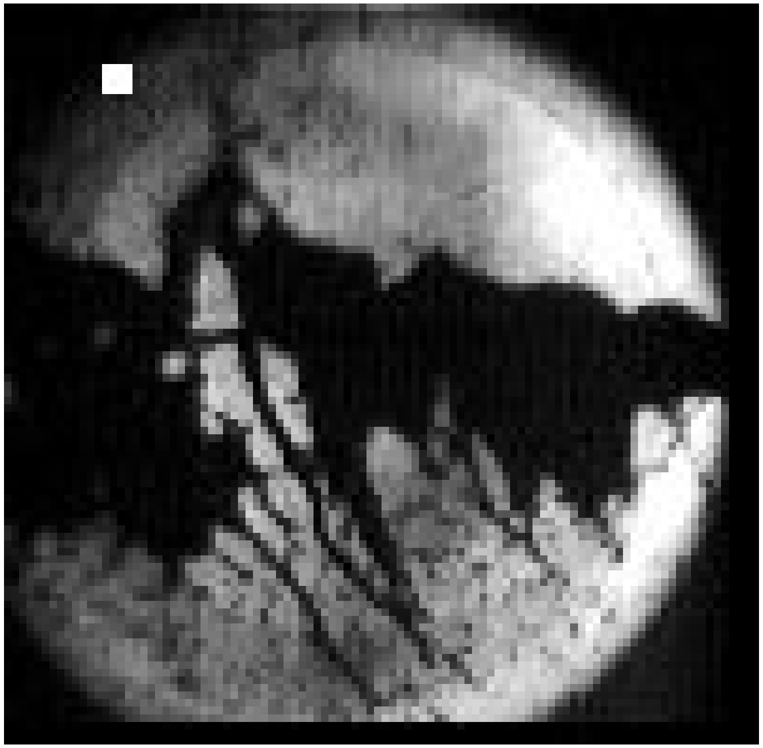
Target R&D

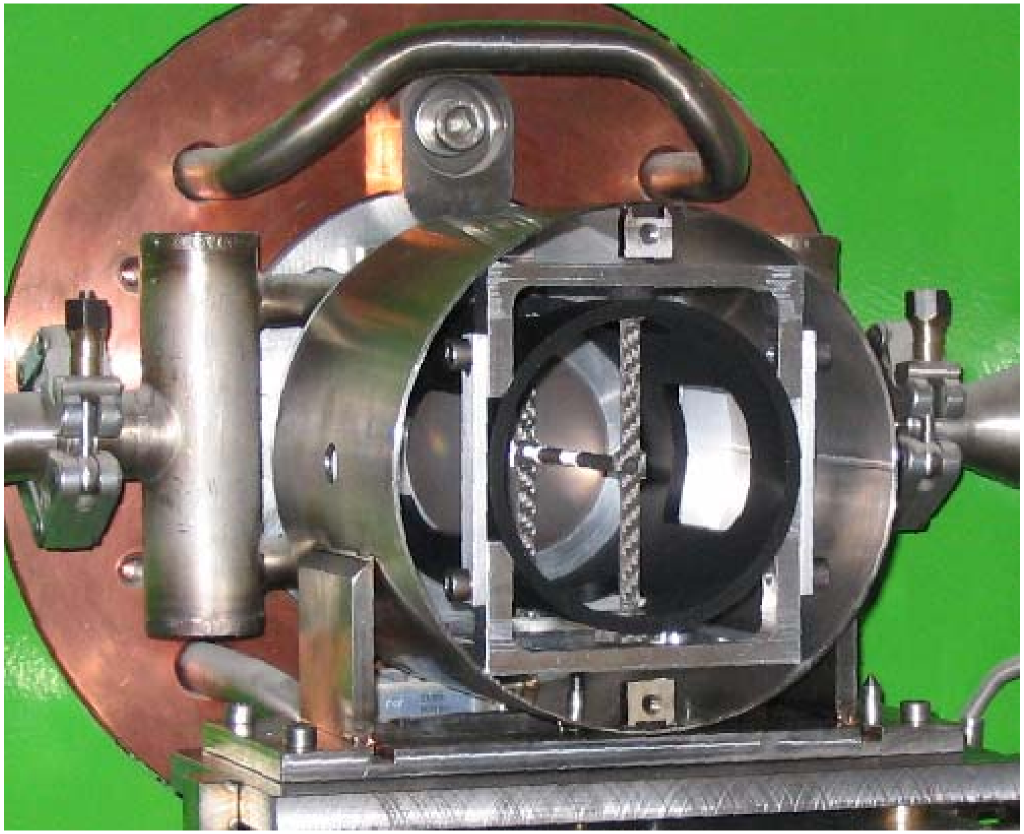
A.Fabich, CERN

NuFact 04



Outline

- Introduction
- Solid targets
- Horn R&D
- Liquid targets
- Simulations
- TT2A target experiment



CNGS target mock-up for in beam-tests at TT40
d=5mm, l=10cm carbon rod

Goal

- Production of n-th generation beams with an intense primary proton beam
  - p^+ on target → pions → muons → ν's

- conversion tool TARGET
  - withstand the power of multi-MW proton machines
    - Target melting
    - Target vaporization
    - Beam-induced pressure waves
    - Radiation damage

Solid targets

Numerous applications today:

but proton beam power < 100 kW

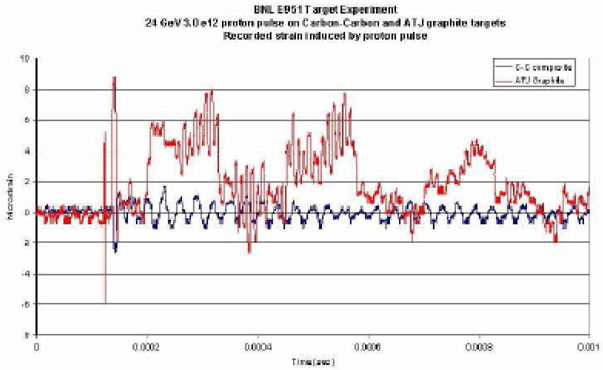
- Basic materials: Beryllium, carbon, tantalum, …
  - low coefficient of thermal expansion

