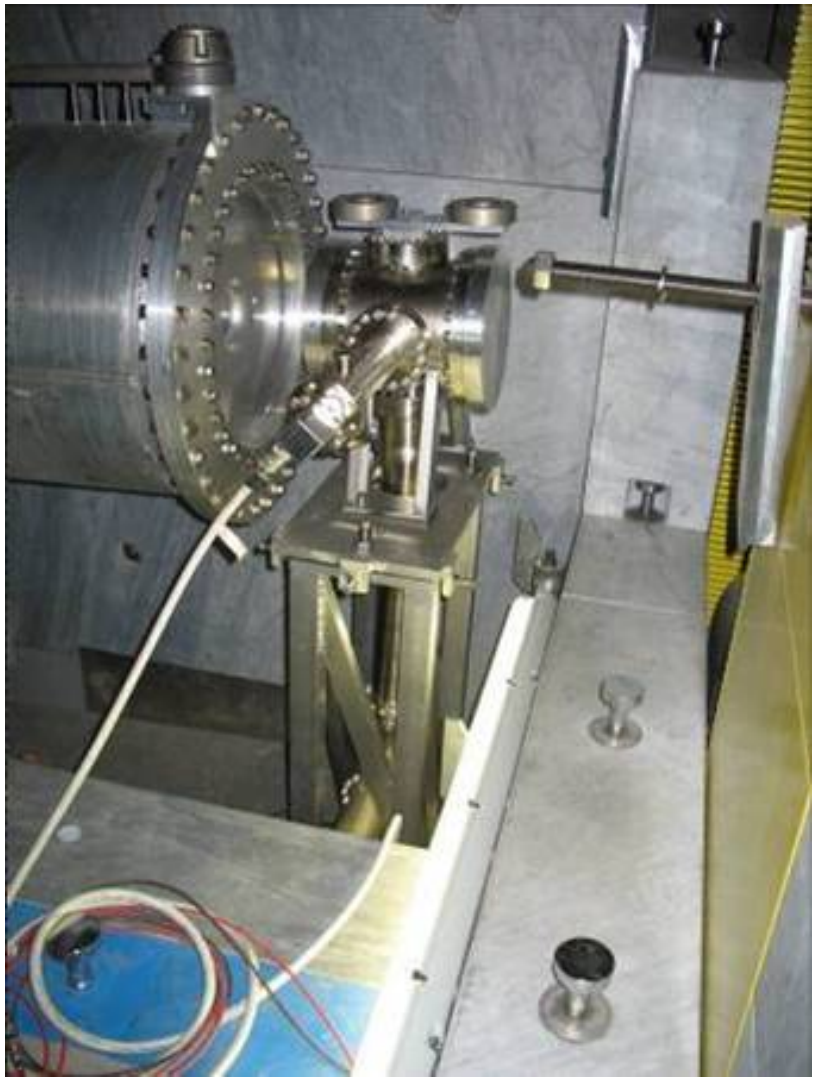
Stripline coupler Pick-up operated in air

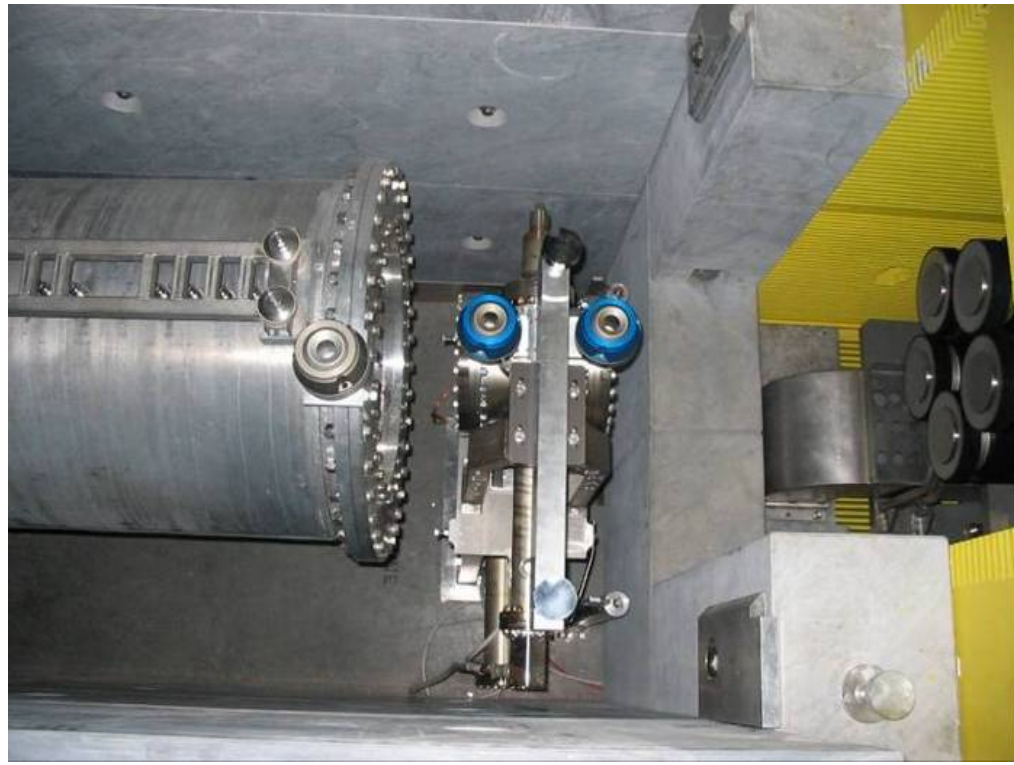
error source	*rms uncertainty*	*tolerance*
BPM (global accuracy)	0.1 mm & ≤± 0.15 mm	± 0.2 mm & ≤± 0.3 mm
Alignment	0.10 mm	± 0.2 mm
Total	0.14 mm	≤± 0.35 mm

