Target Studies for high power proton beams

Particular issues

on the

experimental layout

Experienced at GHMFL/ISOLDE

Contents

- Experiences gained at ISOLDE & GHMFL
  as input for forthcoming experiments
- Concerns only
  - Liquid target = mercury
    - In-beam
    - Magnetic field measurements
- Concept, design, layout, assembling, operation, safety, costs

In-Beam test

- Experimental Chamber
- Optical Read-Out
  - Very similar to Jet Setup
- not discussed here
- Relevant items mentioned in talk

Jet Setup

- Pump station (not discussed here)
- Jet Chamber
- Mercury return flow
- Optical read-out

SAFETY

- Double confinement
  - Outer one not gas tight
  - Not to be broken outside …
- Dedicated Hg laboratory
  - Equipped with safety material (mask, aspirator, gloves, …)
- Mercury waste stream
  - Minimize mercury quantity
  - Quasi-continuous pump ($V_{Hg} \sim r^2 * \pi * v * t \sim 1 l/s * t \sim$ a few liter)
  - To be defined/proven in advance
    - Distillation: minimize waste stream
    - Solidification: demanded by Swiss authorities
    - ultimate repository: provided by –" –
- Minimize number of pulses (<100)
- human exposures
  - During installation, interventions, demontage

Materials

in contact with liquid mercury

- Stainless Steel (316LN)
- Makrolon (LEXAN),
  - no visible darkening after exposure to ~40 pulses
- quartz glass
- EPDM (seal rings)
  - radiation hard to our needs

In magnetic field and in radiation area

Jet Chamber

- Overall 3 different designs (evolution)

    double confinement

    return mercury flow

    optical read-out

    easily decomposable

jet orientation:

Horizontal	Vertical	
return:		
passive	suction	pressurized

Jet Chamber (top view)

- Basic principle for all designs:

