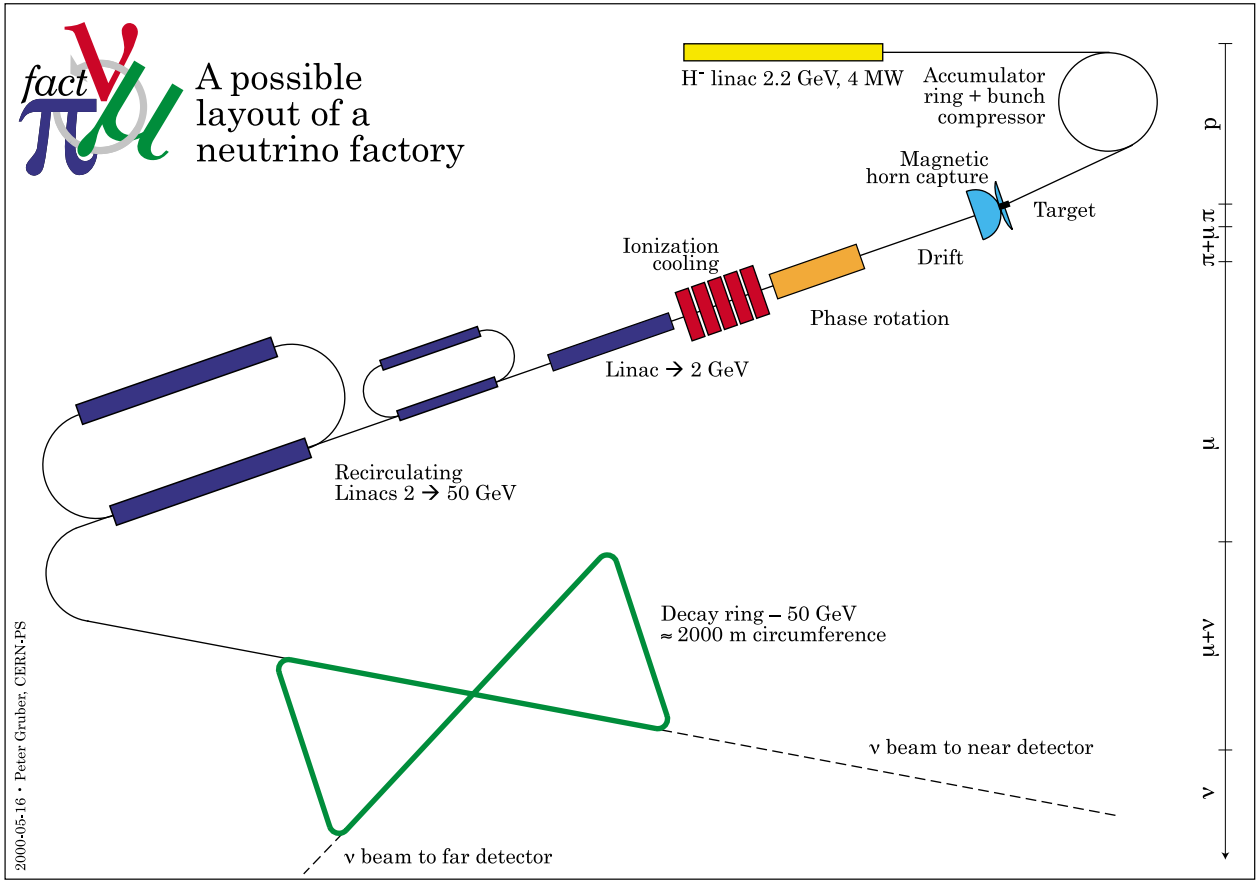
The Pion Production Target for a Neutrino Factory

A. Fabich, S. Gilardoni

Geneva, February 2000

Neutrino Factory



Outline

- basic parameters of proton beam and target
- pion capture
- target properties
  - possible solutions
- liquid target