Studies

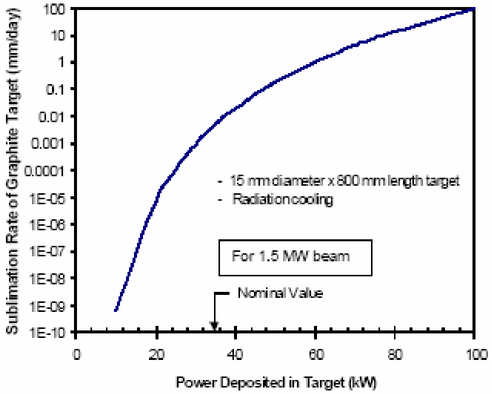
- BNL for a 1 MW proton beam (average)
- ISOLDE with a 10kW -”-
- CNGS with a 500kW -”-
- …

A Carbon Target is Feasible at 1-MW Beam Power

A carbon-carbon composite with near-zero thermal expansion is largely immune to beam-induced pressure waves.



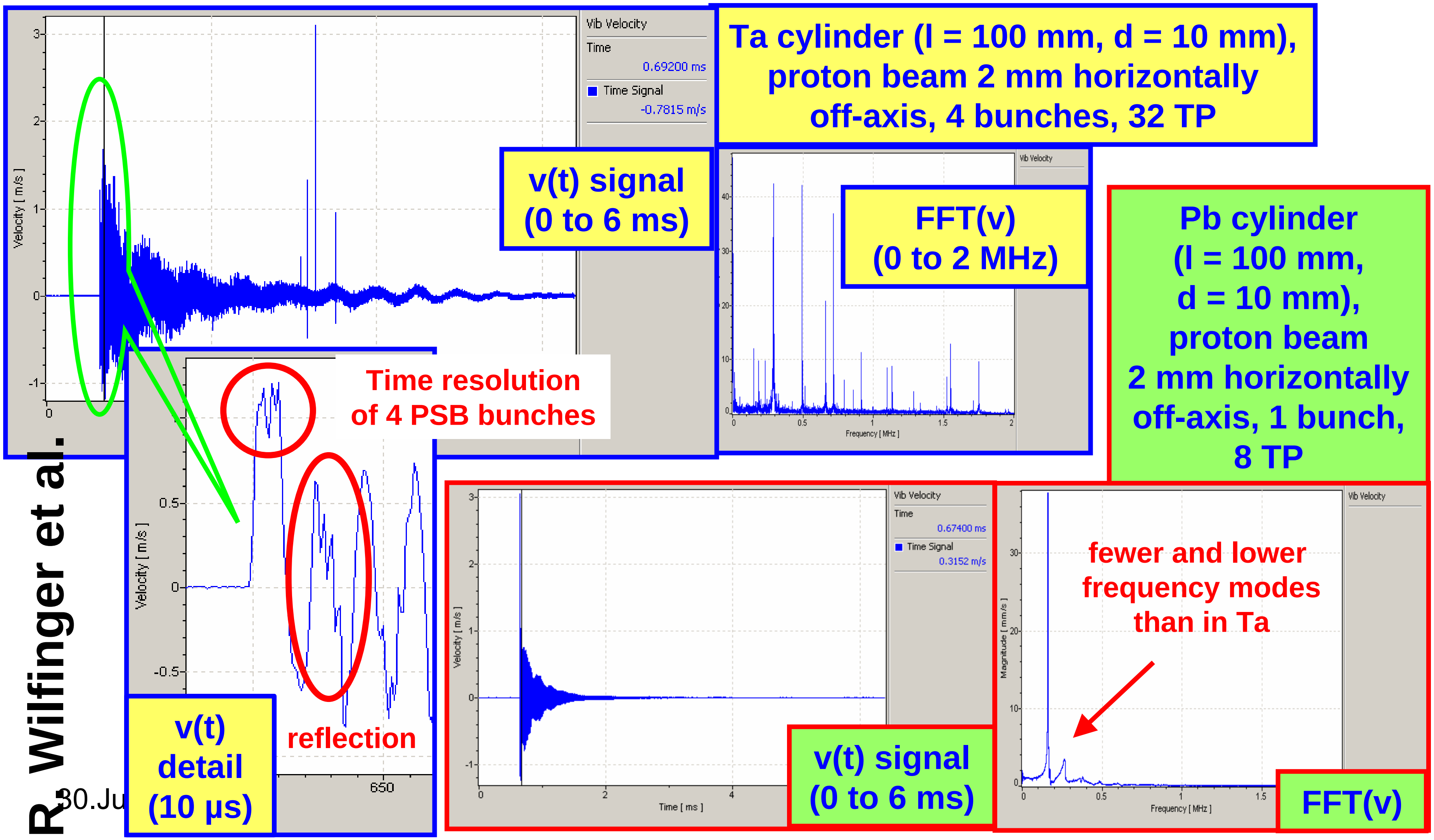
A carbon target in vacuum sublimates away in 1 day at 4 MW.



Sublimation of carbon believed to be negligible in a helium atmosphere. Tests underway at ORNL to confirm this.

Radiation damage is limiting factor: $\approx$ 12 weeks at 1 MW.