✓ inner chamber for jet

Connected by

Straight nozzle

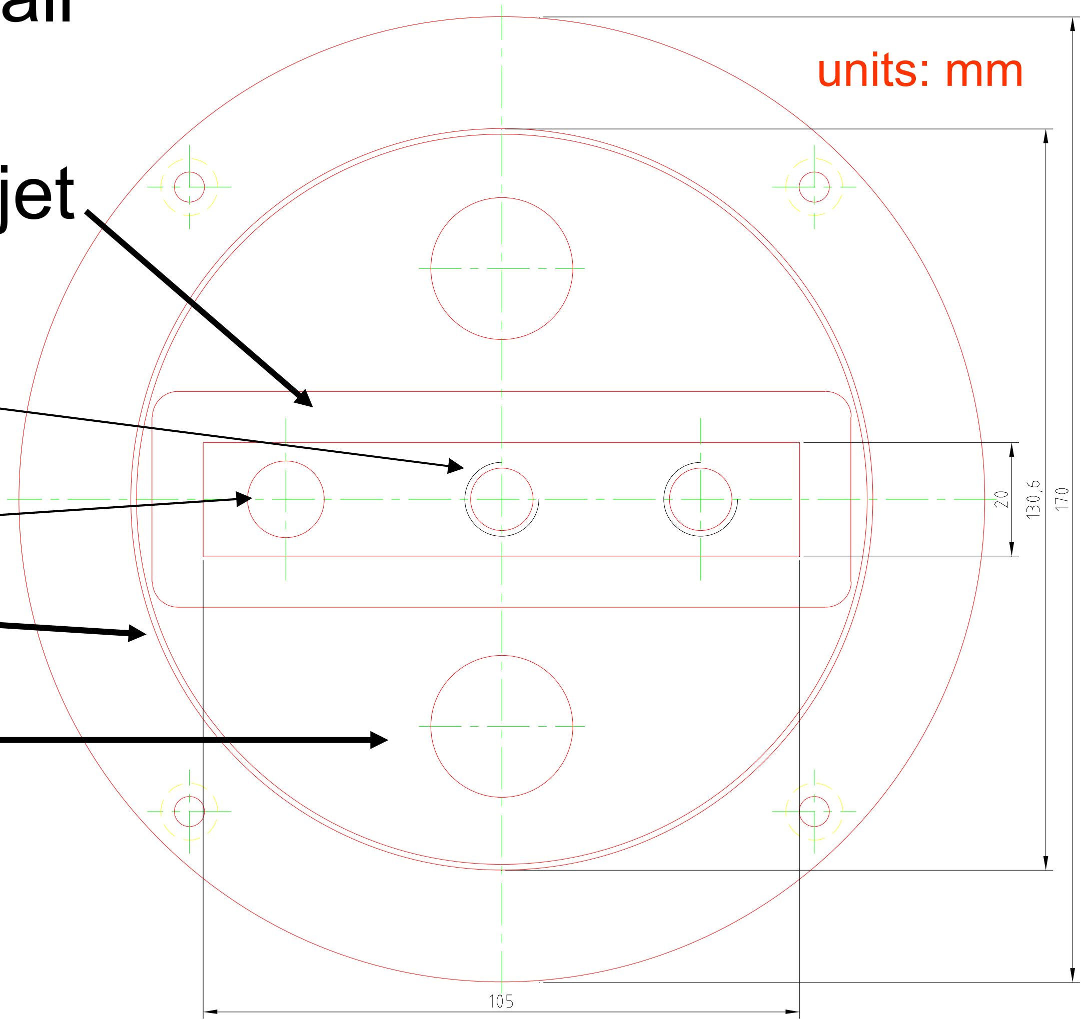
Tilted nozzle

Return pipe

✓ outer inox tube

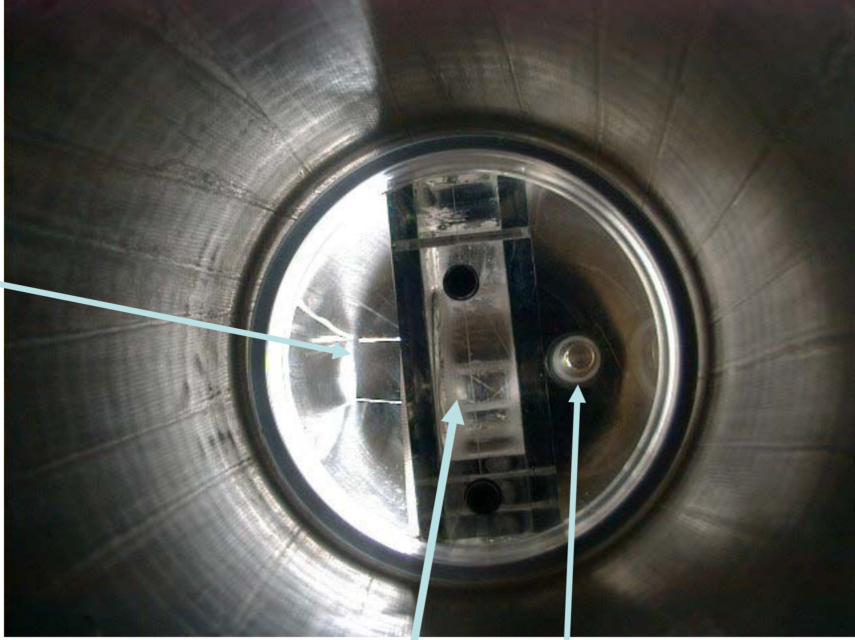
✓ Optical ligth path

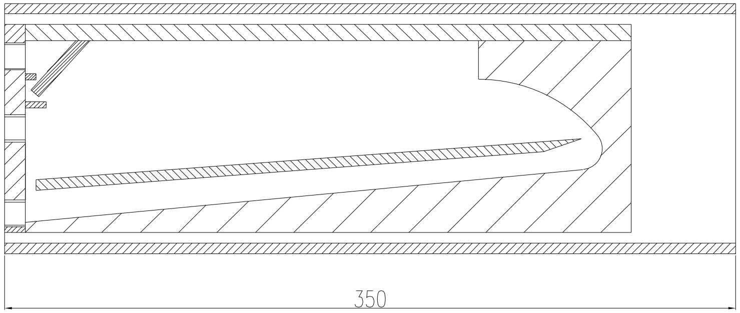
+ mirror(s)