Requirements by Physics

for the pion production target

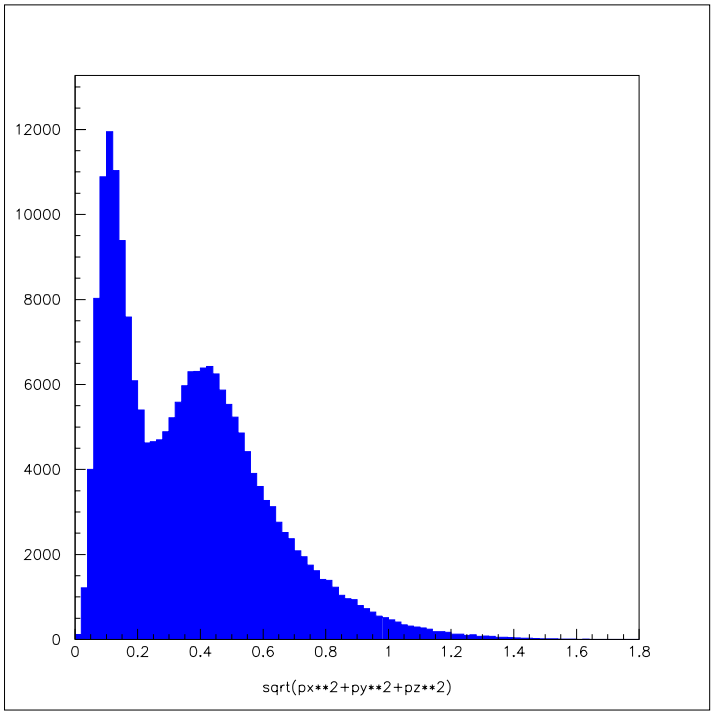
Pion production via Δ resonance:
p + N $\rightarrow \Delta \rightarrow$ N + $\pi^{\pm}$

- length: $2\ \lambda_I$ ($\rightarrow 75\%$ interacts)
- diameter: $2.5\,\sigma$ of p-beam spot size $r \approx 1.5\,\mathrm{cm}$
- target element not important, but $Z \propto \frac{1}{z}$
- ratio $\frac{\pi^+}{\pi^-} \rightarrow 1$ at high Z

small compared to ESS/SNS, due to absorption
NuFact: several litres
ESS/SNS: $\approx 30\,\mathrm{l}$ (total $2\,\mathrm{m}^3$)

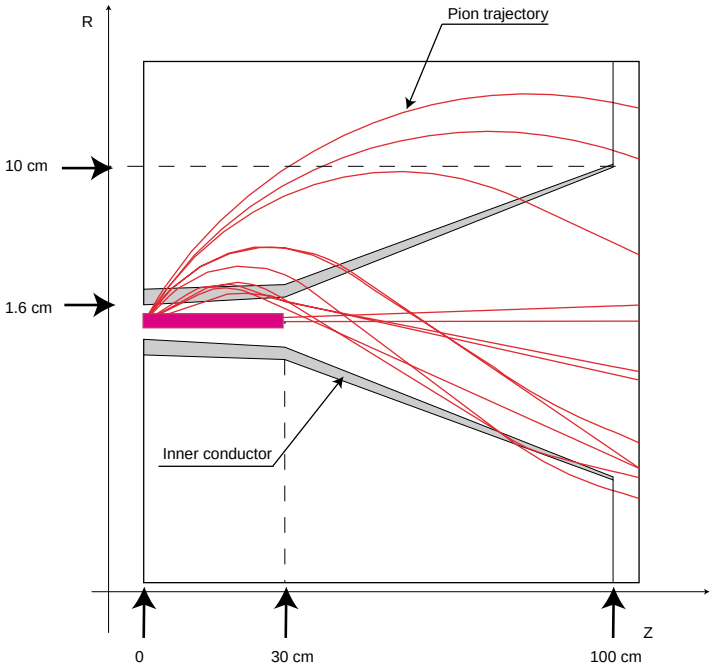
Proton Beam

- $2.2\,\mathrm{GeV}$
- $4\,\mathrm{MW}$
- $1.4\,10^{14}$ p/bunch
- $75\,\mathrm{Hz}$ repetition rate
- $r \approx 1\,\mathrm{cm}$ r.m.s.



p_{tot} of pions at target

Pion Capture (1)



see

http://pgruber.home.cern.ch/pgruber/nufact/gru

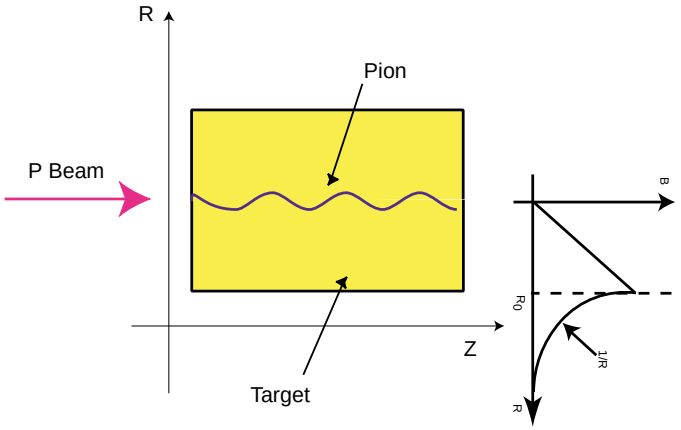
page 21, adiabatic solenoid
20 T in solenoid

