The mercury jet target for neutrino sources

A.Fabich, CERN AB-ATB

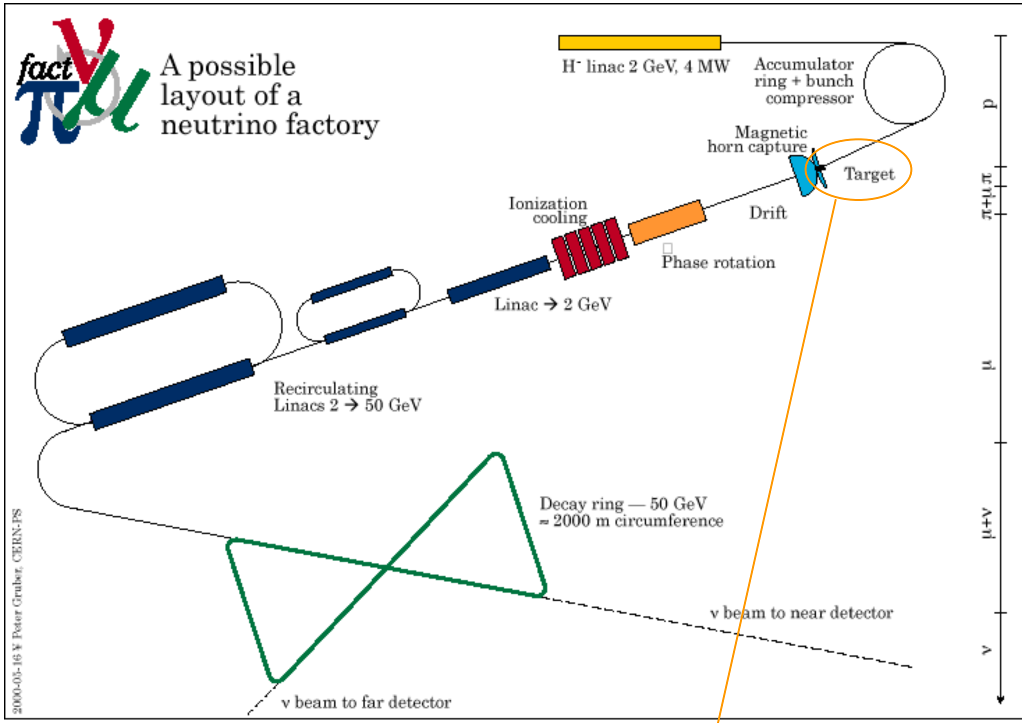
The Neutrino Factory

- Production process:

  $p + p \rightarrow \pi^{\pm} \rightarrow \mu^{\pm} + \nu_{\mu}$

  $\hookrightarrow e^{\pm} + \nu_{e} + \bar{\nu}_{\mu}$

- Ultimate tool for neutrino physics
- Physics demand 4 MW proton beam
  - Pion yield is in first order a function of the beam power only



Target for a primary 4 MW proton beam in order to produce pions

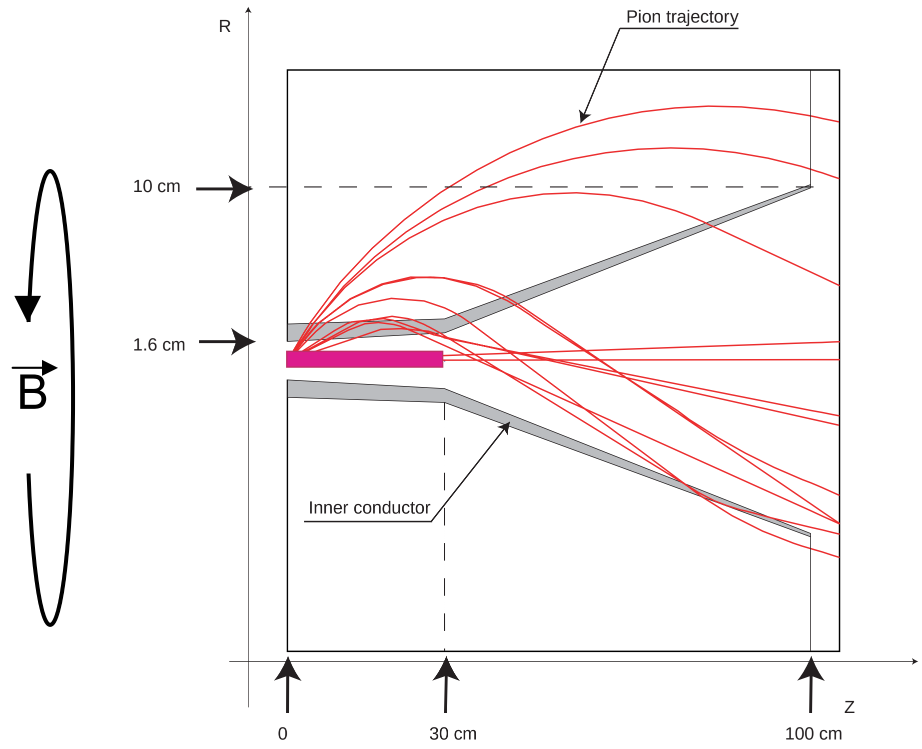
- "smaller" ν-sources:

  super beam (CNGS, MINOS, …)

Target Station

- Focusing device

  Magnetic horn
- Also used in superbeams



A target for pion production

- Size:
  - compromise between production and reabsorption
  - Point like source preferred (High density material)

$$\Rightarrow \text{Length}_{\text{target}} \approx 2\ \lambda_I$$

$$\Rightarrow\ \varnothing_{\text{target}} \approx \text{few cm}$$

similar to a neutron converter?!?!

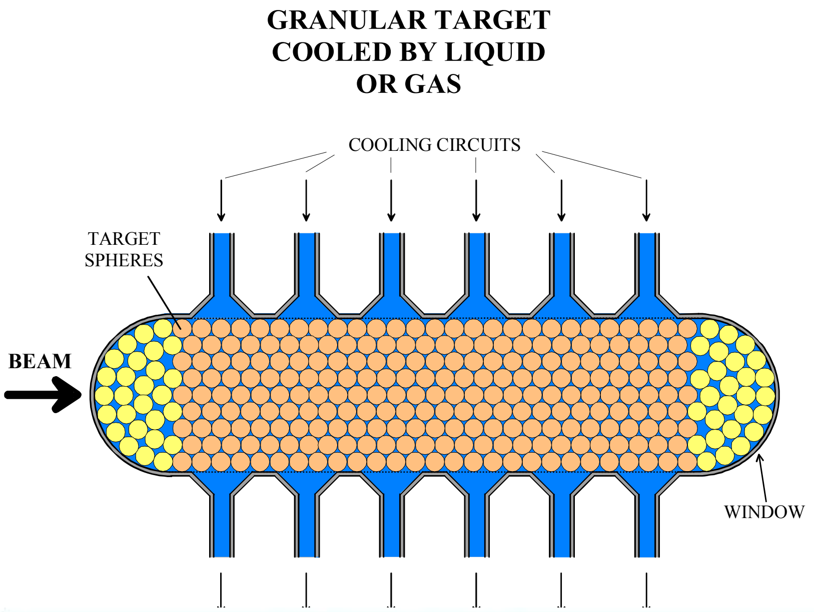
- High Z material increases pion yield

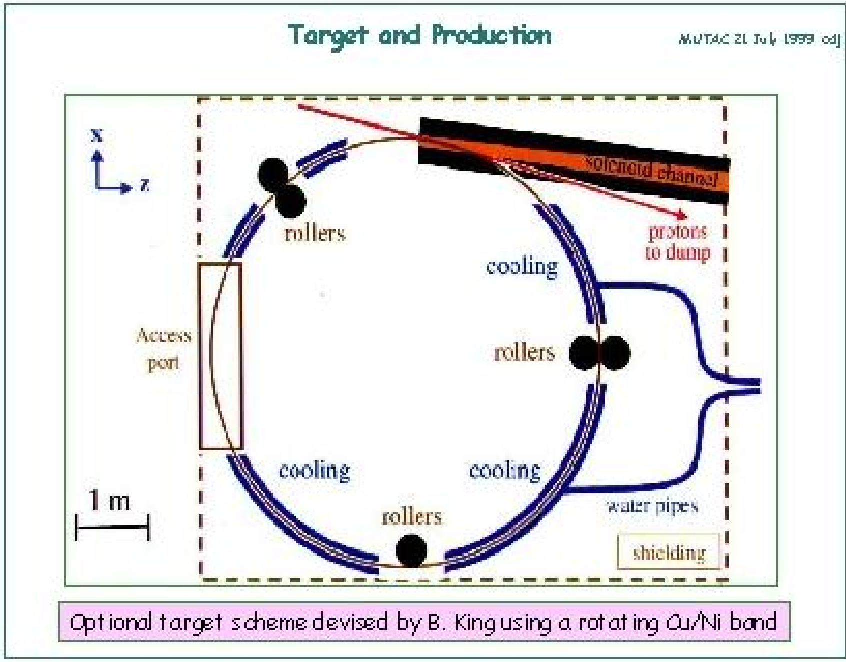
$\Rightarrow$ lead, mercury, …

Target Layout

1) Solid
- Static rod
  - Known technology