Velocity-signal of surface-movement for Ta-cylinder with a Laser-vibrometer

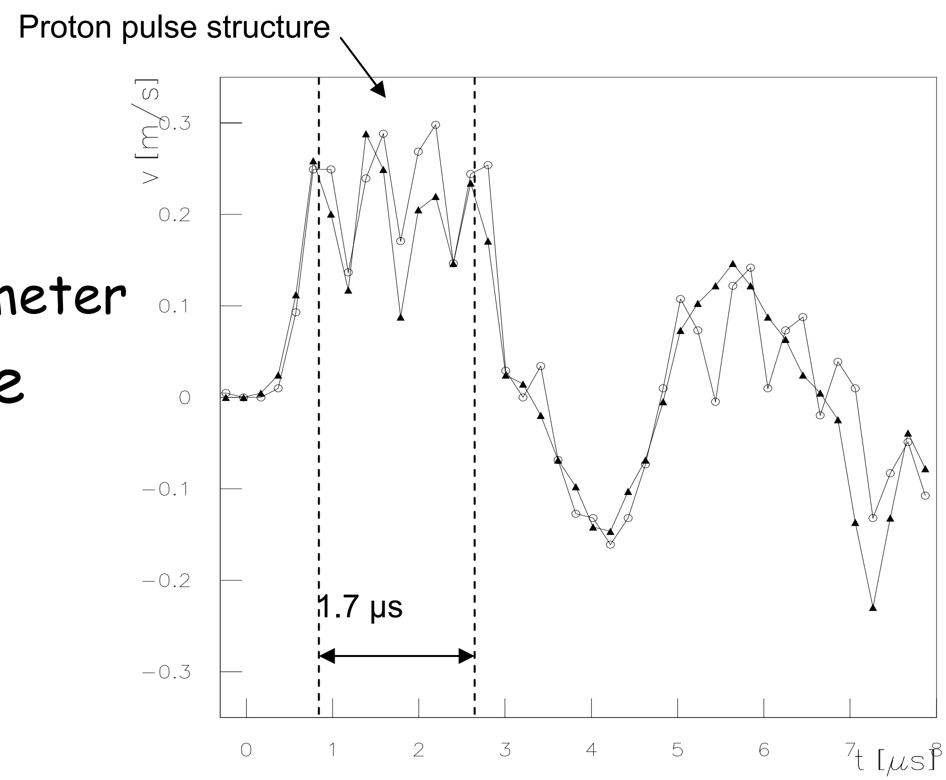


R. Wilfinger et al.

CNGS Target R&D

Proton beam: 400 GeV/c, every 6 sec spill of 2x 2*10^{13} protons
Graphite target d=5mm

- Vibration measurements
  using a laser Doppler-vibrometer
- Demonstration of principle
  - In ISOLDE target area
  - April 2004
  - 2.2 GeV/c, 3*10^{13} p^+/pulse
  - ΔT_{max} ~ 35 K (CNGS 750 K)

