LUCID - The ATLAS Luminosity Monitor

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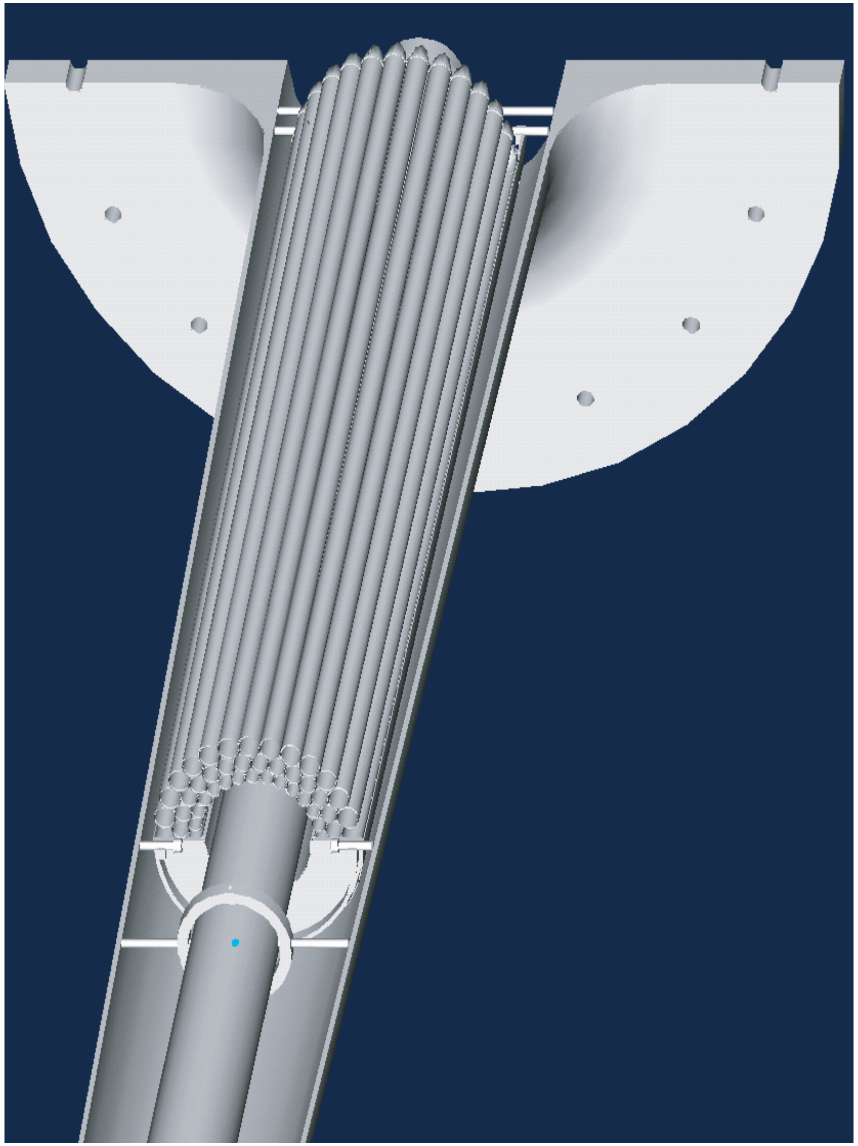


Motivation

Wanted:

A very radiation hard detector to be used as luminosity monitor

Good time resolution to resolve individual beam crossings

Insensitive to soft background particles

Pointing capability

A large dynamic range and no saturation at the highest luminosity

A simple, robust and cheap construction

Solution:

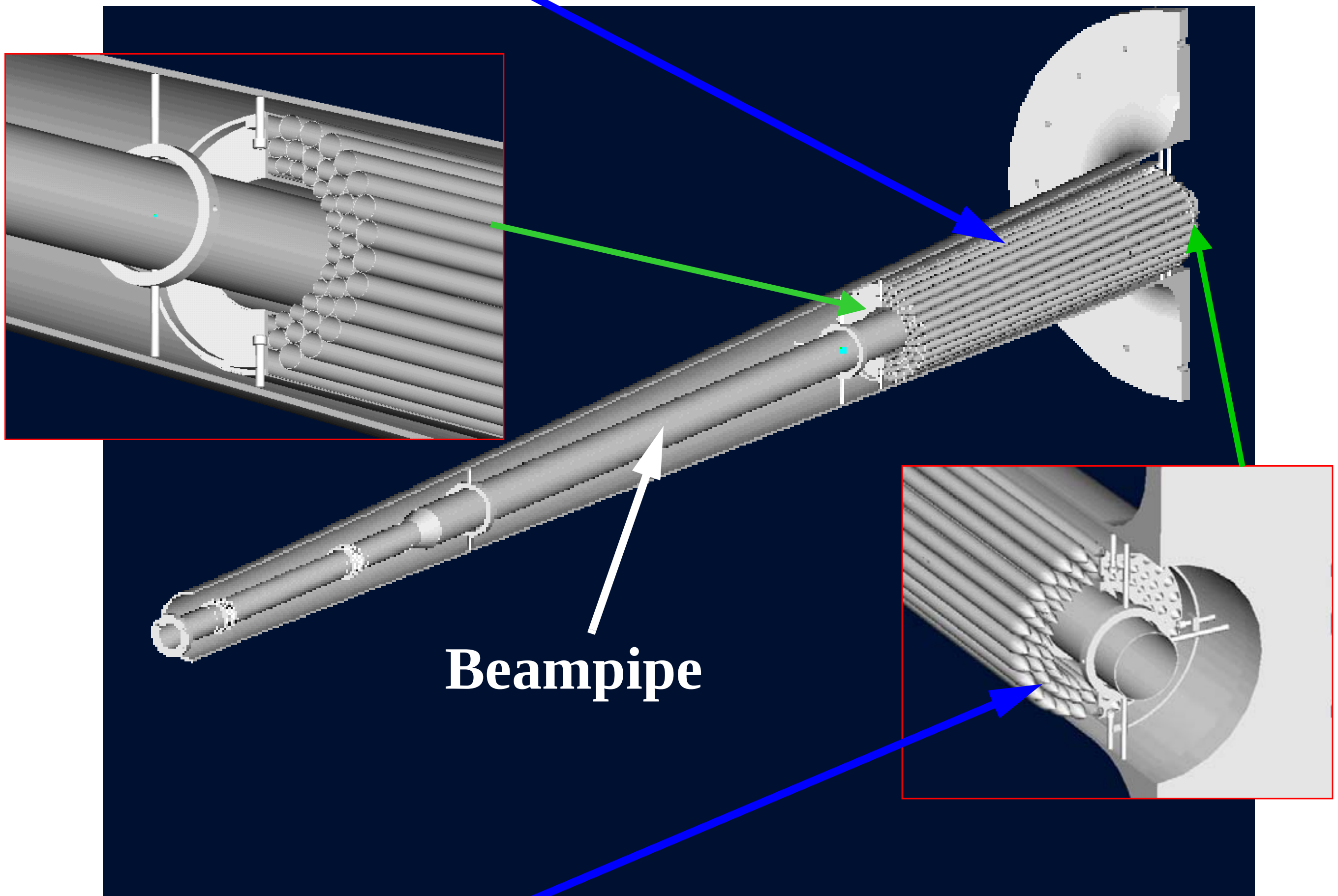
LUCID: LUminosity measurement using a Cherenkov Integrating Detector

The design is based on the Cherenkov Luminosity Counter (CLC) that is operating successfully at CDF.

Gasfilled tubes around the beampipe act as a Cherenkov detector and detects particles from the I.P. that are above the Cherenkov threshold (2.7 GeV for pions and 9 MeV for electrons)

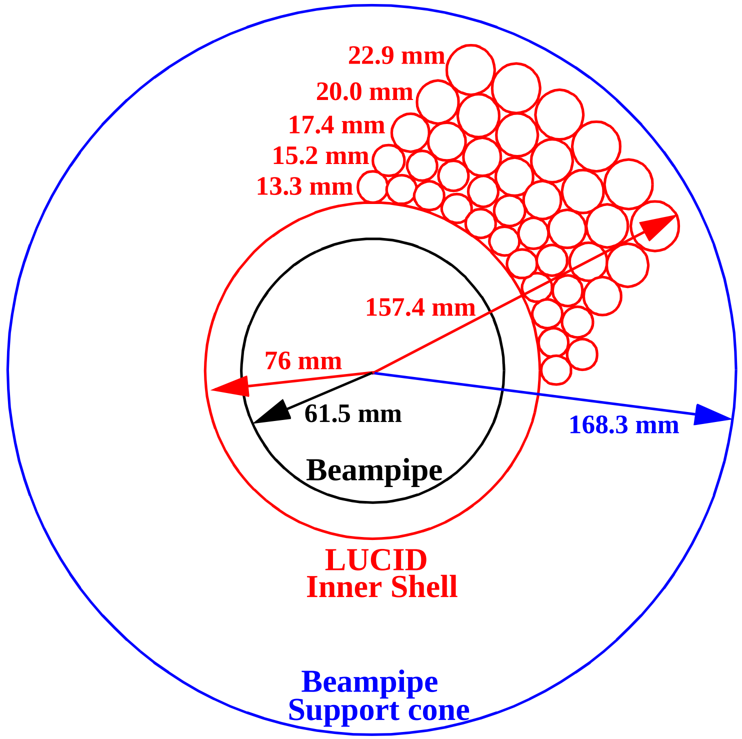
Basics of the detector

2 detectors x 200 Al tubes filled with C_4F_{10} or Isobutane at atmospheric pressure