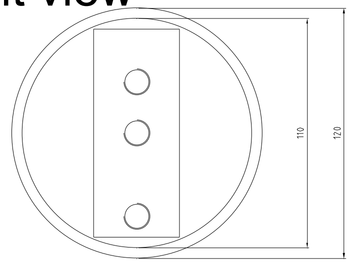


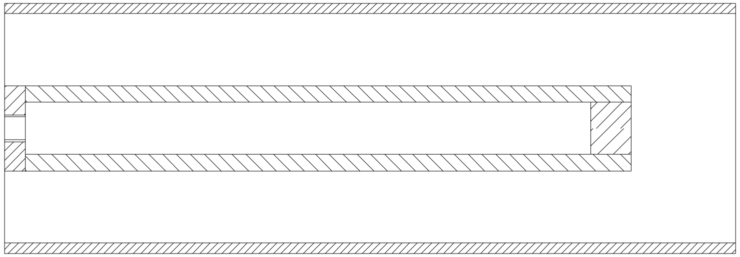
Jet Chamber Version 1

LIS laboratory (CERN)
- solenoid, 1.5 Tesla
- Horizontal bore





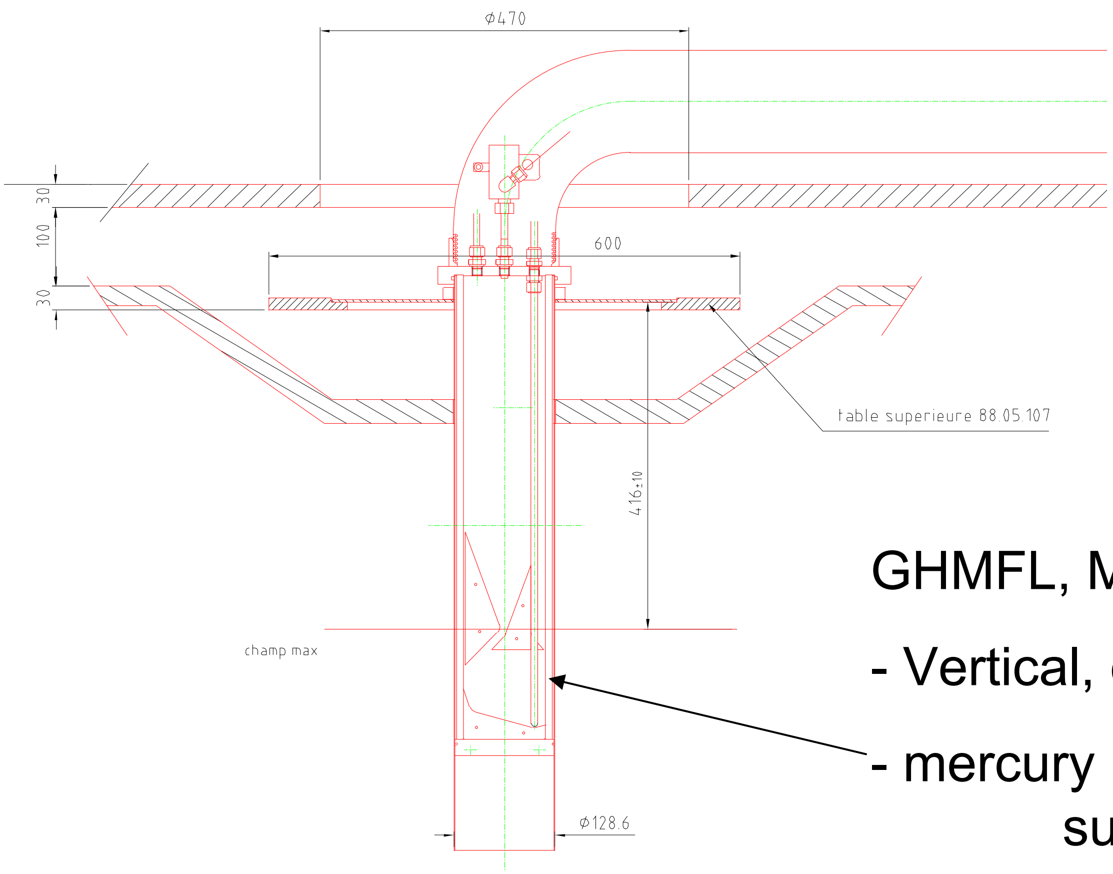




passive return of mercury by tilted plane

- splash drops reduced by
  - ➢ conducting shape
  - ➢ Horizontal baffle

Jet chamber Version 2



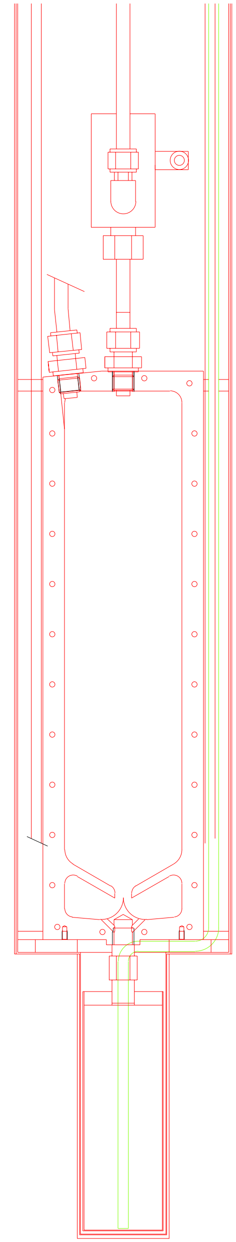
GHMFL, M9

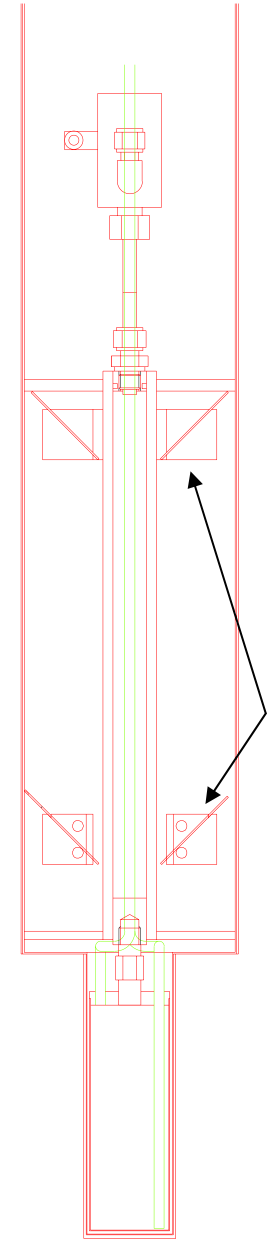
- Vertical, open bore
- mercury recuperation by sucking it back
- mirror system for optical