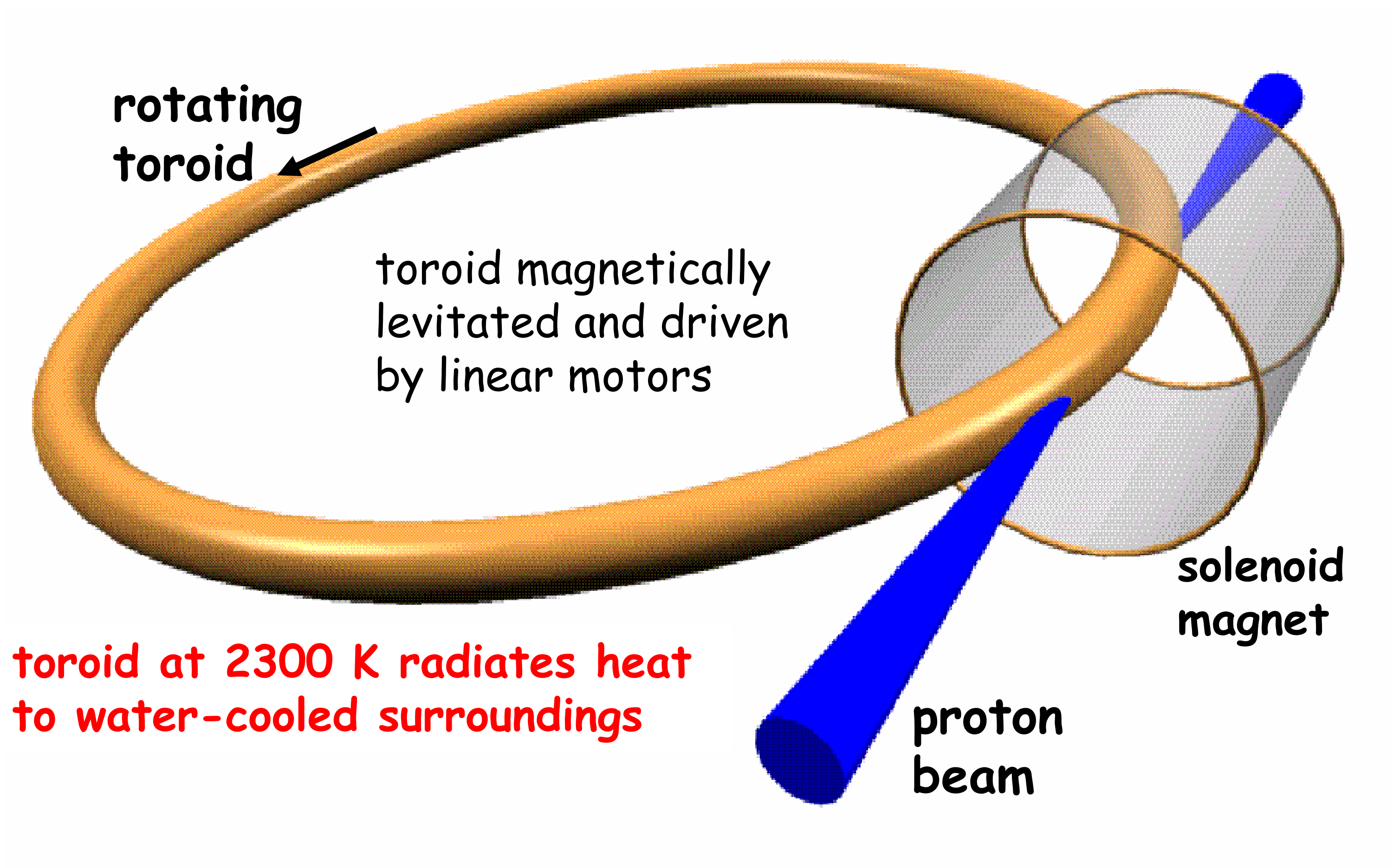


Test at CERN/SPS with nominal CNGS beam in Sept/Oct 2004

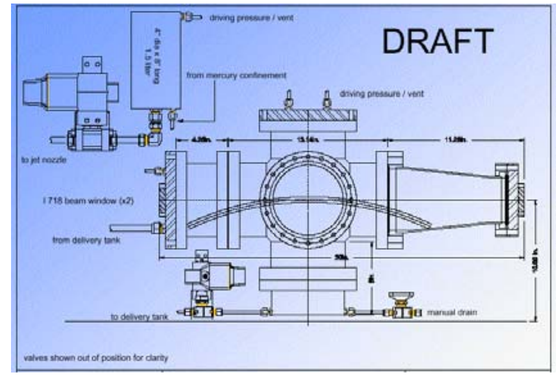
Schematic diagram of the radiation cooled rotating toroidal target

- Distribute the energy deposition over a larger volume
  - Similar a rotating anode of a X-ray tube

R.Bennett, B.King *et al.*



Liquid Target with free surface



• jet	avoid beam window
• Mercury	increased meson yield for high-Z materials, point-like source
• v~20 m/s	Replace target at 50 Hz
• D= 1-2 cm	Optimized for re-absorption of mesons