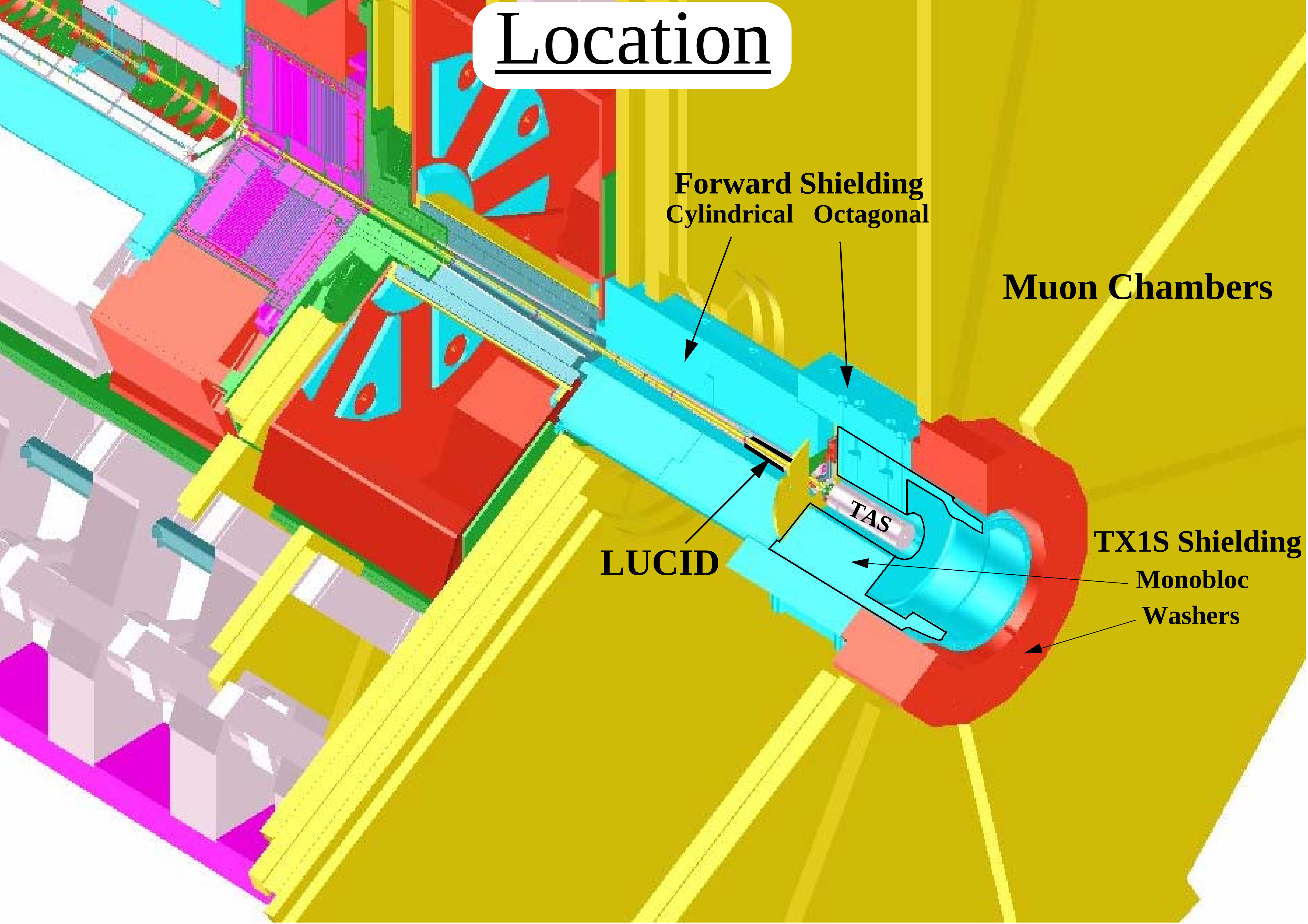
Front view (Z = 16976 mm)

5 layers with 40 tubes each



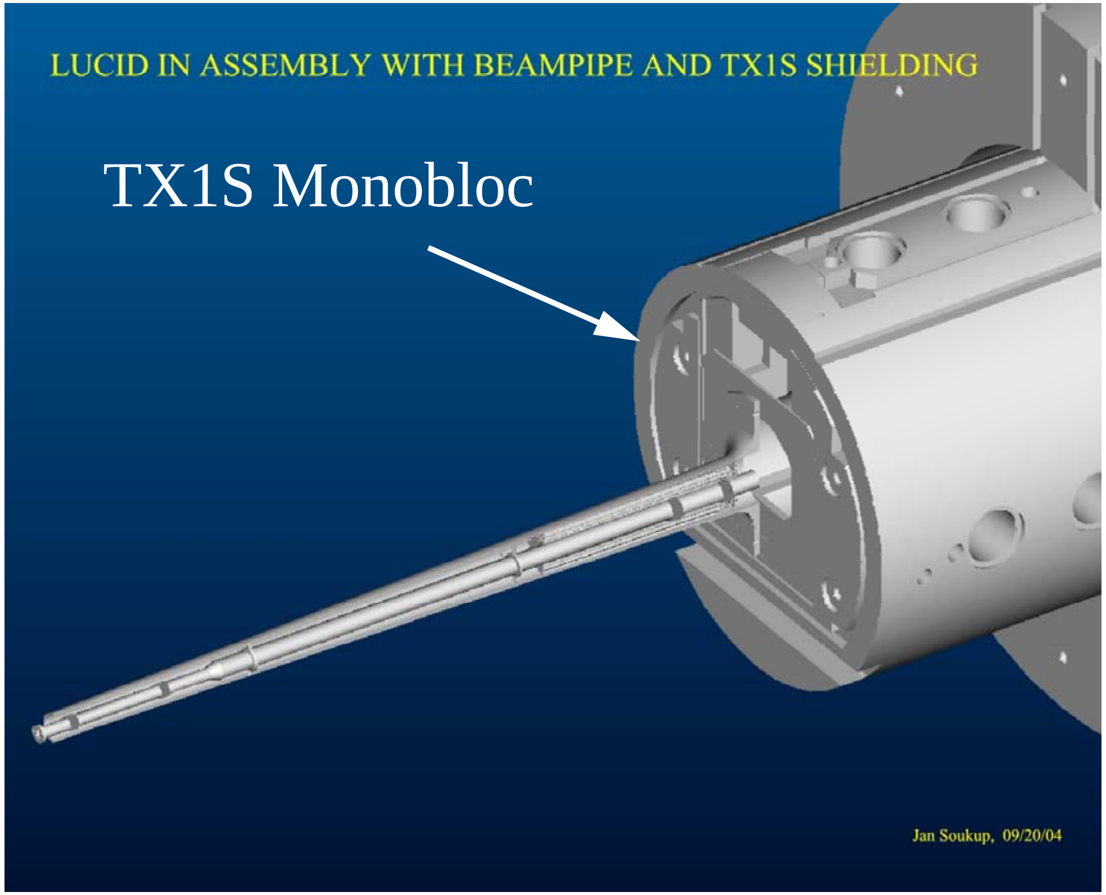
Winston cones at the end of the tubes focus the Cherenkov light onto quartz fibres

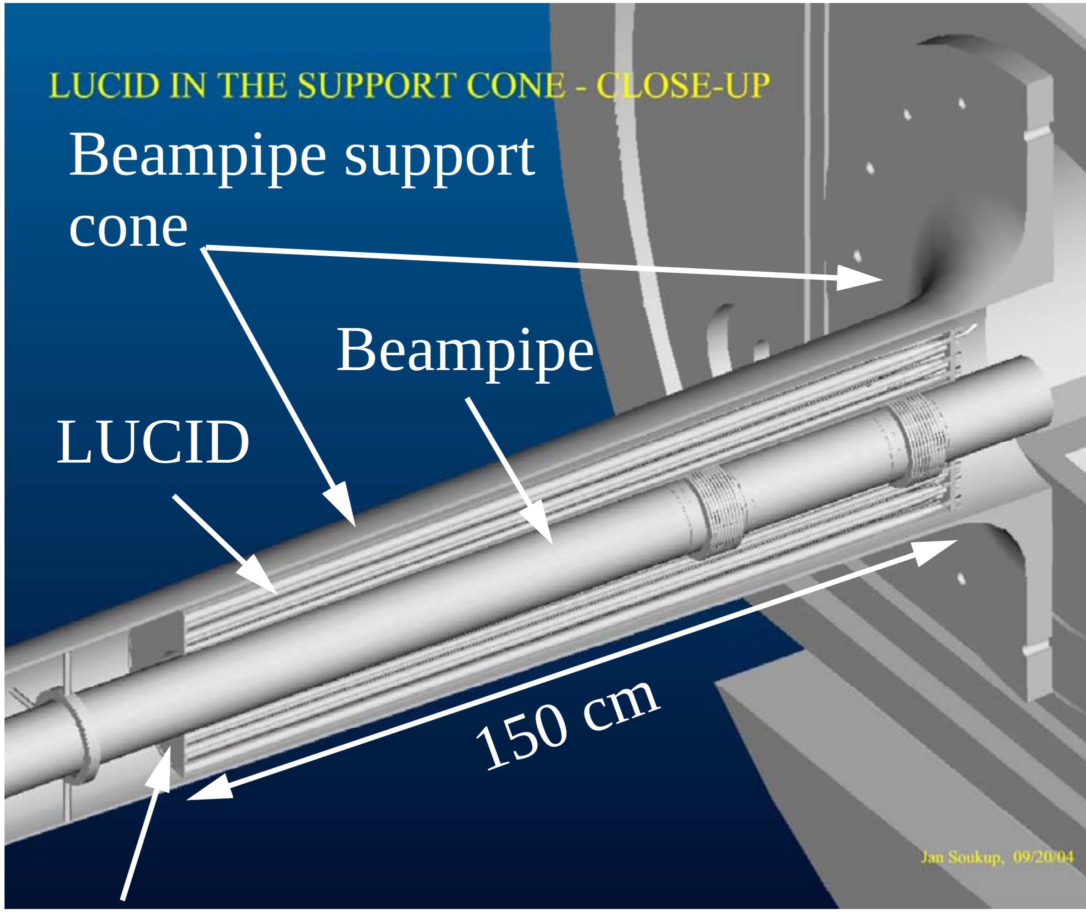
Location


Forward Shielding
Cylindrical
Octagonal
Muon Chambers
TAS
LUCID
TX1S Shielding
Monobloc
Washers

Location of the detector

The situation when the forward shielding is removed:



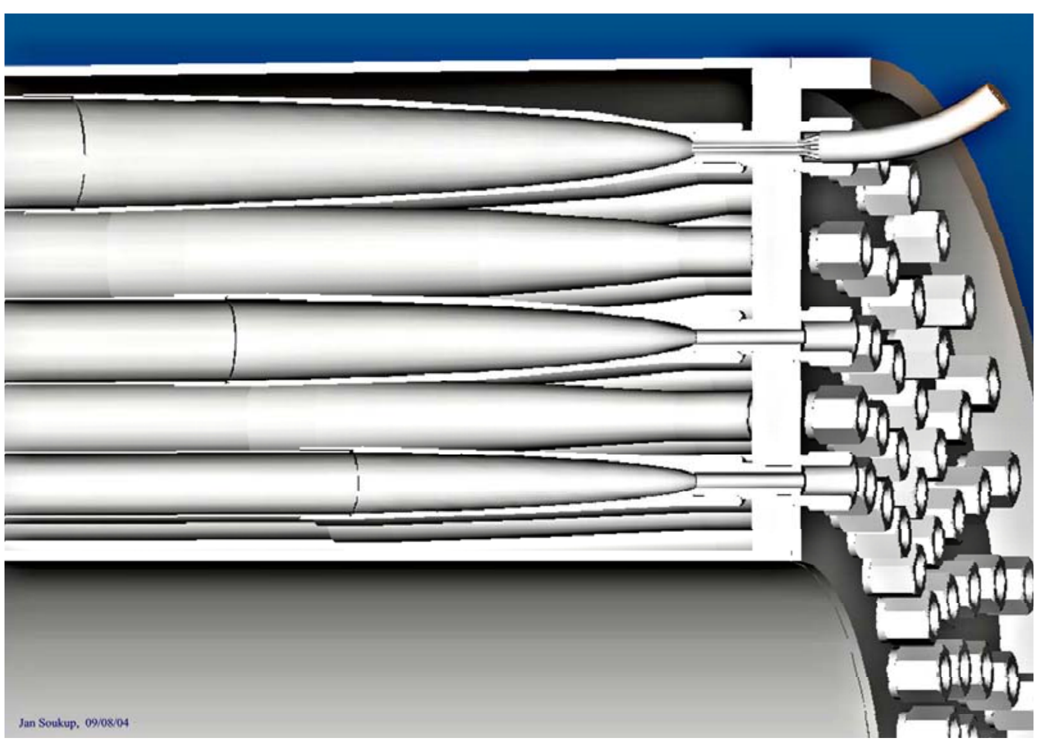


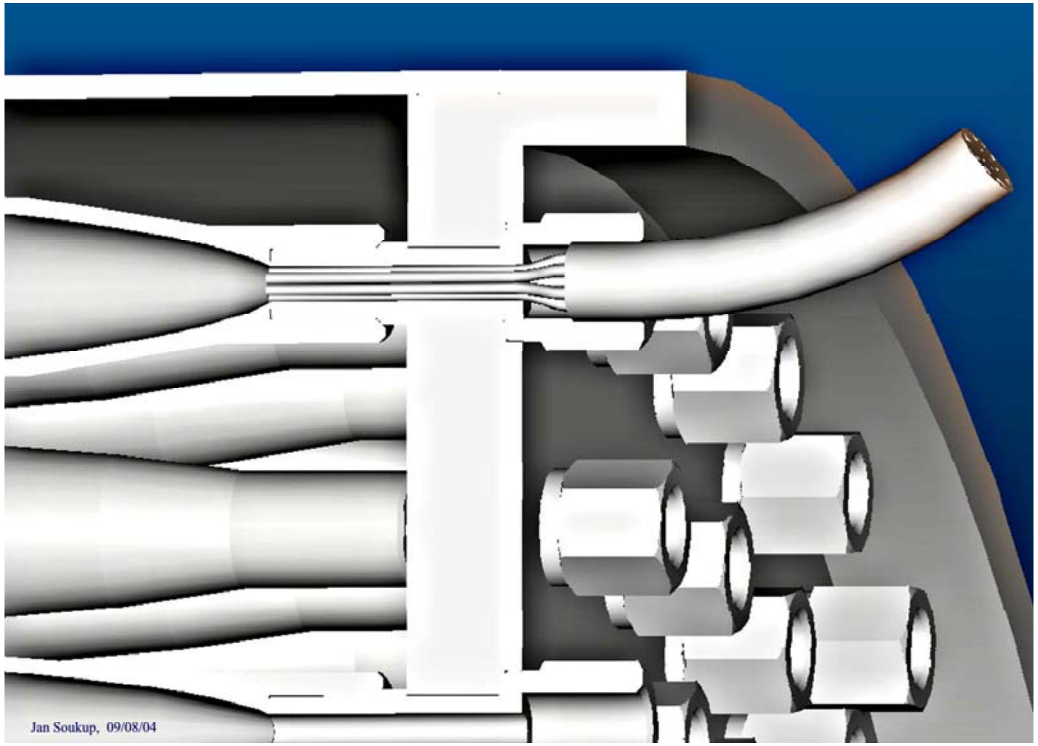
The front face of each detector is at 17 m from the IP

$$\eta_{max} = -\ln[\tan(0.26^{o}/2)] = 6.1$$

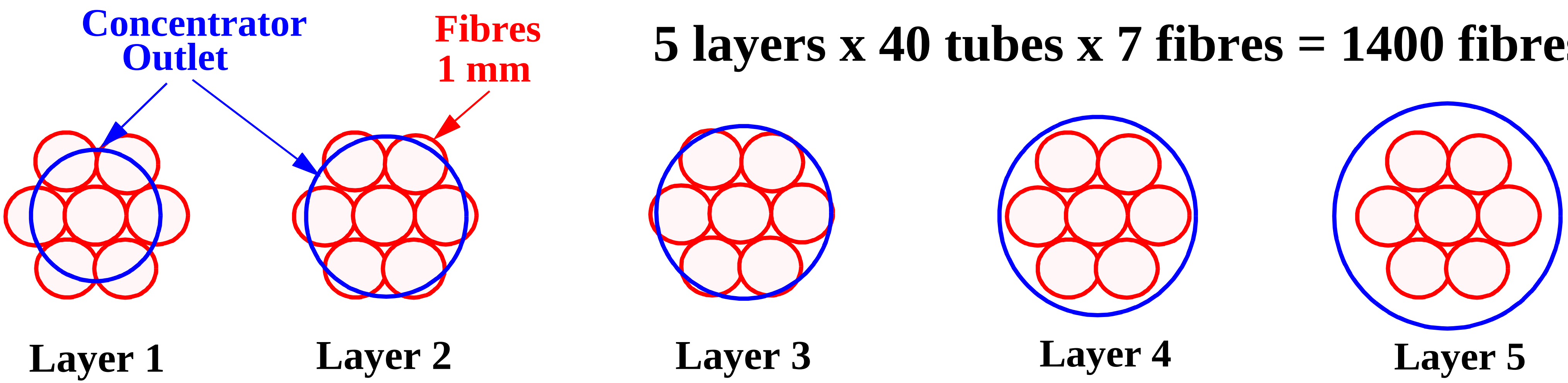
$$\eta_{min} = -\ln[\tan(0.53^{o}/2)] = 5.4$$