Jet Chamber Version 3 (final)

- GHMFL, M9
- Vertical bore, closed at lower end
- Mercury recuperation by overpressure

- After gaining experience with this system it fully satisfied the aimed goal for this kind of test!

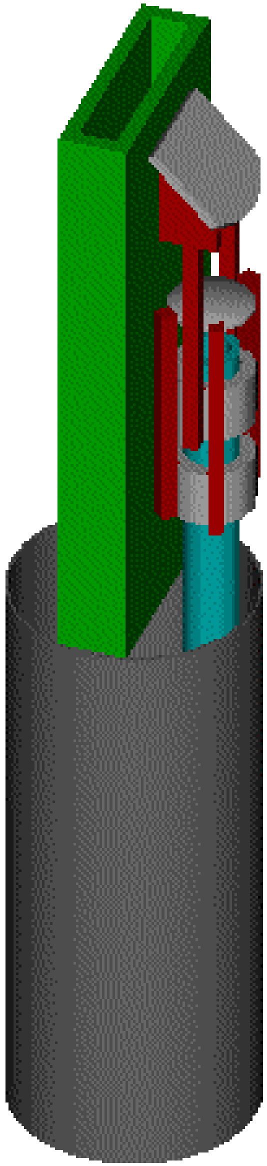




Sliding mirror system in two different positions

Optical read-out

- Achieve maximum observation area
  - Restricted by bore size
  - Outside jet chamber
    - Sensible mirrors separated from Hg jet
    - avoid unwanted mercury in the light path
- 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