  - Won’t withstand 4 MW?
- Granular target
- Moving solid: rotating band/chain
  - Analogon to rotary anode of X-ray tube
  - mechanically feasible?

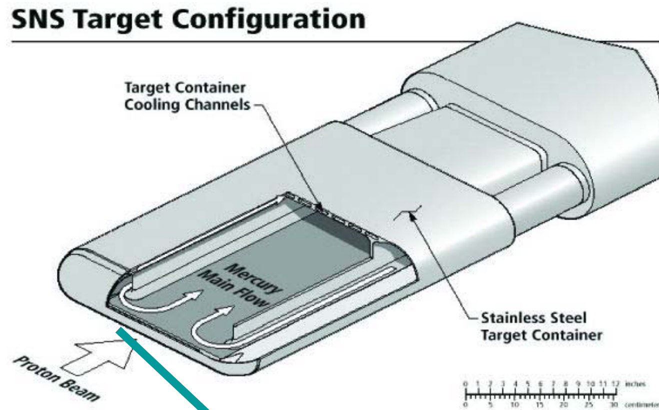
2) Liquid
- Internal stresses are no issue
  ⇔ replace with each proton pulse
- Passive cooling



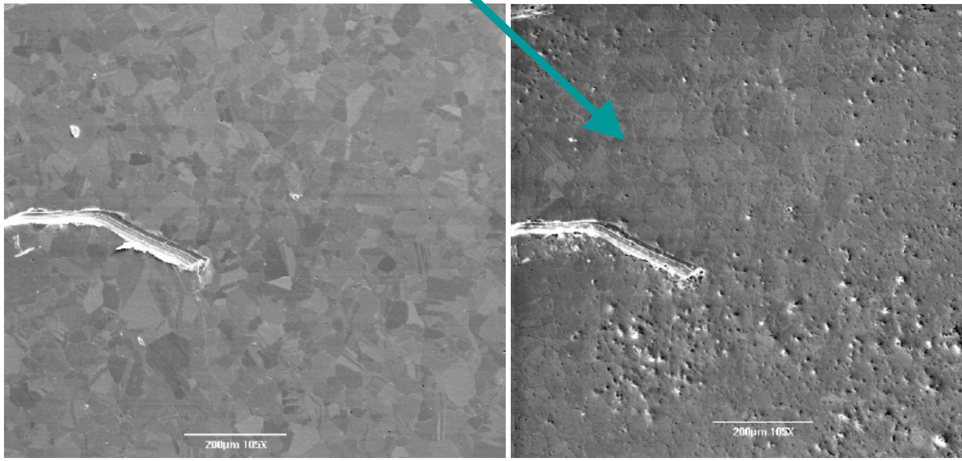


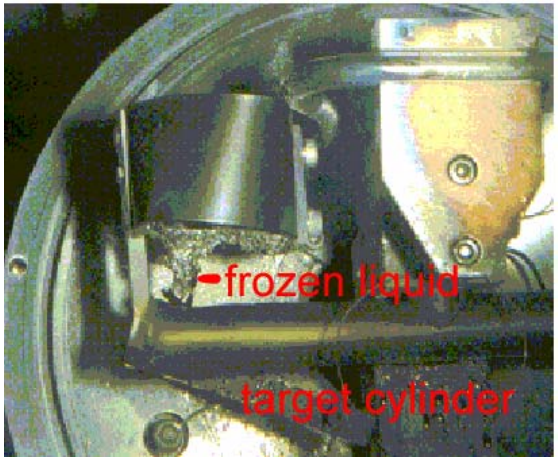
Optional target scheme devised by B. King using a rotating Cu/Ni band

Beam Window



- **Critical Issue**
  - High energy deposition by primary beam
    In beam window
  - Cavitation induced in target material
    causes pitting and
    rapid failure of beam window





solution:

- staggering
- increase spot size

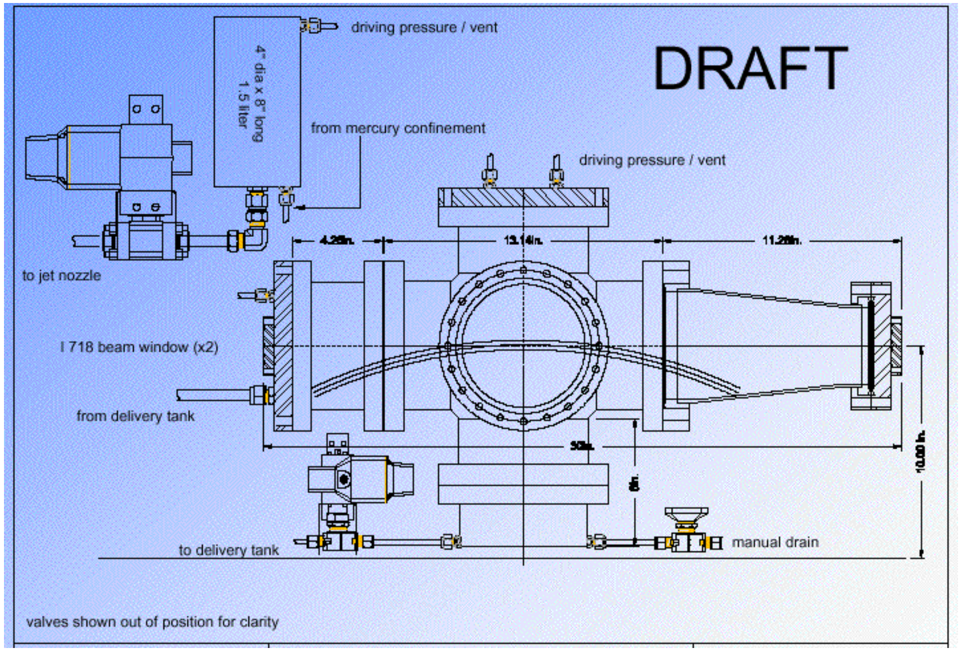
ISOLDE confined liquid target

Target w/o Beam Window

avoid direct contact of target with beam window

Mechanical Solution:

1) vat (with vertical beam)
2) jet (free flying target)



Mercury

- High Z
- Easily available
- Liquid at room temperature

  Very convenient for R&D
- Remove radioactive isotopes by distillation
- “only” compatible with INOX/Titanium

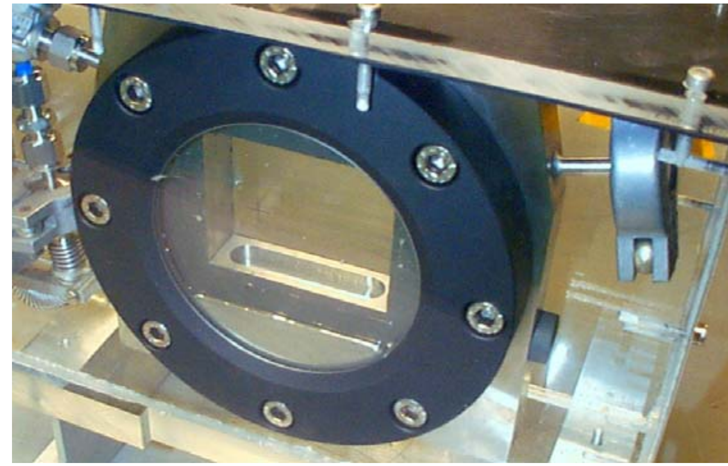
Nominal jet parameters using mercury:

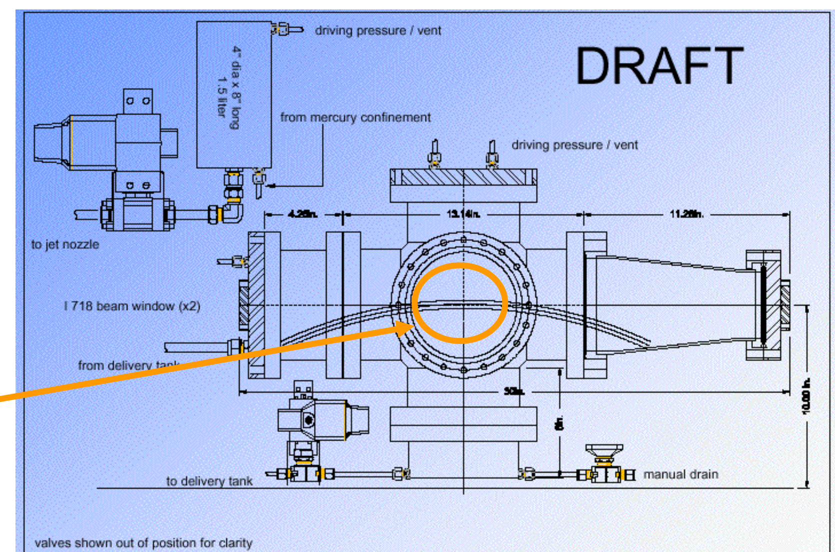
- **intersection beam-target: L ≈ 30 cm**
- $\varnothing_{target}$ **≈ few cm**
- **v = 20 m/s (from repetition rate f=50 Hz)**