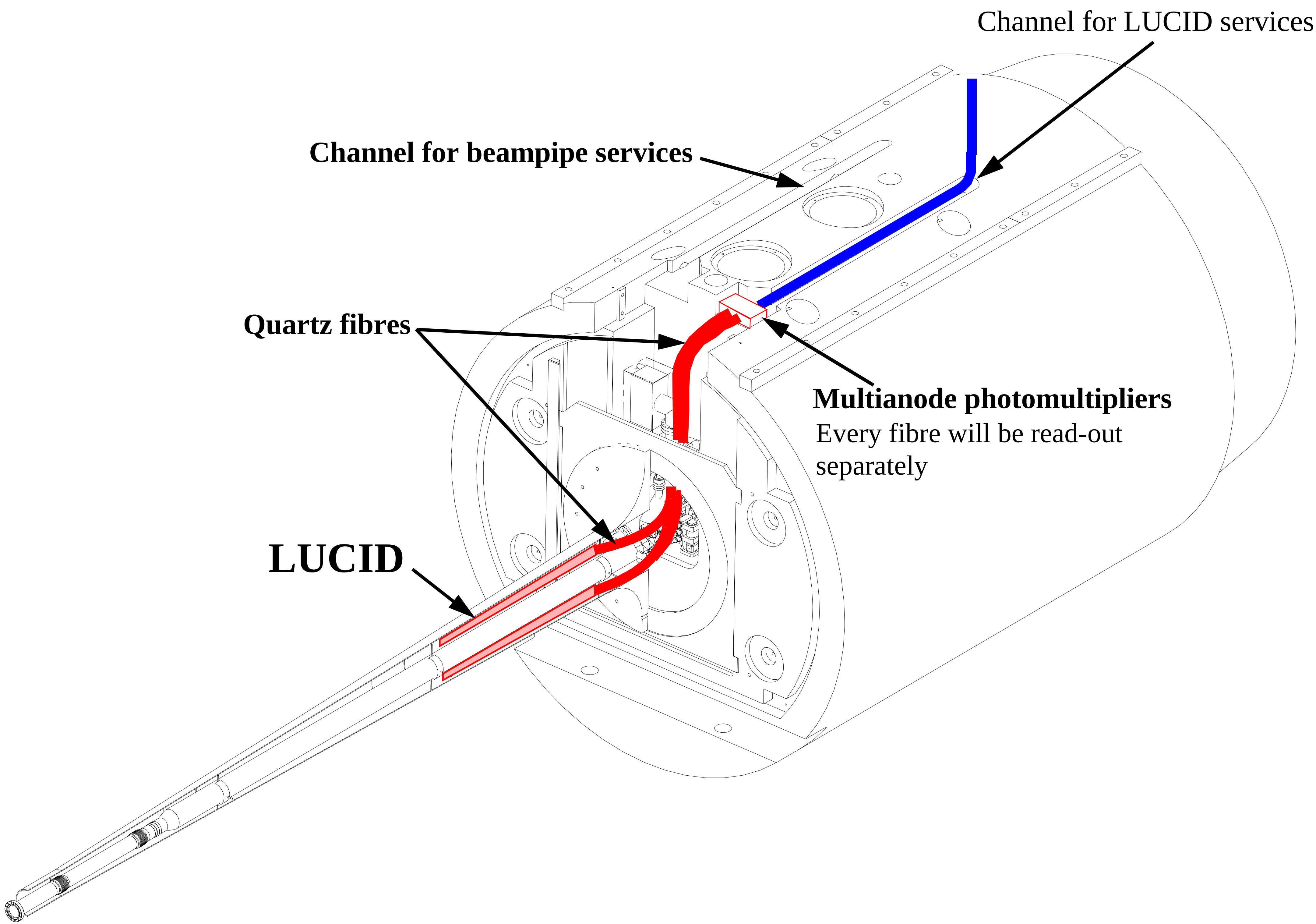
The fibre read-out





5 layers x 40 tubes x 7 fibres = 1400 fibres

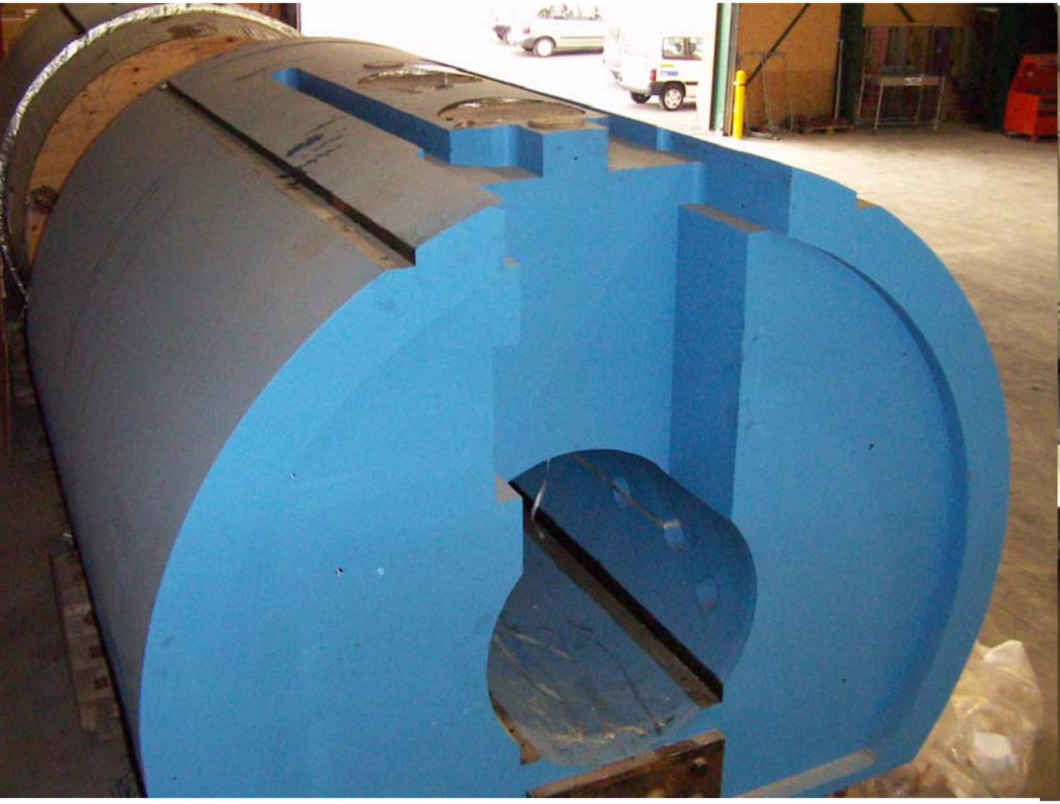



Channel for LUCID services
Channel for beampipe services
Quartz fibres
Multianode photomultipliers
Every fibre will be read-out
separately
LUCID

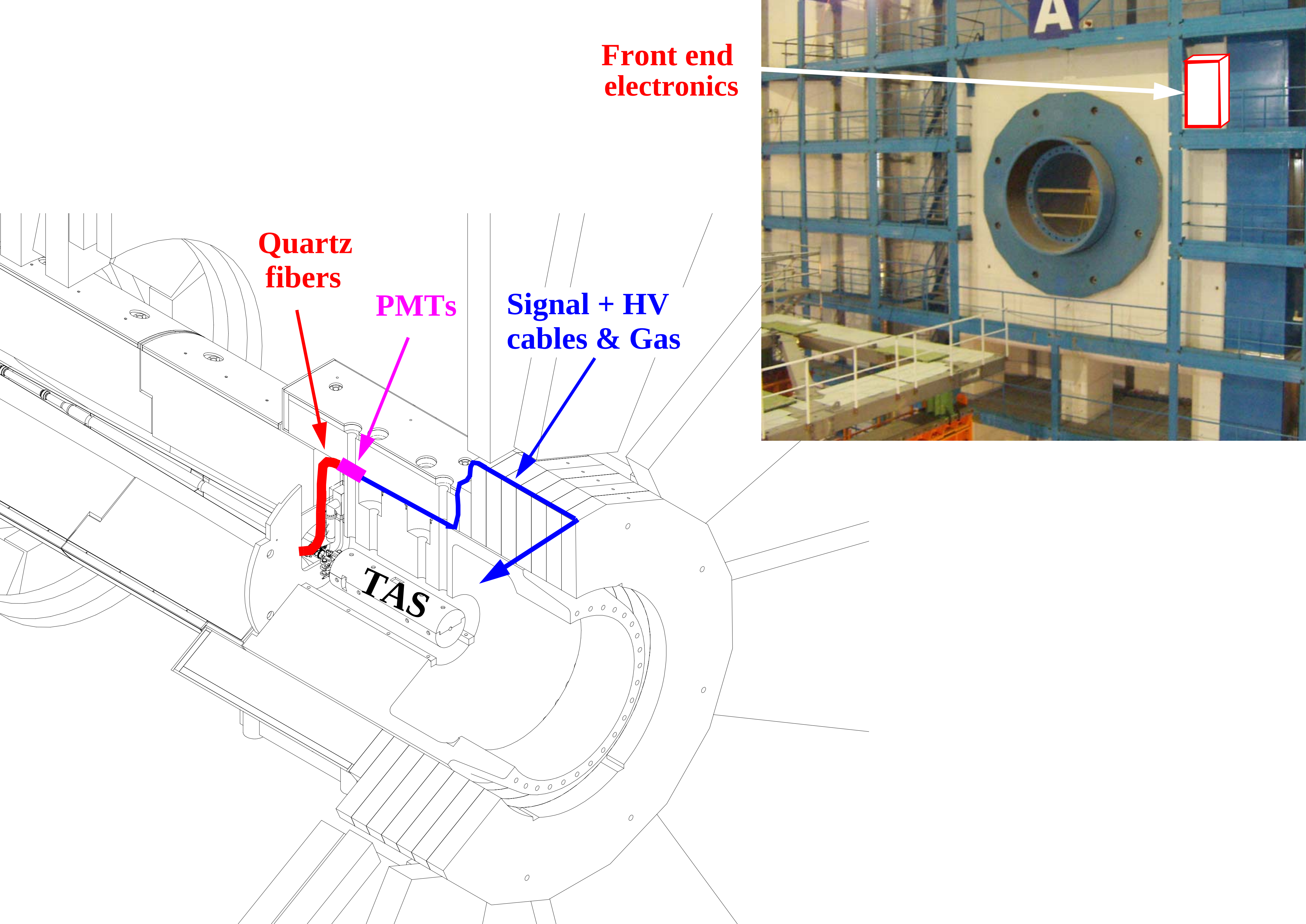
The fibre read-out

A mock up of the TX1S shielding has been made at Univ. of Alberta to study fibre routing, space allocation & integration.