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

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

Camera position

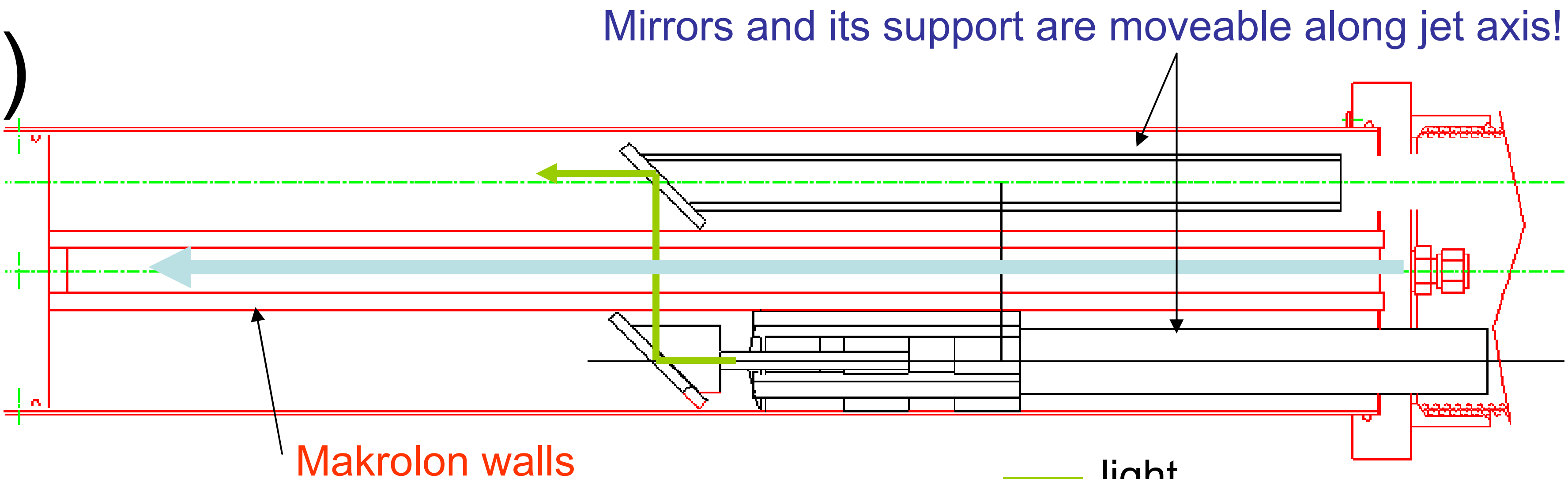
- Far from target and behind shielding
  - Due to radiation
    ISOLDE: ~ 10m and 2m concrete
- Not in magnetic field
  - OLYMPUS camera is magnetic
  - Operation inside magnetic field never tested

Light source

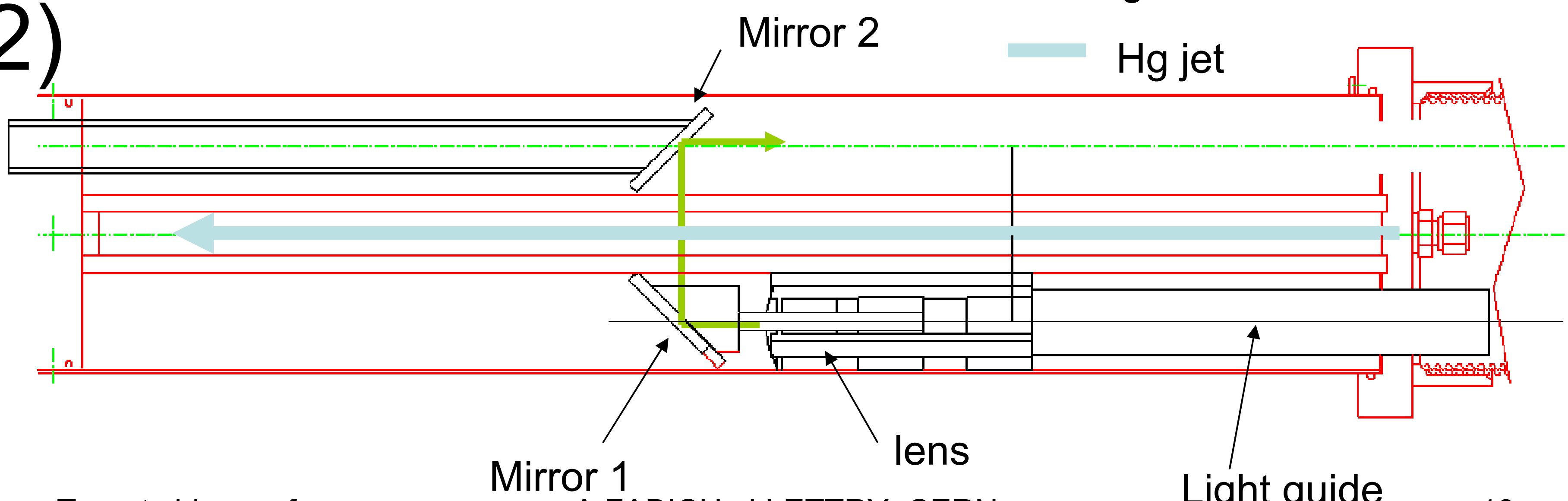
- At easily accessible place
- Light via glass fiber inside experiment