-> very reliable position reading



Downstream Target Beam Instrumentation (TBID)



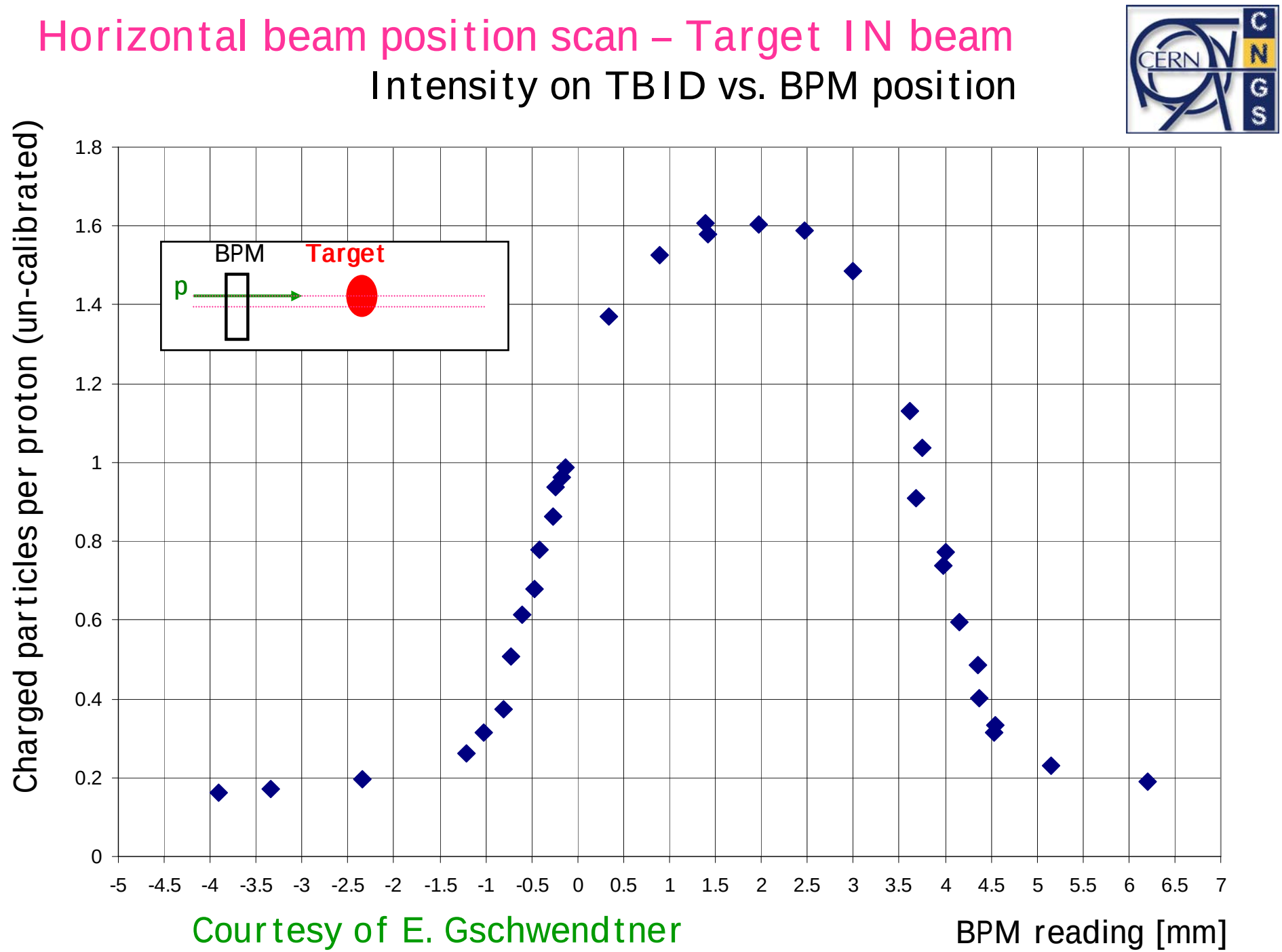


Secondary emission monitor
12 µm Ti foils
in vacuum

Measures all charged particles downstream the target

-> check efficiency of particle production in the target

Horizontal beam position scan – Target IN beam



Courtesy of E. Gschwendtner

The CNGS commissioning with beam proved the importance of

- detailed hardware commissioning
- complete “dry” commissioning
- having screens along extraction channel and proton line for the first beam passages
- save protons used during commissioning

Summary - Outlook

CNGS project was approved on December 1999

Civil Engineering– Equipment design- Production- Installation- Commissioning phases lasted 6 years: CNGS handed over to operation on 18 August 06

Project completed within budget and on schedule.

Proton beam line and secondary beam line were successfully commissioned.
First shot down the line reached the target at about center.
Beam is very stable and parameters are within specification.
Experiments at Gran Sasso saw signals correlated to the CERN-CNGS beam.

Let's run the facility for physics with nominal beam intensity !

Thank you to all the colleagues from CERN and laboratories all over the world who contributed to the project's success.

Two posters related to CNGS:

E. Gschwendtner, **TUPAN095**
on CNGS Secondary Beam Results and Simulations,
incl. experience from short 2006 physics run

V. Kain, **TUPAN096**
on Extraction Channel from SPS towards CNGS beam-line