Reality

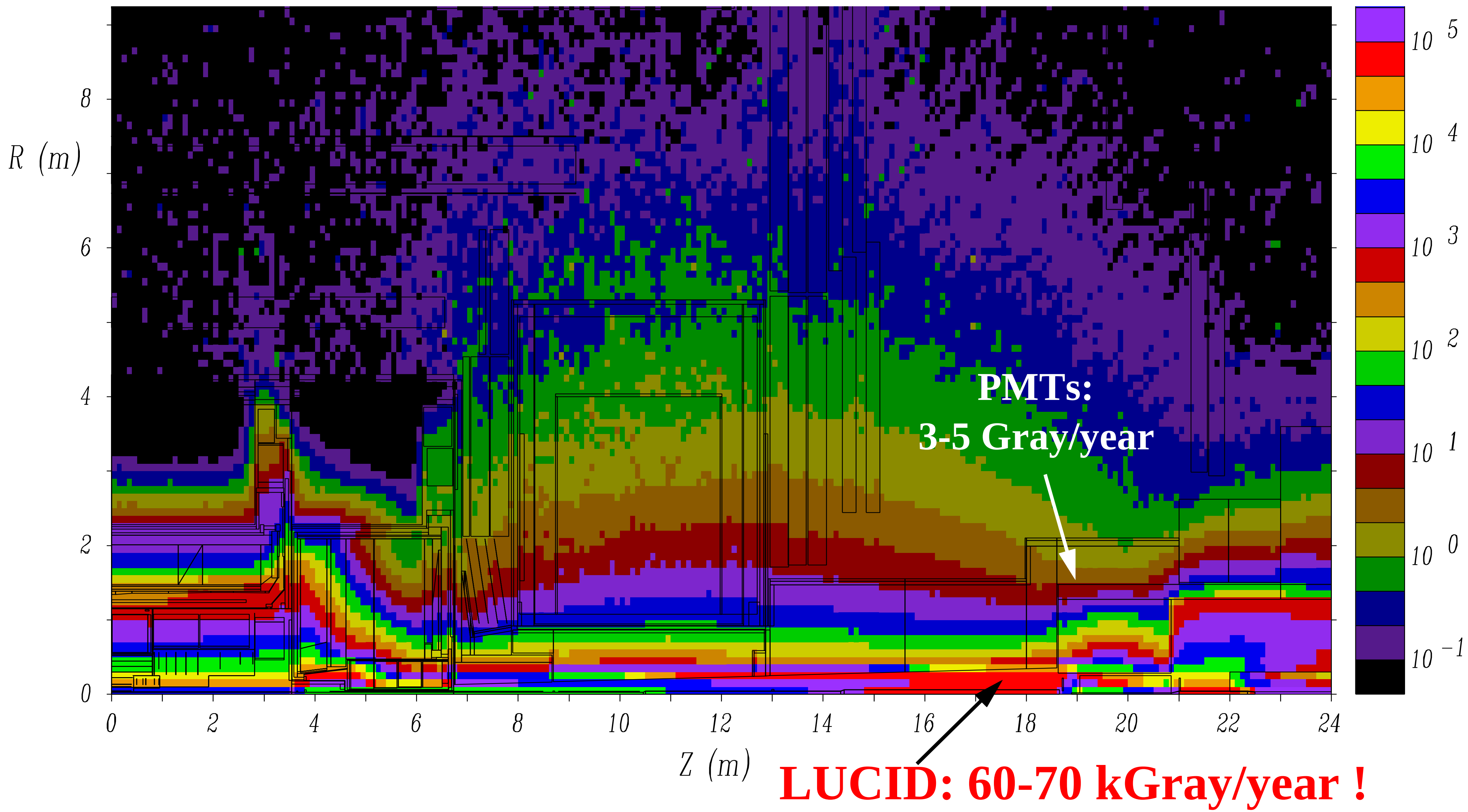


Mock Up

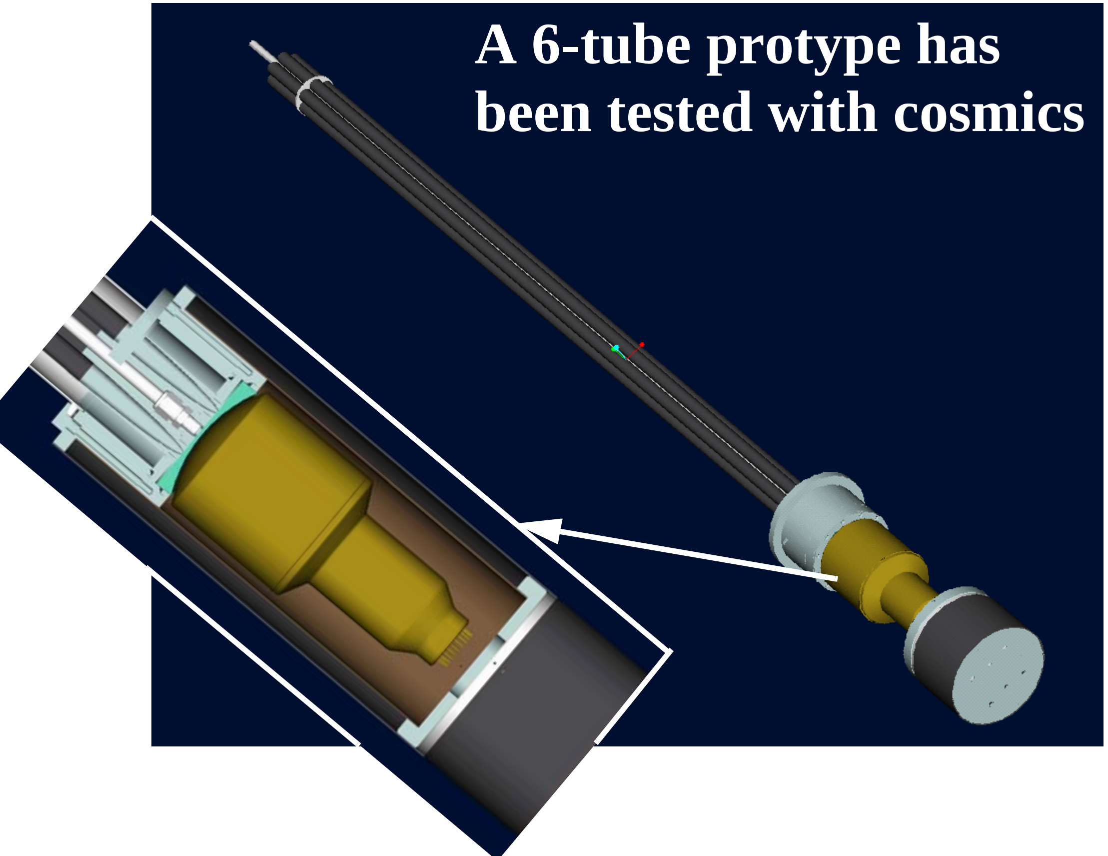

Front end
electronics
Quartz
fibers
PMTs
Signal + HV
cables & Gas
TAS

Radiation levels

Total Ionizing Dose (Gray/year) at a luminosity of 10^{34} $cm^{-2}s^{-1}$



Prototype Testing



The protype was read-out by a 5 inch PM.

The low counting rate (1/hour) is consistent with Monte Carlo predictions.

A beam test at Fermilab with muons is planned for this summer.

Mechanical Design Report

LUCID is described in a letter of intent to LHCC (CERN/LHCC/2004-010)

- The project was encouraged to continue by the LHCC

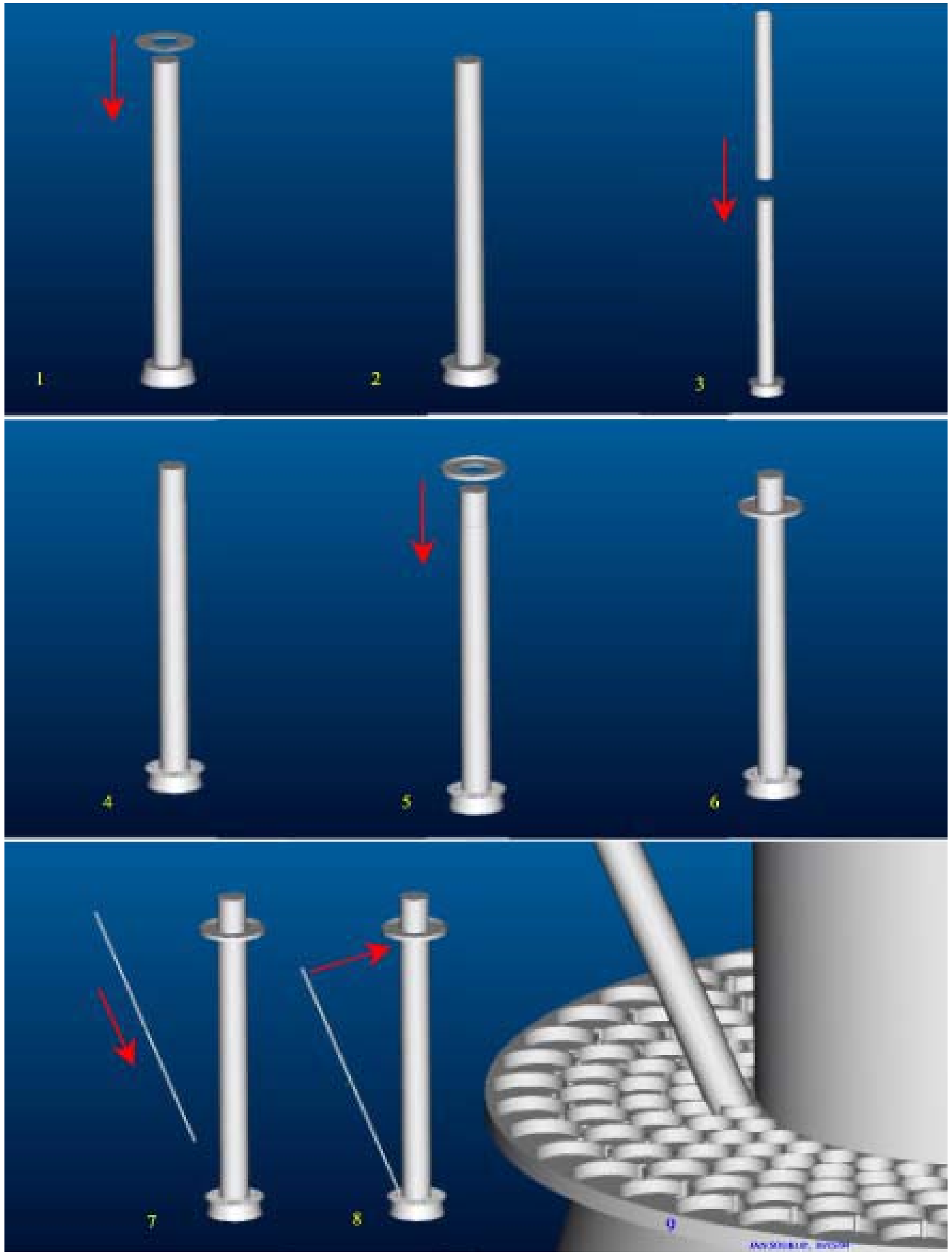
The LUCID Mechanial Design Report (EDMS: ATL-UL-ES-0001) details the