Optical system: light path

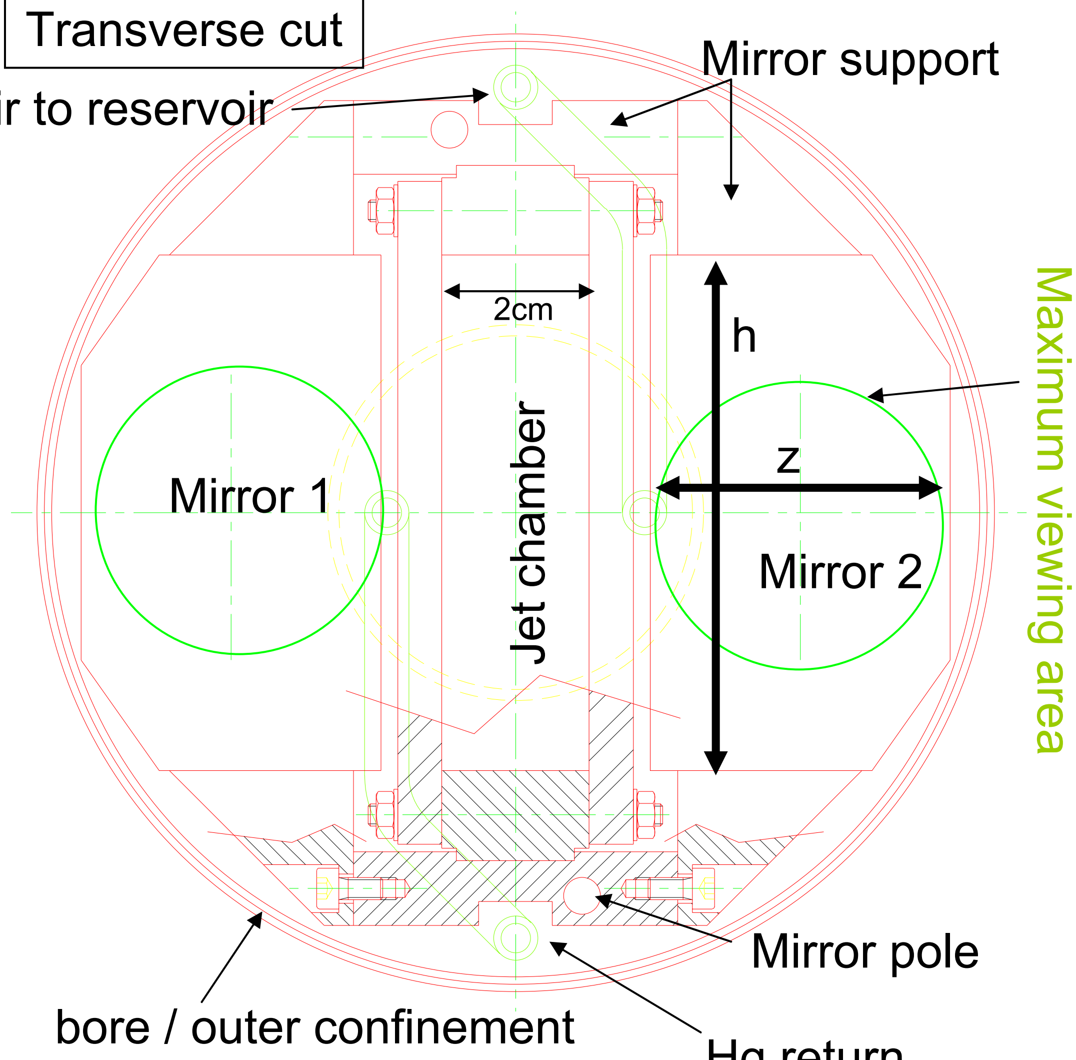
1)



2)