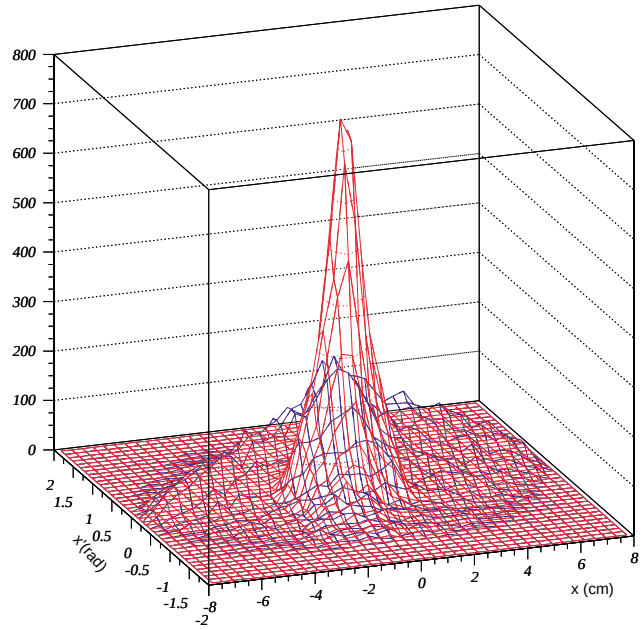
no magnetic field inside

up to 3 T in volume

Pion Capture (2)

Pulsed Target: magnetic field by high current through target





current: 1 MA

ϵ of solenoid/pulsed target

Target Properties

- element
- solid, liquid, gaseous
- moving, static

technical problem of impact of one p-pulse on the next one

- withstand power deposition
  - by proton beam - by current (pulsed target)
  $\Rightarrow$ thermal-mechanical shock
- impact of magnetic field

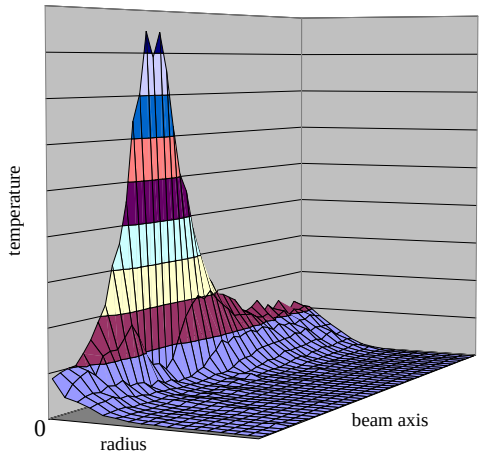
Energy Deposition

by proton beam

$\approx 0.5\,\mathrm{MW}$

always the same for given beam

- $z_{peak} \approx 0.5\lambda_I$
- $\Delta T_{peak} \in [10^2, 10^3]\,\mathrm{K}$



by current of pulsed target

$1\,\mathrm{MA} \rightarrow 1\,\mathrm{MW}$

corresponds to two times $\frac{dE}{dx}_{proton}$

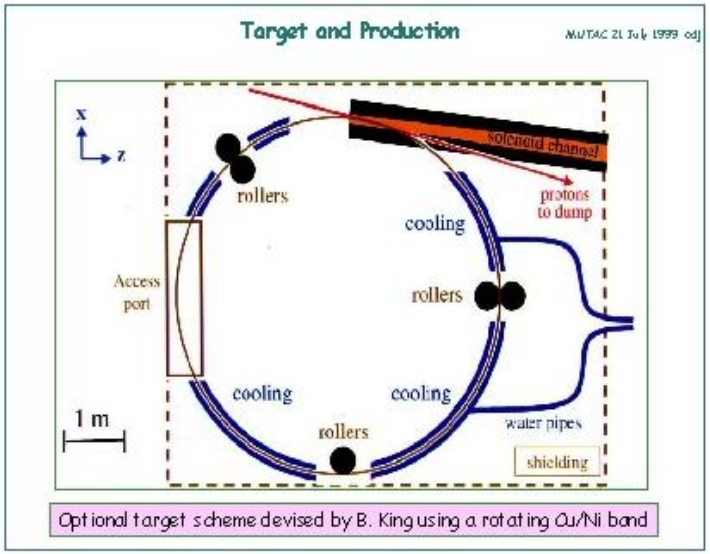
Solid Target

- +
  - a fixed shape
  - easier handling
- -
  - thermal-mechanical shock $\rightarrow$ disruption
  - radio-isotopes: mass-separation not easy