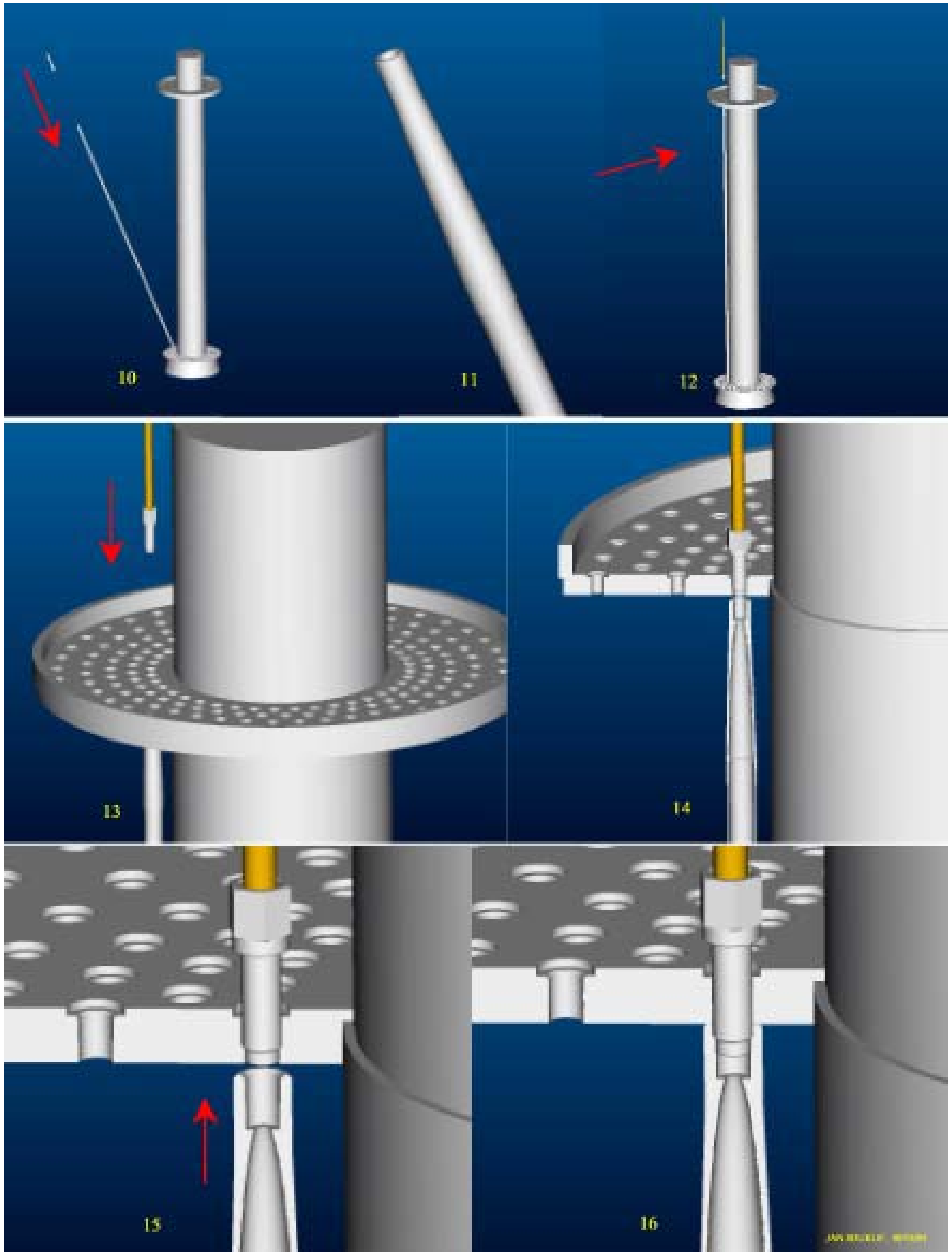
- Space allocation for LUCID
- Pattern of Cherenkov light-collecting tubes
- Design of Winston cones
- LUCID gas volume
- Front bulkhead
- Rear bulkhead
- Optical fibre feed-throughs
- Optical bundle tips
- Gas connections
- Weight of various LUCID elements
- Assembly procedure

An Engineering Change Request has been written but not yet circulated

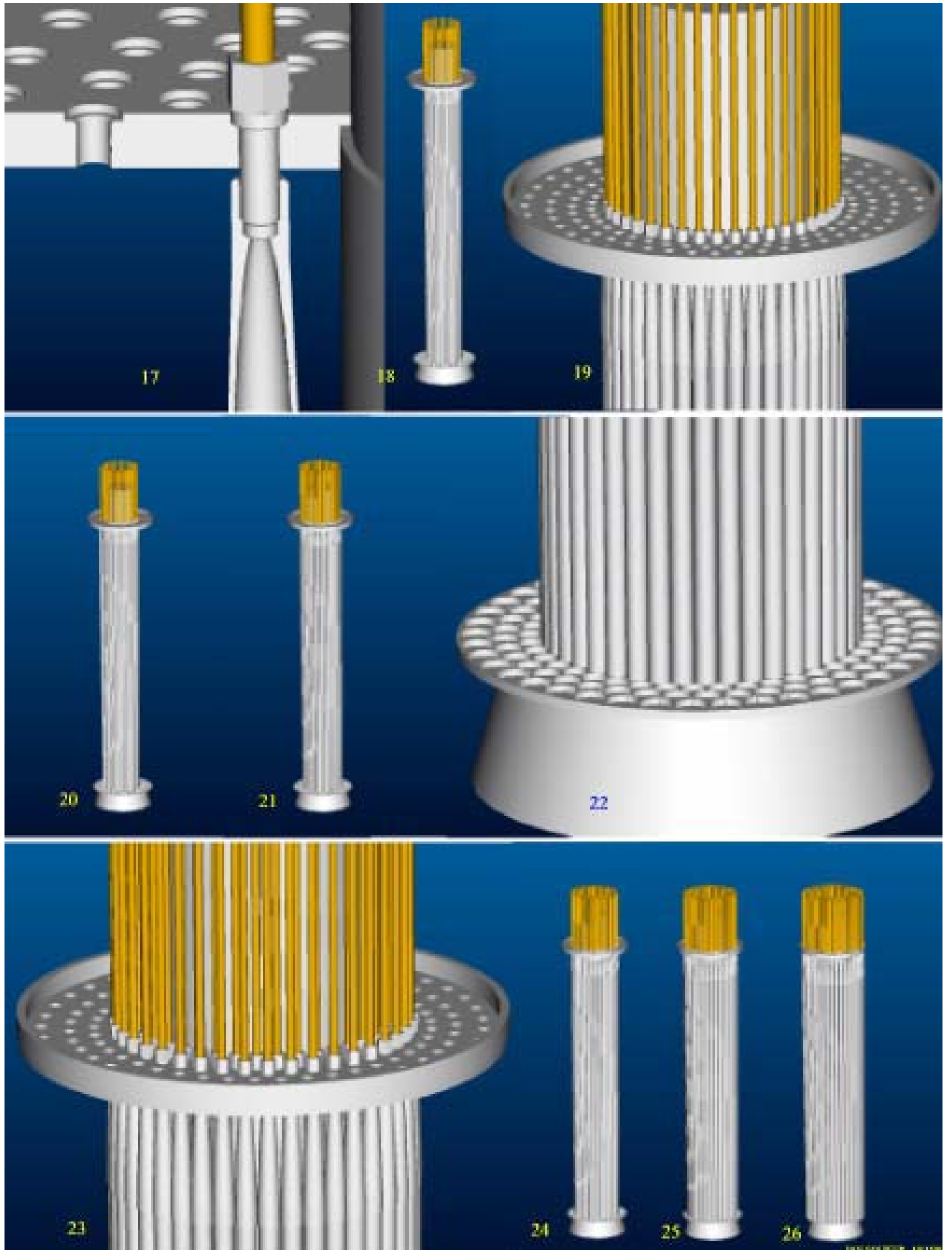
- Clearance and alignment needs further study