Optical System (2)



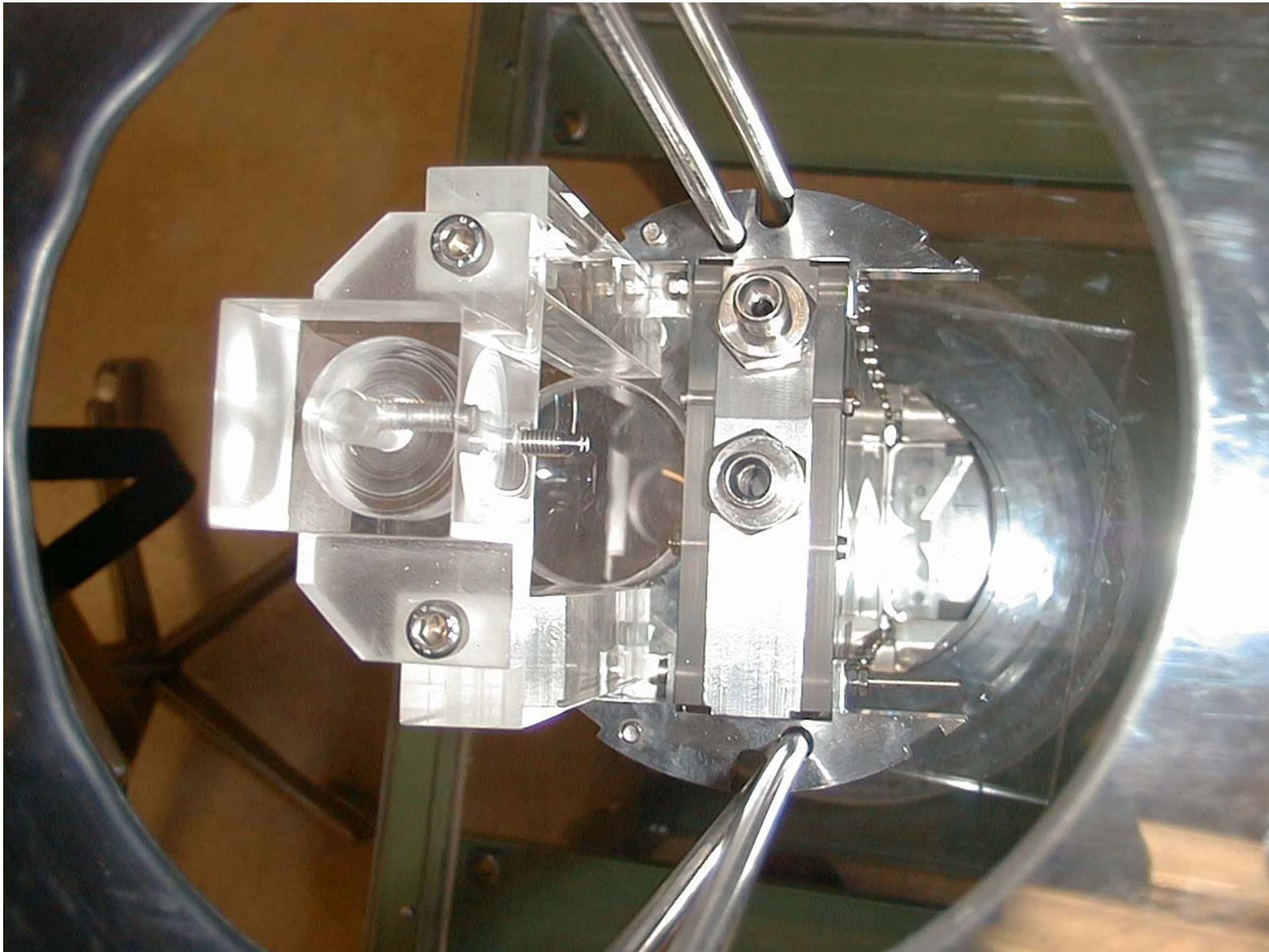
Bore of magnet 13 cm contains:

- jet chamber
  - steel frame
  - Makrolon plates
- mirror system
  - support (adjustable in height) around jet chamber
  - 2 mirrors
- mercury recuperation system

The maximum observation along jet is defined by magnet bore minus the width of the jet chamber (minus some safety margins)
- Total area given by h and z