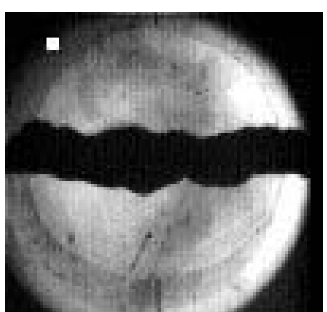
R&D

- Investigate behavior of liquid targets with free surface
- Observe surface movements
- Done within last two years at CERN & BNL
  - Experimental conditions one order of magnitude below nominal parameters
- Exp. target configurations
  - Static: **thimble & trough**

    simplify experimental setup
  - **jet**





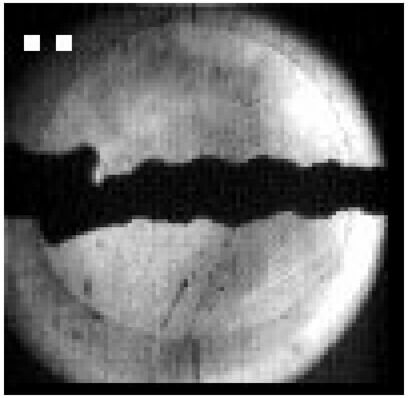


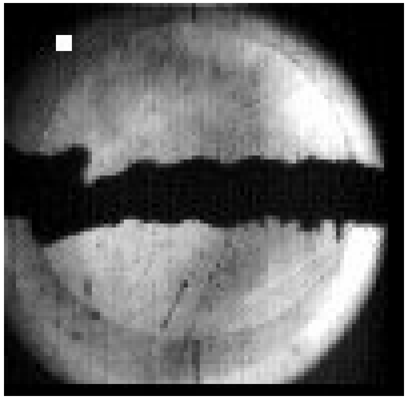
view of optical read-out

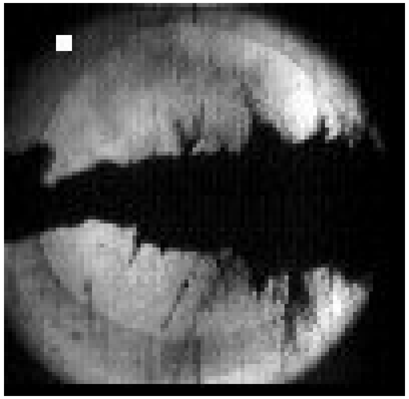
Jet test at BNL E-951

K. Mc Donald, H. Kirk, A. Fabich, J.Lettry

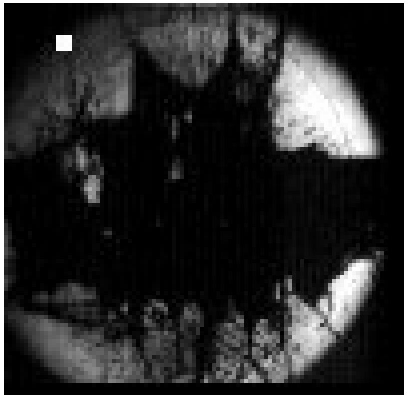
Event #11   25th April 2001







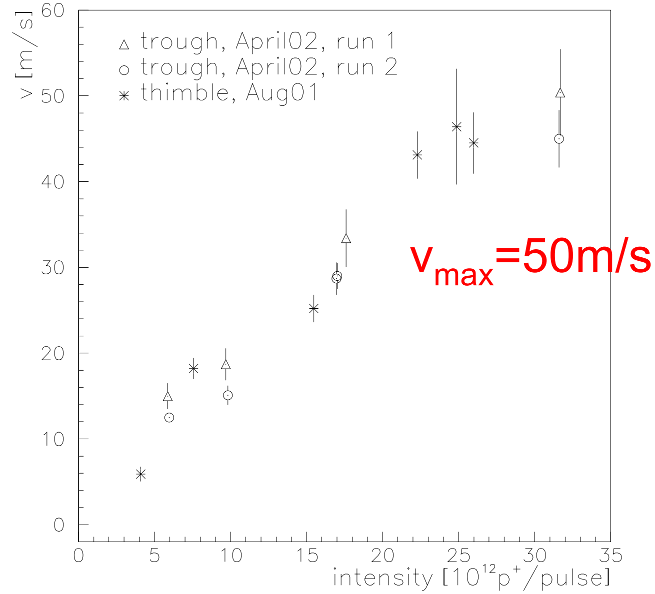
Picture timing [ms]
0.00
0.75
4.50
13.00



P-bunch: 2.7×10^{12} ppb
100 ns
t_o = ~ 0.45 ms

Hg- jet : diameter 1.2 cm