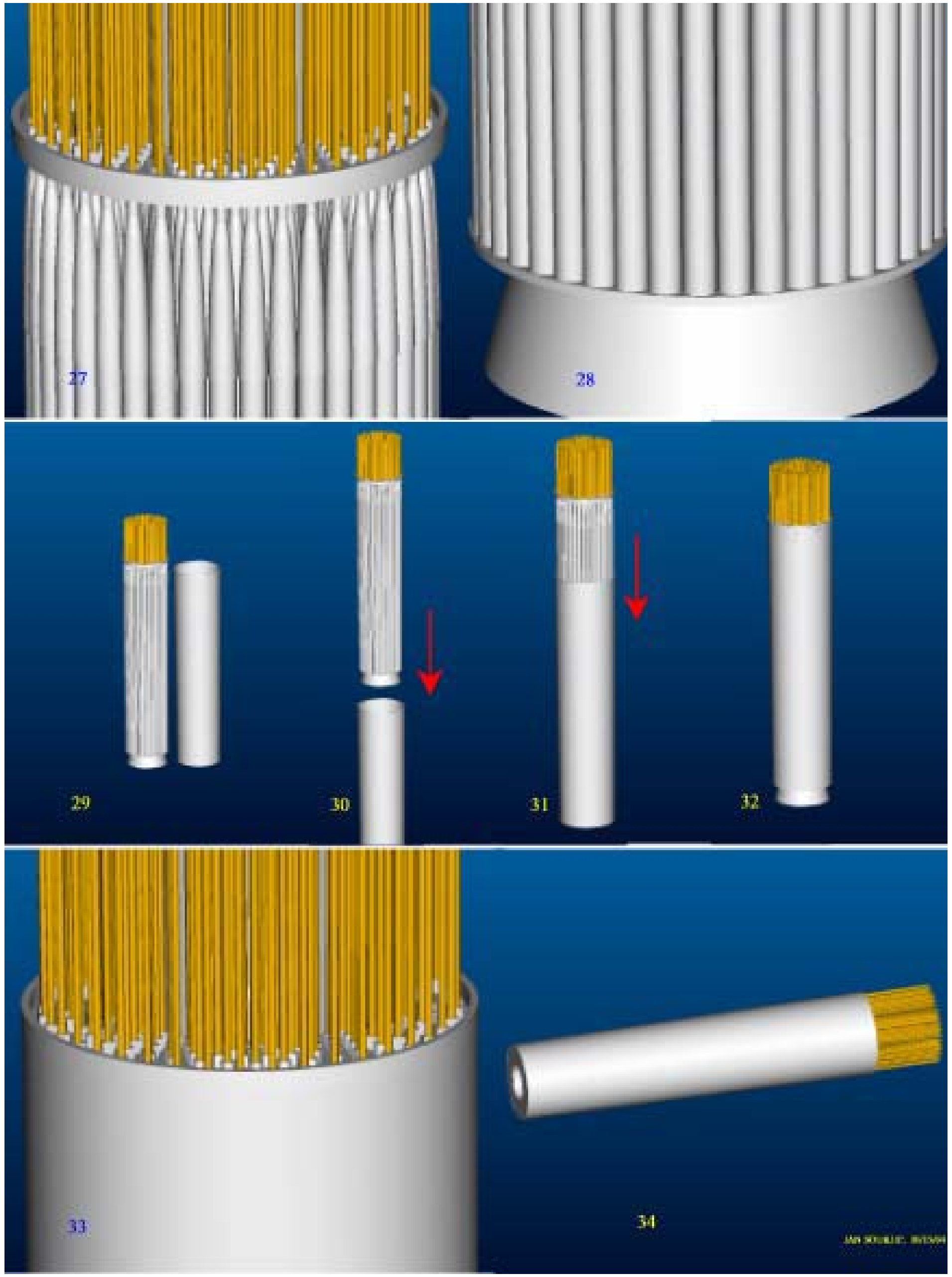
Mechanical Design Report - Assembly





Mechanical Design Report - Assembly





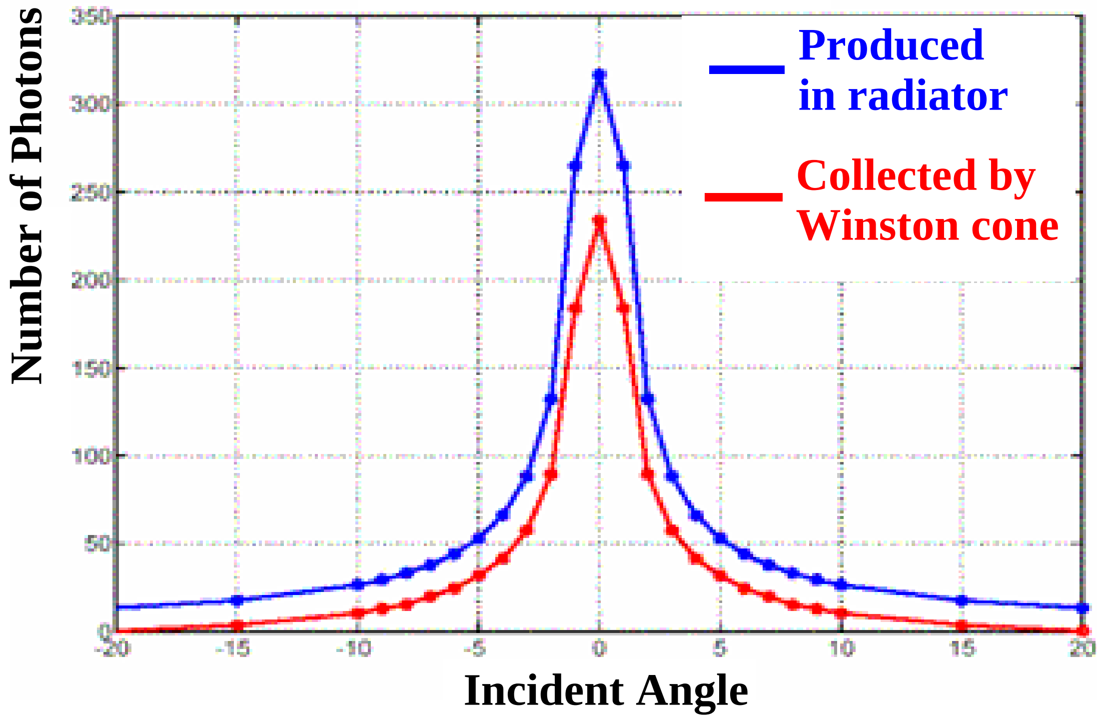
LUCID Technique - tested at CDF

Much more light from primary particles than secondaries and soft particles.

- **Much shorter paths for secondaries**
- **Cherenkov thresholds**

A particle from the IP will produce about 320 photons of which some 230 will be collected by the Winston cone.

Simulation of detector responce to 20 GeV muons



Excellent time resolution (140ps @ CDF)

- **One can follow bunches**

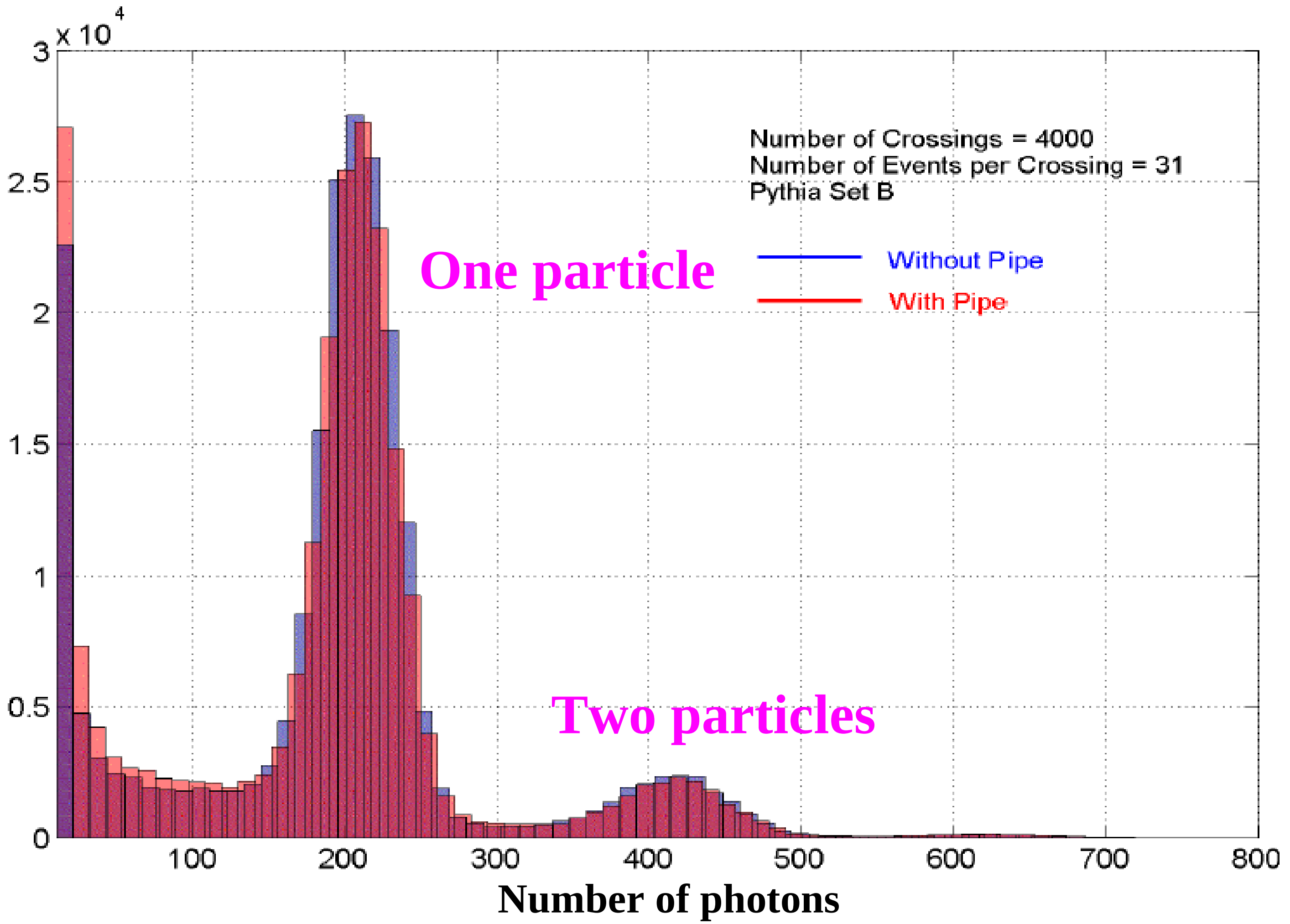
The detector is radiation hard and light (40 kg) since it is made of aluminium.

LUCID Simulations

Since there is no Landau fluctuations for Cherenkov light emission one gets an excellent amplitude resolution.