Solid Target

- static: carbon rod
  - length $80\,\mathrm{cm}$
  - tensile strength sufficient?

- moving: metal band
  - circumference $\approx 20m$
  - velocity $20\,\mathrm{m/s}$



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

Liquid Target

because of instability due to energy deposition target exchange needed

- +
  - replaceable after each impact event
  - destruction allowed
  - mass separation easier
    - by distillation/filtering
- -
  - handling in case of hazards

Liquid Jet

- material: mercury, lead, ..., molten metal
- replaced after each impact
  - assure a target at $75\,\mathrm{Hz}$
  - velocity $\approx 30\,\mathrm{m/s}$
  - injection
  - recover

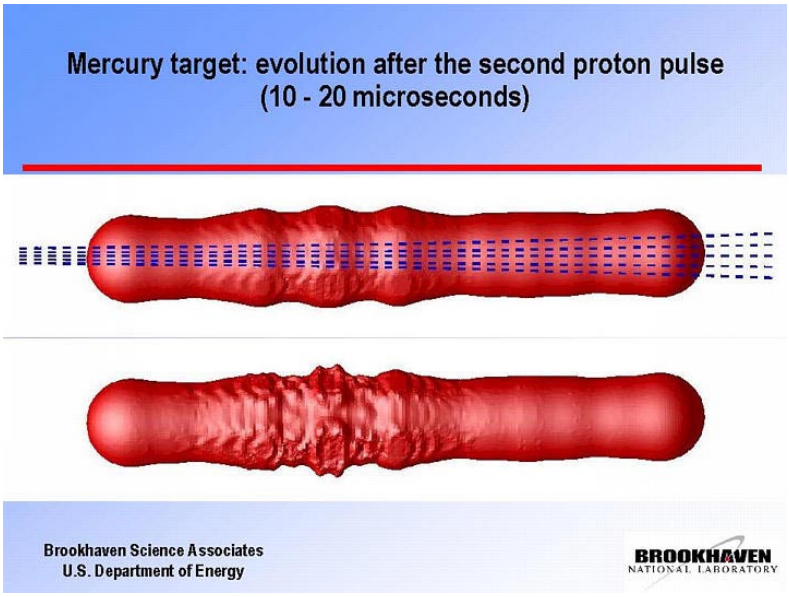
mercury jet

- density $13\,\mathrm{kg/l}$
- interaction length $13\,\mathrm{cm}$
- target mass $\approx 3\,\mathrm{kg}$

Effects on Metal Jet

- proton impact
  $\Rightarrow$ thermo-mechanical shock-waves $\Rightarrow$ surface velocities up to $50\,\mathrm{m/s}$
- magnetic field
  $\Rightarrow$ repulsion at injection into B-field
  $\Rightarrow$ distortion in B-field

Thermo-mechanical shock

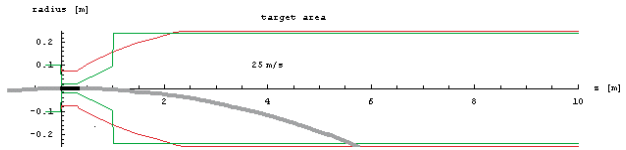


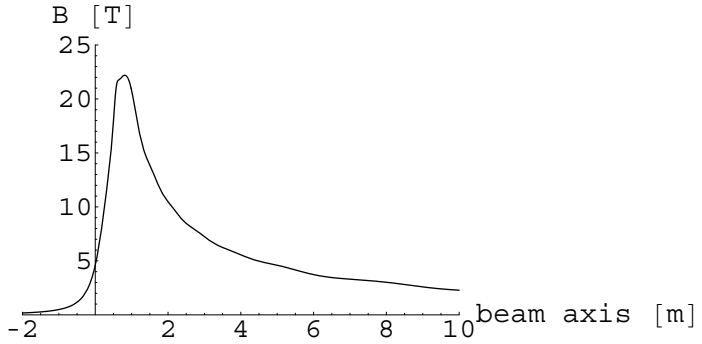
credit: R. Samulyak (BNL), simulation with FronTier code