jet-velocity 2.5 m/s
perp. velocity ~ 5 m/s

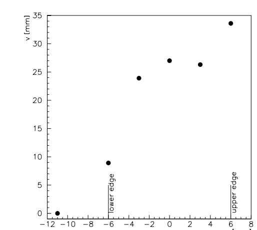
Experimental Results



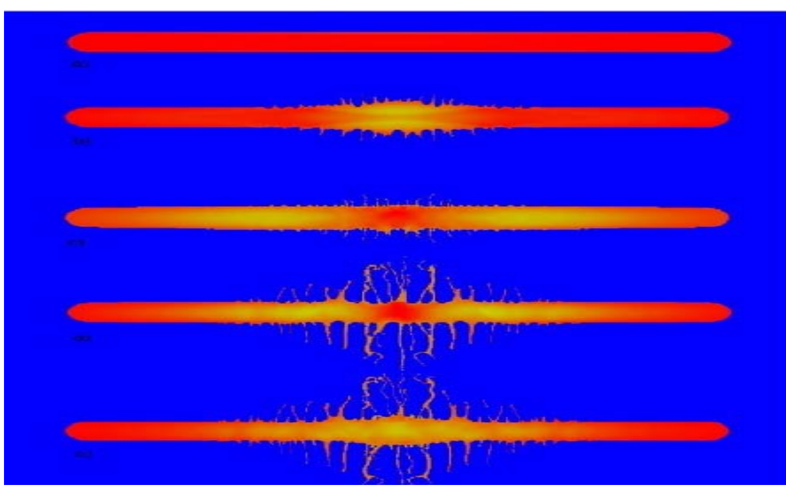
1) Scaling laws for splash velocity in order to extrapolate to nominal parameters

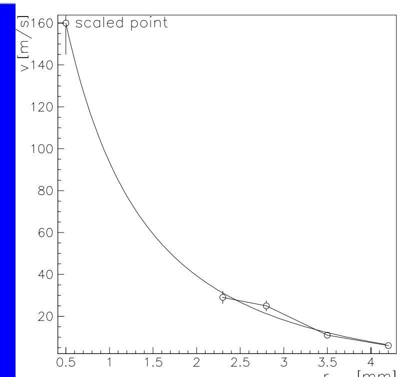
   Beam variables: pulse intensity, spot size, pulse length, pulse structure, beam position

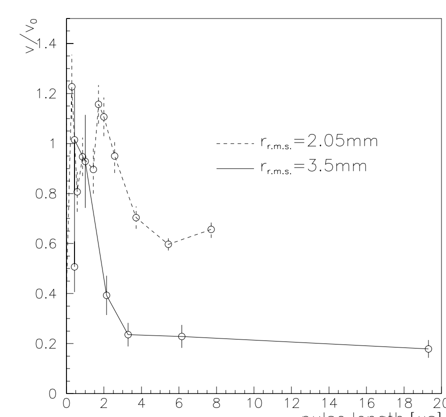
2) Benchmark for simulation codes



R.Samulyak, FRONTIER







- Jet target is a valid option used in a high power proton beam

- Hg jet for EURISOL:
  - less space restrictions
  - neutron yield, not pions
  - no material constraints
  - DC beam results in lower splash

- Presently ongoing (US):
  - Establish a nominal jet:

    v=20 m/s permanent flow

      a few ten kW energy stored

      Flow rate ~ 50 Liter/s