??? What is the impact on the jet by

- 4 MW proton beam
- 20 T solenoidal field

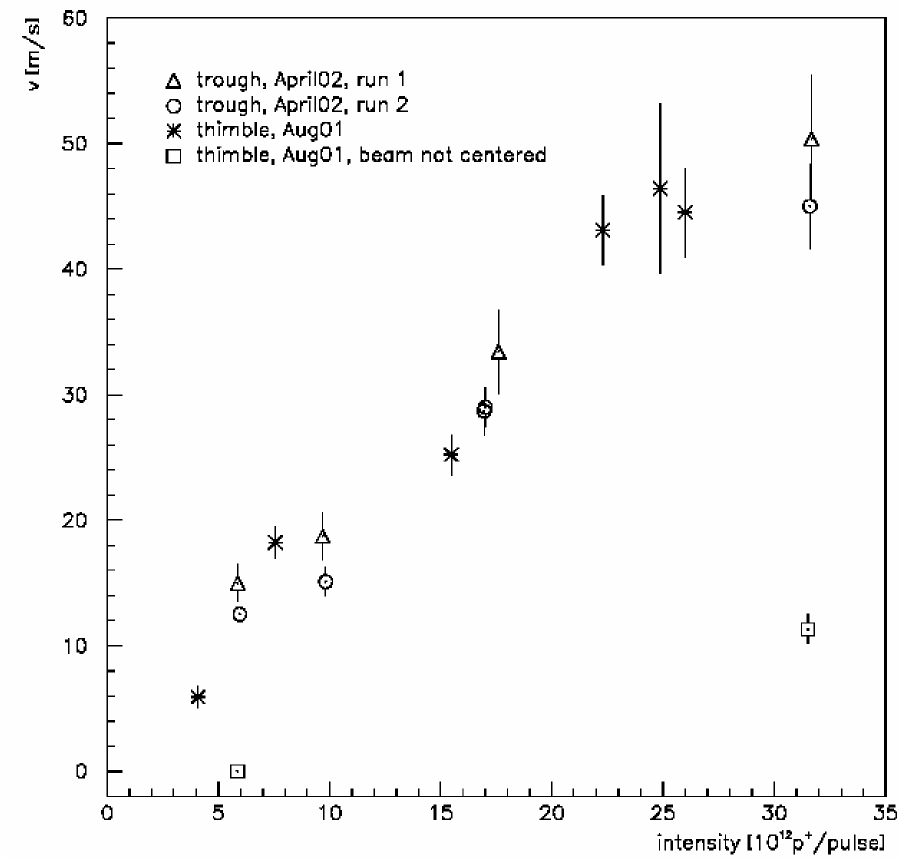
- MOVIE

Previous experimental results

Independent measurements

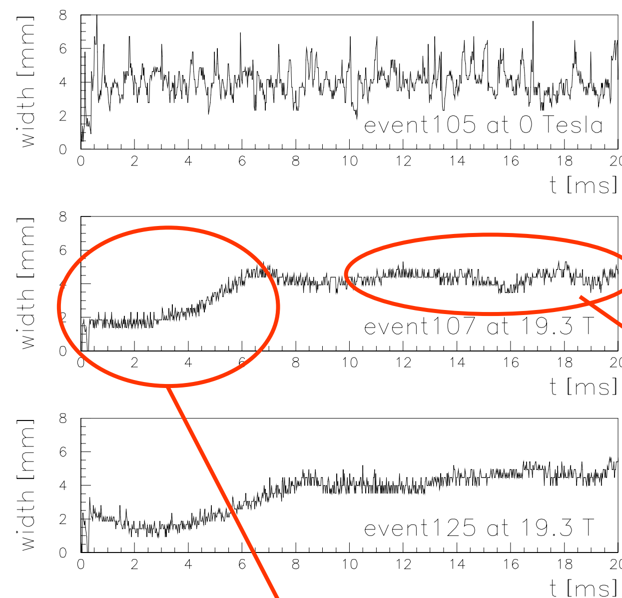
CERN/BNL

Proton induced shocks



at GHMFL

MHD



At B=0 T

At B=19.3 T

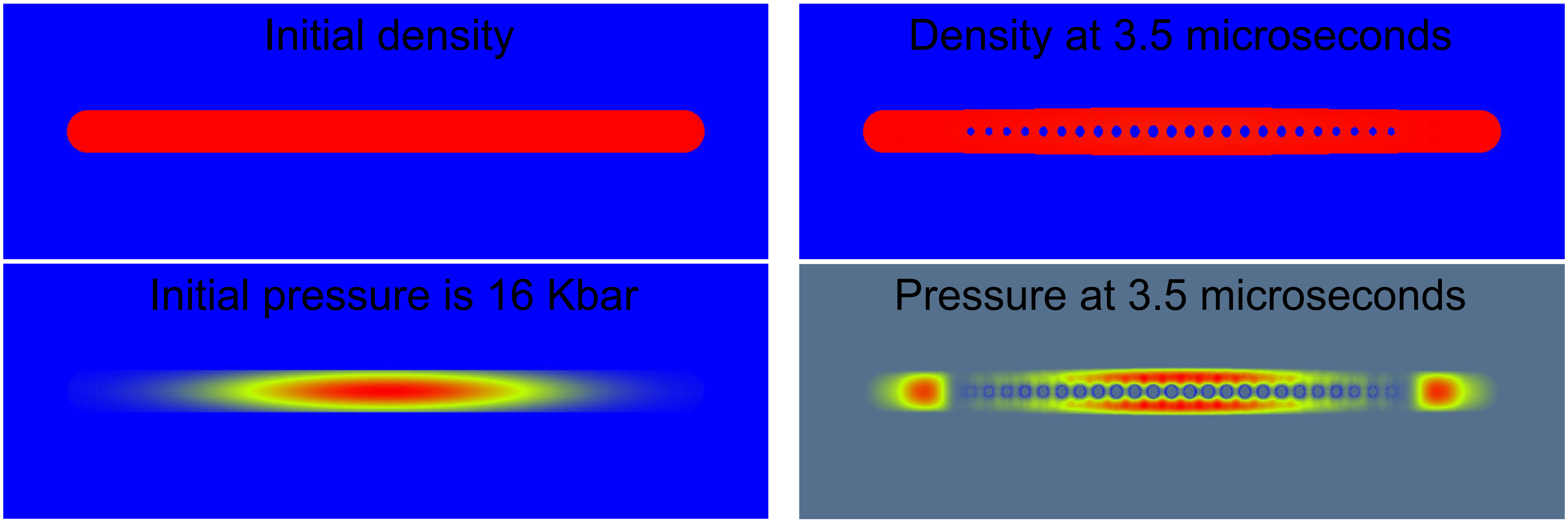
Jet smoothing

At B=19.3 T

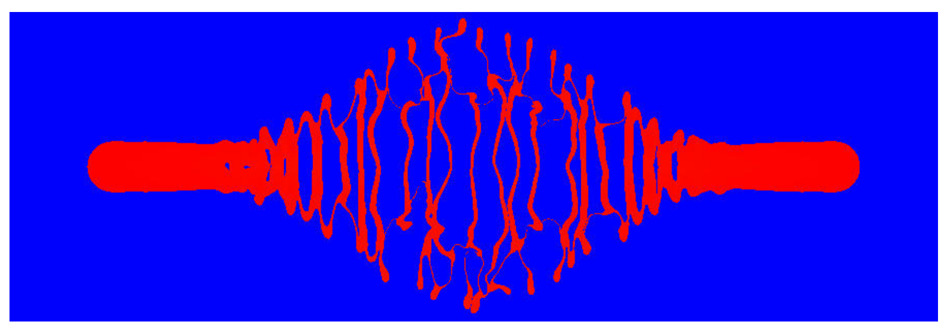
Tip shaping

Low resolution run with dynamic cavitation. Energy deposition is 80 J/g

R.Samulyak et al.



Density at 620 microseconds



Previous test series

- BNL&ISOLDE: proton induced shocks
- CERN at GHMFL: MHD
- no observation of combined effects of proton induced shocks and MHD
- one order off nominal parameters

	ISOLDE	GHMFL	BNL	TT2A	NuFact
p+/pulse	$3\ 10^{13}$	----	$0.4\ 10^{13}$	$2.5\ 10^{13}$	$3\ 10^{13}$
B [T]	---	20	---	15	20
Hg target	static	15 m/s jet (d=4mm)	2 m/s jet	20 m/s/ jet	20 m/s jet (d=10mm)
	DONE	DONE	DONE	OPTION	DESIGN

Experiment Site Considerations

- Nufact Study 2 Beam Parameters:
  - 16 TP (10^{12} Protons) per bunch 24 GeV, 1 MW Scenario
  - 32 TP per bunch (x2 rep rate) 24 GeV, 4 MW Scenario

BNL AGS capabilities

4 TP per bunch E951 experience

6 to 8 TP foreseen (with bunch merging)

No multi-bunch single turn extraction (g-2 rebuild)

Exp. area: E951

CERN PS capabilities

5 TP per bunch normal operation

7 TP multi-bunches foreseen (for CNGS)

Multi-bunch single turn extraction available

4 bunch flexible fill of PS from booster available

Exp. area: TT2A

Towards a nominal target

- LOI (Nov03) and proposal (May04) submitted to INTC
  - http://cdsweb.cern.ch/search.py?p=intc-2004-016

- perform a proof-of-principle test
  - NOMINAL LIQUID TARGET (not regarding rep. rate) for a 4 MW proton beam
  - in solenoid for secondary particle capture
  - single pulse experiment at CERN PS