Magnetic Field

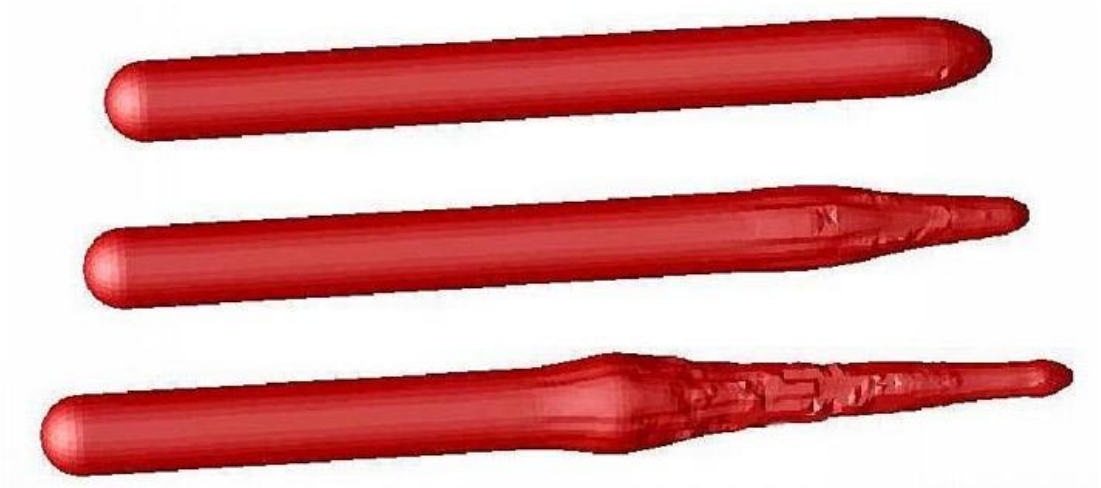
only in case of solenoid (pulsed target)

- squeezing/distorting of Hg in gradient field
- pinching in solenoid



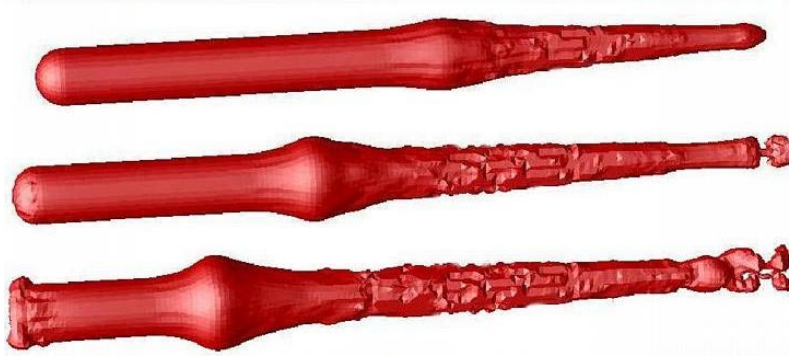


Entering Solenoid



credit: R. Samulyak

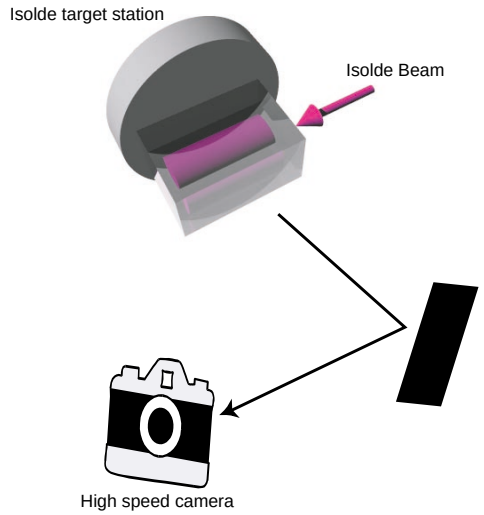
Leaving Solenoid



credit: R.Samulyak

Experiments at CERN

- liquid metal jet in magnetic field
- in-beam tests at Isolde



Safety Issues

- p→4 neutrons
- radiation
  LEP was peanuts!
- Hg handling
  - Hg is toxic
  - radioisotope production

