Experiments with liquid jets

C. Johnson
CERN

History
CERN Mercury Jet Target - version 1985

Muon Collider Collaboration
Targetry Workshops 1997-99

CERN Mercury Jet target - version 1999
Experiments with liquid jets

History:

1984 CERN High power targetry for pbar production - solid target

Then in 1985 studied series of pulsed-current targets to improve pbar yield by factor 2-3

A. Poncet proposed self-switching target in form of Hg jet and constructed prototype
Experiments with liquid jets

Muon Collider Collaboration
default solution for target
is liquid-metal jet ⇒

Other options studied:

Tungsten powder target

Band saw target

Liquid slurry jet

Problem with W slurry ⇒
Experiments with liquid jets

Proton flux: \(3 \times 10^{15} \text{ protons cm}^{-2} \text{ s}^{-1}\)

After 1 month of use the specific activity of a heavy metal fixed target (\(3 \pi\)) would be:
And the total activity:

For a liquid target the specific activity would be greatly diluted - useful if manual intervention considered.

The dose rate at 1 m from the fixed target (1 day decay time)

If the target is water cooled then the from a typical closed-circuit heat exchanger the equilibrium dose rate at 1 m would be

The total activity of volatile spallation products (e.g. xenon, iodine) would be:

These would have to be captured in the target enclosure air/vacuum system

\begin{align*}
\text{Si} & \quad \text{old units} \\
\text{Si} & = -3 \times 10^{12} \text{ Bq g}^{-1} \\
& = -5 \times 10^{15} \text{ Bq} \\
& = 1.3 \times 10^9 \text{ Ci} \\
\text{Si} & = -100 \text{ Sv h}^{-1} \\
& = 10^4 \text{ rem h}^{-1} \\
\text{N.B. 10 X for the Beam Dump} \\
\text{Si} & = -1 \text{ to } 3 \text{ Sv h}^{-1} \\
& = 100 \text{ to } 300 \text{ rem h}^{-1} \\
\text{Si} & = -10^{12} \text{ Bq} \\
& = 270 \text{ Ci}
\end{align*}
Experiments with liquid jets

Isodose contours show radiation dose in rad/h for 1.5 x 10^{16} protons on target (from A.H. Sullivan) based on measurements in AA and ACOL target areas.

Plan production target and capture solenoids
Experiments with liquid jets

The extremely high induced activity levels may well provide the overriding reason for the use of a mercury jet target.

The specific activity is greatly reduced compared to a fixed target (the "bandsaw" target is somewhere between the two).

In addition, as proposed by Helge Ravn, the mercury would be distilled to remove most non-volatile spallation products. Volatile products would also be removed from the target area into filters or tanks.

Remember that the tungsten shield around the target must absorb 10 times the beam power in the target itself. A beam dump incorporated into this shield would resemble a spallation or transmutation source target - i.e. another liquid metal system (possibly Hg).

For these reasons we decided to re-construct the Hg jet target. (gallium/tin and gallium/indium room-temperature liquid metals have been studied. They both have undesirable wetting properties (at least for lab tests) and the former produces an oxide scum)
Experiments with liquid jets

Model liquid-metal jet target
CERN 1999
Experiments with liquid jets

Model jet target
Experiments with liquid jets

- nozzle
- fast pneumatic valve
- model Hg-jet
- target
Experiments with liquid jets

New jet target delivers 30 ml of liquid per shot at pressure from 0 to 100 bar
Single-shot or up to 15 Hz repetition rate

Tested with water.
Awaiting minor modification before filling with mercury.

Then study hydrodynamics as function of:
  pressure
  time
  nozzle size and length
Later - magnetohydrodynamics in 20 T solenoid field and
  Shock effects in beam