Collaboration

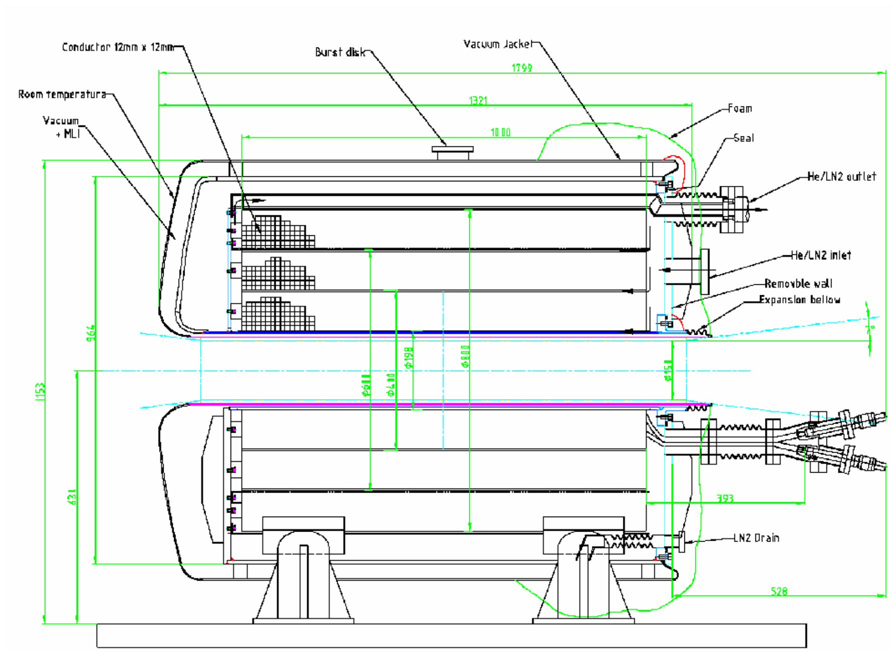
- Participating Institutes
  - Brookhaven National Laboratory
  - CERN
  - KEK
  - Oak Ridge National Laboratory
  - Princeton University
  - Rutherford Appleton Laboratory
  - …

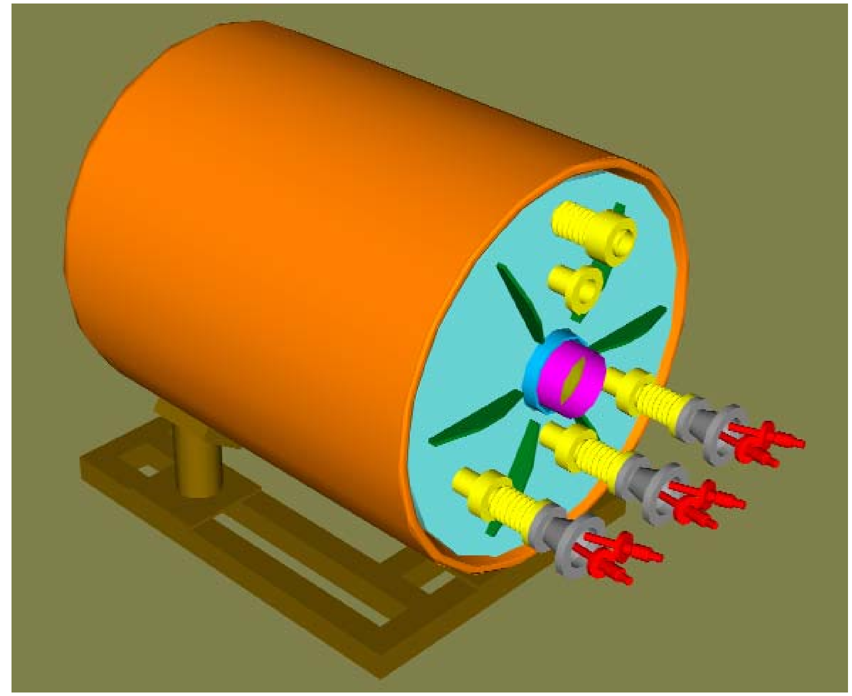
Sub-systems

- Solenoid
  - LN2 circuit
  - Power
- Jet chamber
  - Mercury circuit
- Diagnostics
- PS beam

SAFETY
BUDGET
TIME SCHEDULE

High Field Pulsed Solenoid





- 70 K Operation, LN2 cooled
- 15 T with 4.5 MW Pulsed Power
  - 1 second flat top
- 15 cm warm bore
- 1 m long beam pipe