SAFETY MARGINS ~ 1mm

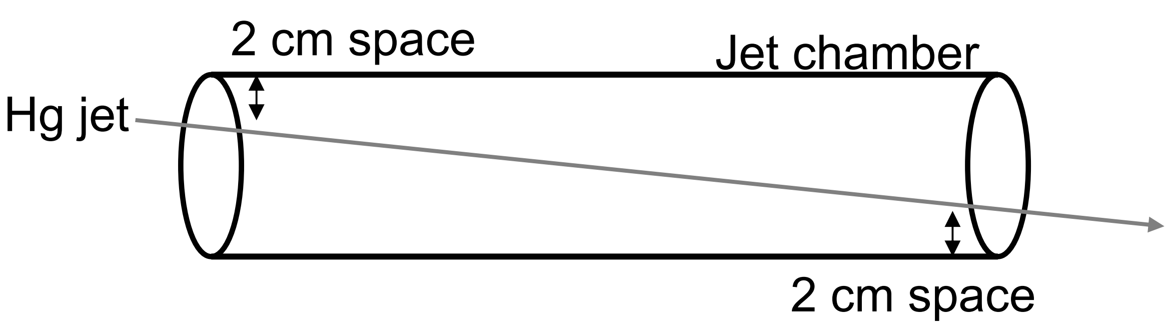
flexibility!



Jet

- Bore, 1m long, 15 (20?) cm diameter, 15 T pulsed
  - Jet offset from entrance to exit given by

Intended inclination:	100 mrad →	10 cm
Jet diameter		1 cm
(Gravity)		5 cm (v_{jet}=10 m/s)
		2.5 cm (v_{jet}=15 m/s)



Space contains:
- outer confinement
- frame of jet chamber
- fixation of jet chamber
- Hg return path?
- tolerances

It is not impossible, but one has to keep in mind,
that the place inside the bore is one more time very tight.

Mercury Recuperation

1) Through the bore
   - Needs space inside the bore

2) Loop closed outside the coil
   - Safes space inside the bore
   - But needs braking the Hg loop on disassembling

The Nozzle

- Several different types of nozzles produced
  "special" types did not improve results
- Straight nozzle produced stable jet
  Only if exit was properly machined

Data evaluation/analysis

- Automated digital image analysis is a usual thing
  - GHMFL analysis was tougher in case of "shaken" movies, sometimes needed human intervention

Dis-/Assembling, Operation

- Constructions chosen such
  - that every part could be accessed easily
- Never needed to open mercury loop unforeseen
  - Except for interventions on the pump (Hg-lab)
- Most annoying: “shaking” setup
  - Due to physical connection of optical and jet system
  - Solved by additional wedges to clamp setup
- Optical misalignment occurred
  - While/after ramping B-field
  - Caused by magnetic forces and cooling
  - Readjusting optical alignment needed

Beam monitoring

- ISOLDE:
  - spot size measured “offline”
  - in advance MWPC installed and Quadrupole settings calibrated (reliability sufficient)
  - aluminum foil for later verification
  - Variation of TRIM’s: moving spot size shows effect in mercury splashes

Permanent online beam monitoring desired

FTE's

- PhD student: 2
- Technical student: 2
- Technician 1
- Others: 1

6

- Workload: concept, design, construction, operation and analysis of
  - In-beam experiment
  - in-magnetic-field experiment

Budget (excl. FTE)

188 k€

Main items:

- Camera + videoscope: 60 k€
- Main workshop: 33 k€
- Material store: 22 k€
- Hg vapor monitor: 10 k€
- Pump: 6k€
- Mercury: 3 k€ (Mercury purity 99.99+ %: 2600 ChF/liter)
- 50 k€: external suppliers, computer, optics, transport GHMFL, …

1 € = 1 $ = 1.5 ChF

Main Issues towards a design

- Adapt for a jet diameter of 1 cm
  - Mercury flow quasi-continuous?
- If basic CERN principle preserved
  - Optical system inside the bore
    - Two camera systems at the same time? (semi-mirrors)
  - Replace Makrolon by Quartz
- Obey safety issues

Accessibility of bore from two sides makes a lot of things easier.

Optical read-out after the coil

- no direct observation in interaction region
- reconstruction on evaluation
- optical and jet setup physically separated
- makes life inside the coil a lot easier