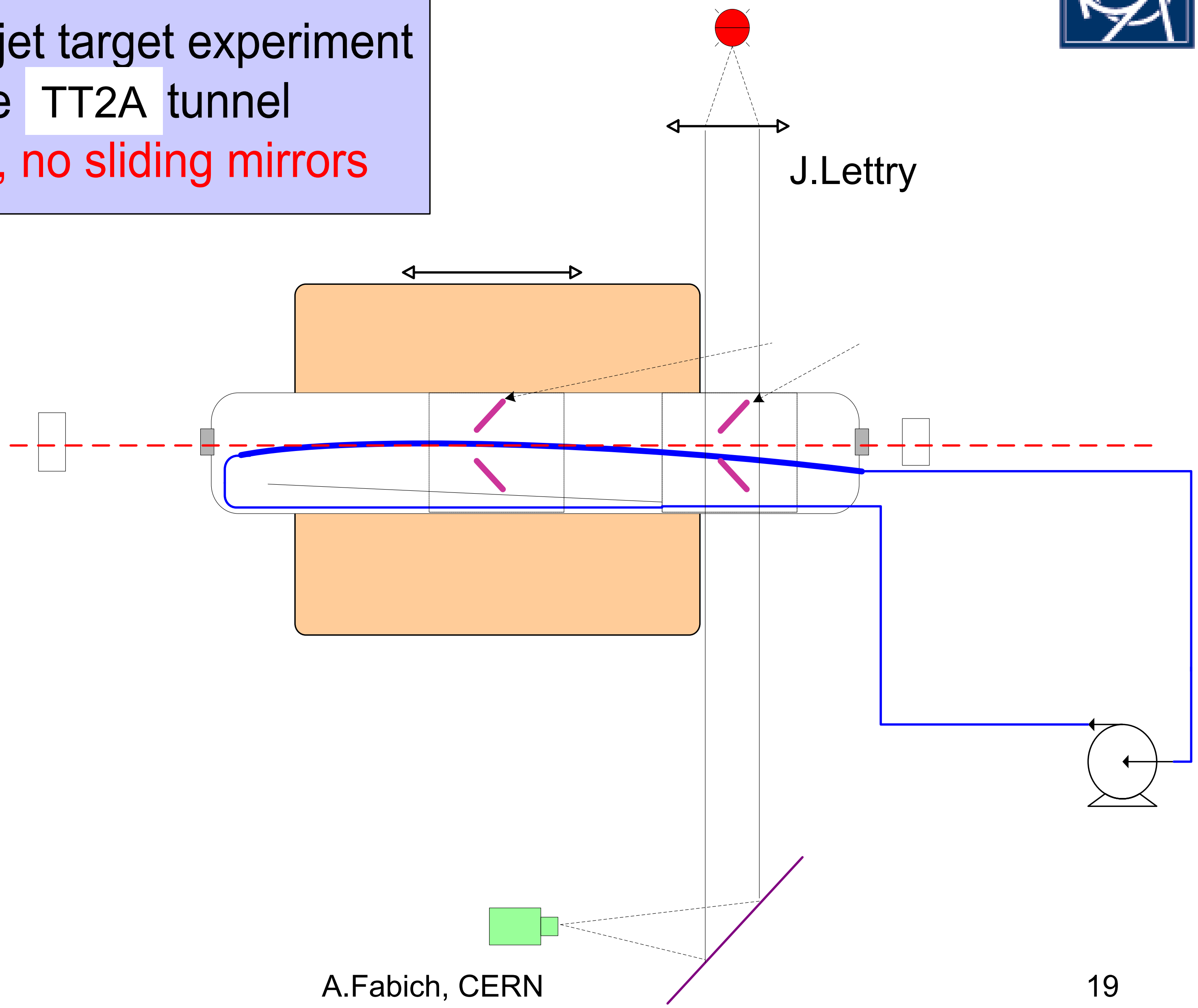
Peter Titus, MIT

Construction started

Nufact Hg-jet target experiment in the TT2A tunnel

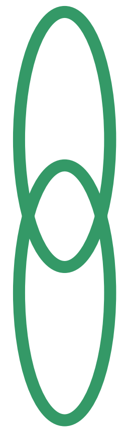
classical, no sliding mirrors

J.Lettry



Varied parameters

- parameters to vary:
  - Magnetic field (0-15 T)
  - Pulse intensity (1-25 10^{12} p.o.t.)
  - Pulse length (0.5-2 μs)
  - ~~Spot size~~
  - Beam position (±5, 1 mm)

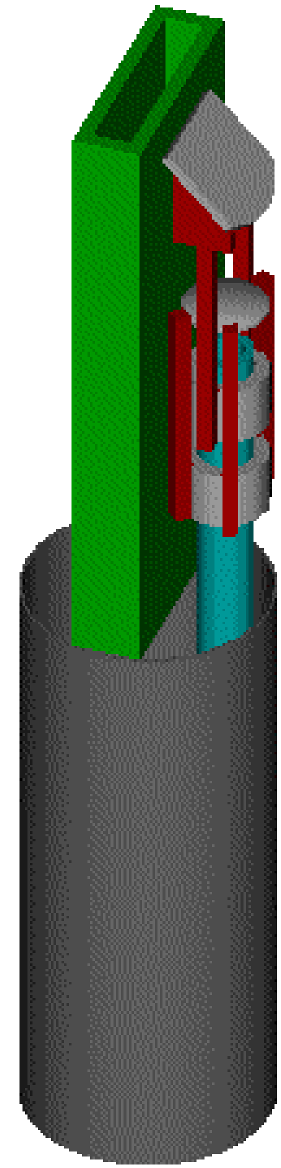


- Total number of pulses on target (without tuning): <100
- Needs ~3 weeks of beam time

- Diagnostics:
  - Optical system with high-speed camera
  - Particle detector: interaction efficiency

Optical read-out

- Based on experience from GHMFL
  - Use similar setup
- High-speed camera: >10k frames/s
- Light path
  - Source: laser, a few mW
  - Inserted via glass fiber
  - Optical lens to get large parallel beam
  - Deflected transverse the Hg jet by mirror
  - Second mirror guides light towards camera
- Shadow photography

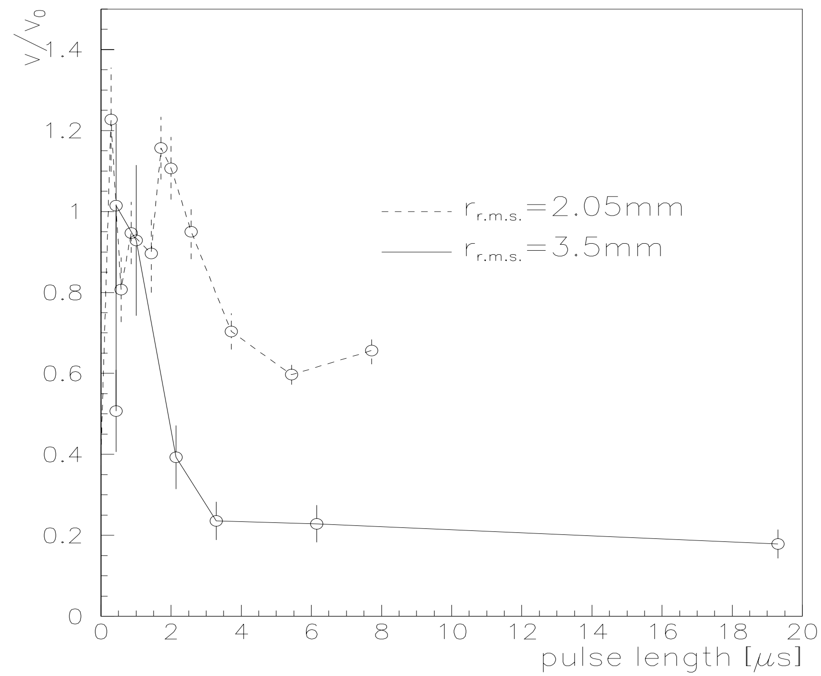


From GHMFL: we can fit the optical system in this very small space
From ISOLDE/BNL: we can record at a distance of at least 15m

OPTICAL READ-OUT is BLIND in case of a perfect jet!

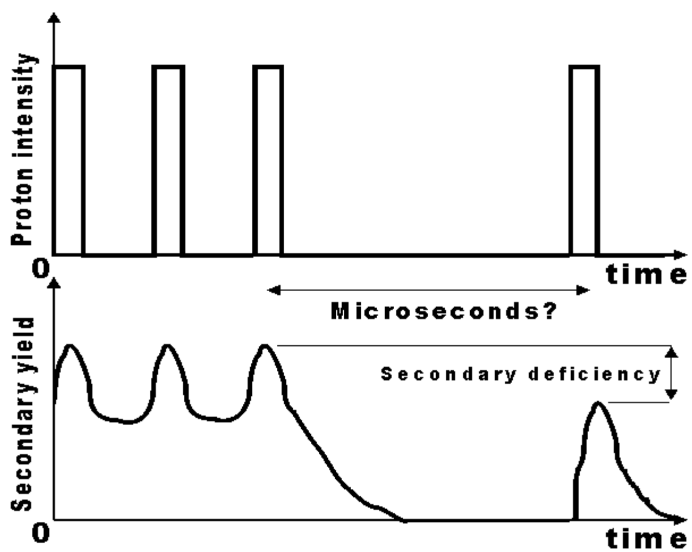
Cavitation in Liquid targets

- Cavitation was already "observed" at ISOLDE
  - Unfortunately only indirect observation by splash velocity
  - No observation of sec.particle yield
- Does it reduce the secondary particle yield?
  - Most probable not an issue for American design, but for facilities using "long" pulses



PS beam

- momentum p = 26 GeV/c
- 4 bunches within 8 PS buckets at our discretion
- t_{pulse}= 0.5-2 microseconds
- t_{bunch}=50ns full length, peak-to-peak 250 ns
- spot size at target: r<2 mm r.m.s.



Pump-Probe method
for cavitation studies

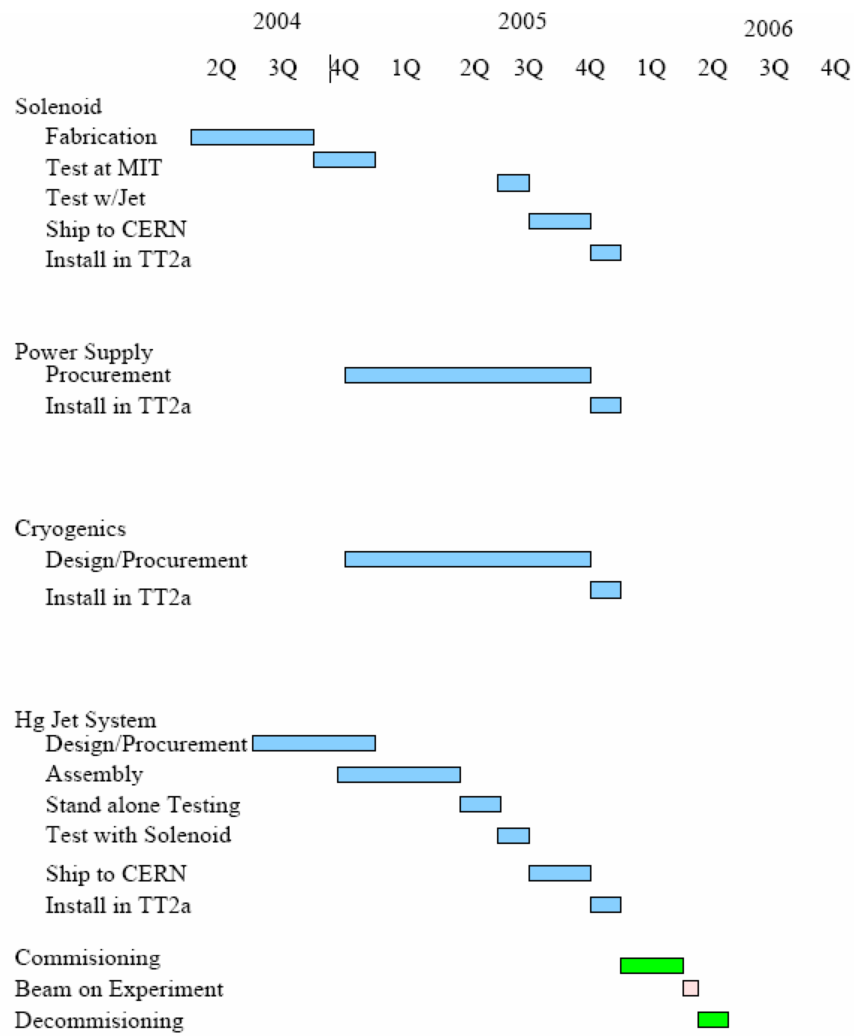
Secondary particle yield measurement

- measure interaction efficiency either by
  - Radiation monitors
  - Disappearance of primaries
    - Pick-up monitor downstream of target
  - Appearance of secondaries
    - total particle yield within
    - Partly coverage of solid production angle sufficient
    - Off-axis
    - Detector
      - Simple, e.g. scintillator
      - radiation hard or installed far

Time schedule

- 2003
  - Autumn LOI
- 2004
  - March detailed study at CERN
  - Spring solenoid constr. launched
  - Spring proposal to INTC
- 2005
  - January solenoid delivered to MIT
  - April solenoid test finished
  - June solenoid shipped to CERN
  - September test at CERN
- 2006 April final run at PS start-up

Budget: ~2.5 M$



Conclusion

- Studies on solid targets are ongoing, but these are not suitable for a beam power >1.5 MW
  - Possible approach: rotating target
- Step-by-step R&D on liquid jet targets has been very successful.
- needed proof-of-principle test
  - jet target in a magnetic field exposed to a proton beam