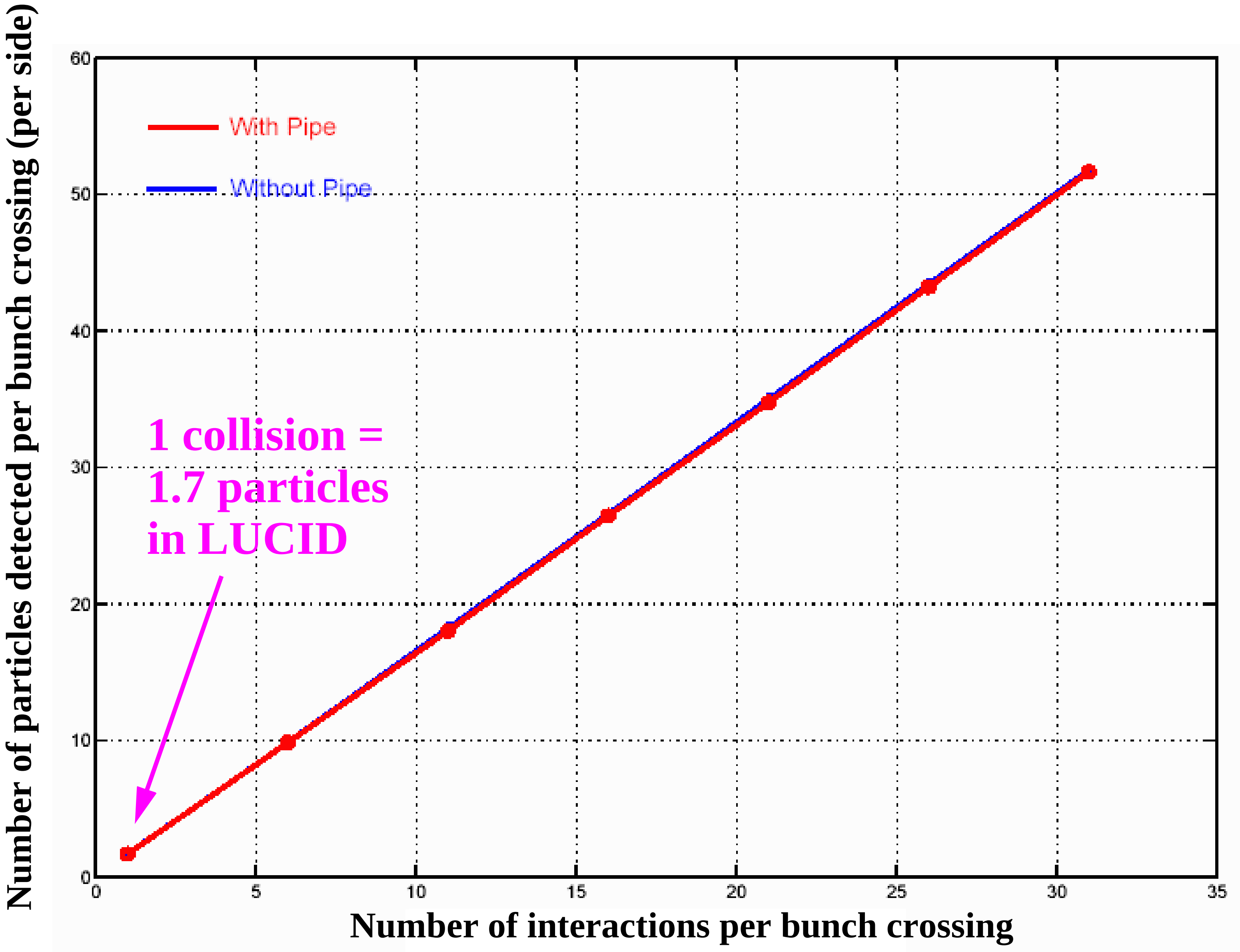
- One can count multiple particles/tube

- No saturation of the detector even at very high luminosity



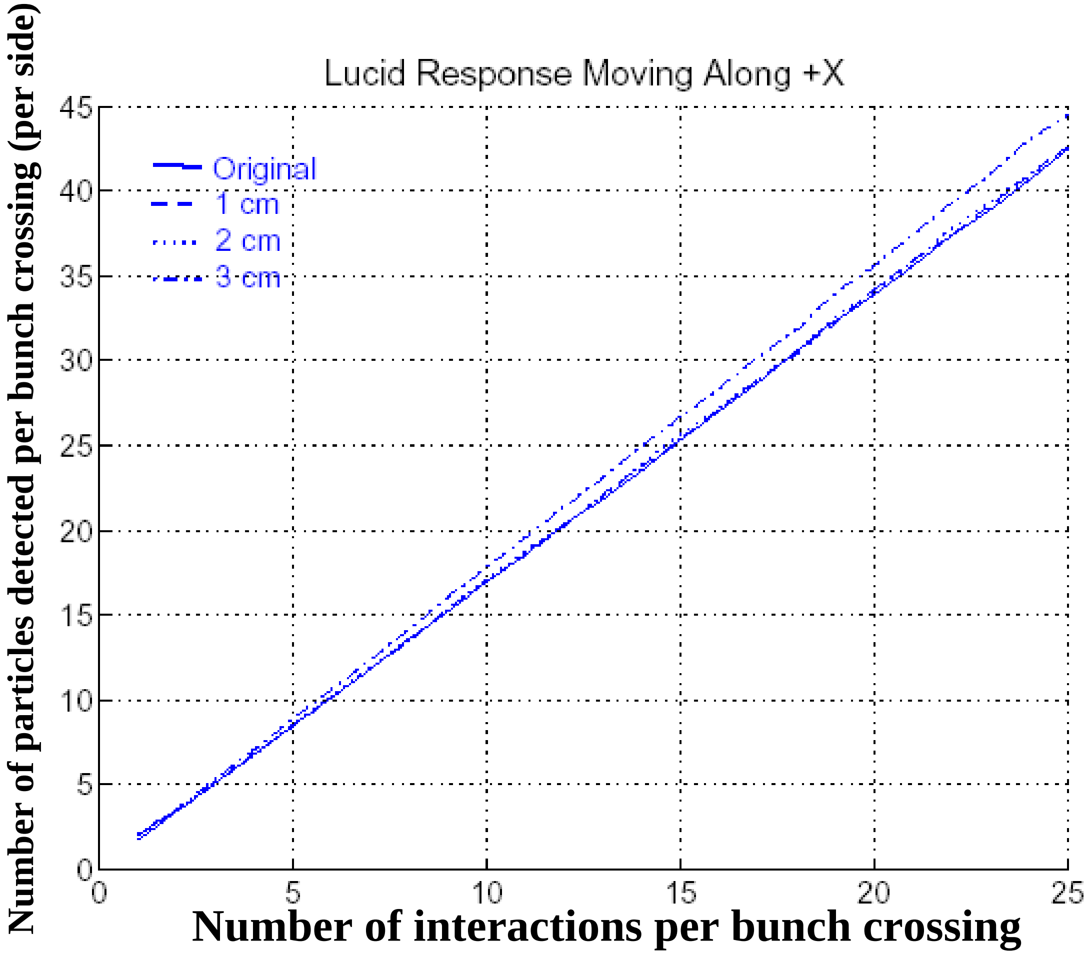
LUCID Simulations

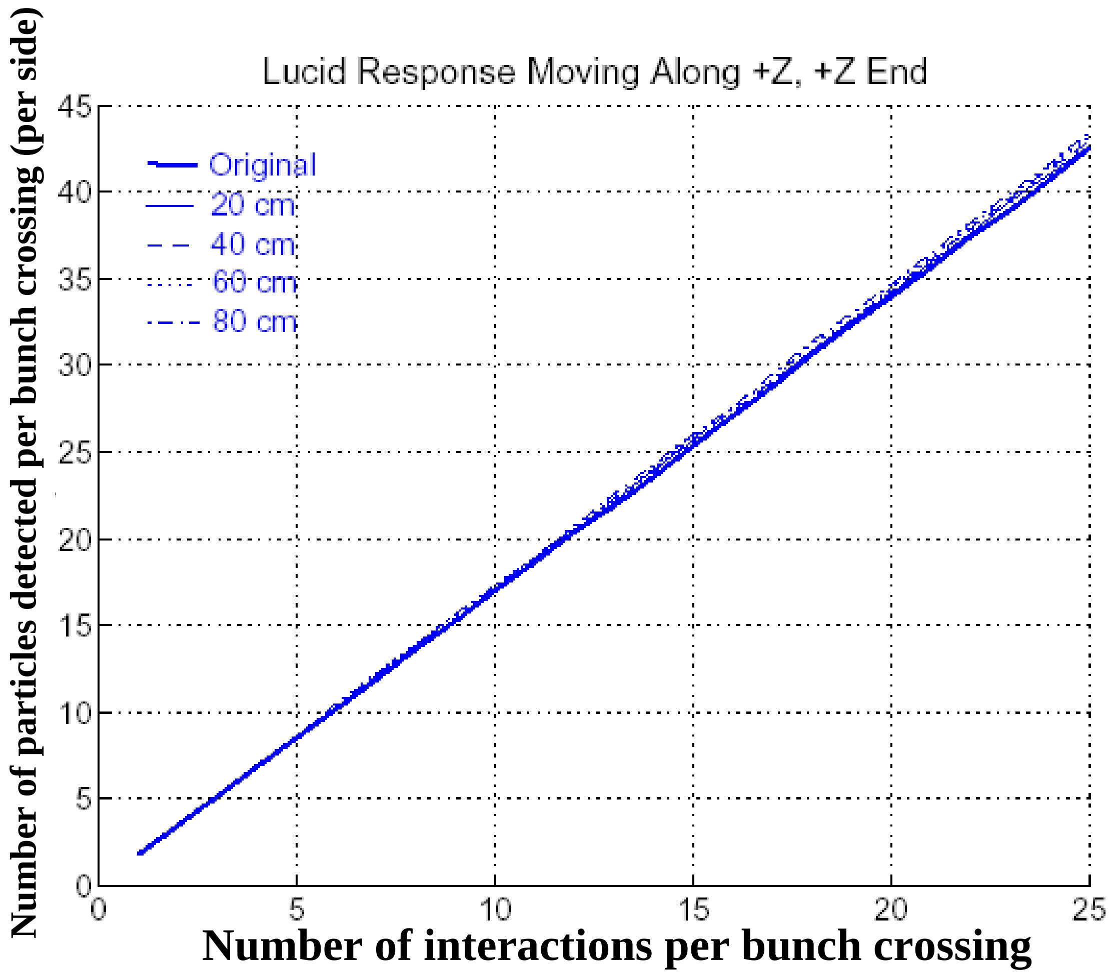
Simulations shows a perfectly linear relationship between the number of particles measured in LUCID and the luminosity.



LUCID Simulations

The LUCID response when the IP is moved in X and Z:





Calibration & Dynamic Range

Calibration using elastic scattering data

Lumi = 10^{27} cm^{-2}s^{-1}

Lumi = 10^{27} cm^{-2}s^{-1} → 10^{34} cm^{-2}s^{-1} A factor 10^{7} !

At 10^{27} there will be 2×10^{-4} interactions/bunch → 1.7 part./inter.

At 10^{34} there will be 20 interactions/bunch → 33 part./bunch

Calibration using single W/Z production

Lumi > 10^{30} cm^{-2}s^{-1}

The rate of W → lν is expected to be 60 Hz at high luminosity

The uncertainty in the rate of W/Z events is currently about 4%

CDF is also using the process W → lν for absolute normalization

Calibration using $\gamma\gamma \rightarrow \mu\mu$ data

Lumi > 10^{30} cm^{-2}s^{-1}

QED process

The muons are centrally produced with small acoplanarity

About 10k events/day at high lumi if P_T>3 GeV (1.5k if P_T>6 GeV)

Overall Calibration

Cost estimate for LUCID

The LUCID detector is estimated to cost about 100 kCHF to build:

- 2400 machining hours @ 5 CHF/hour = 12 kCHF
- Material cost = 56 kCHF
- 1100 hours for assembly @ 5 CHF/hour = 6 kCHF
- Cost of tooling, jigs etc = 5 kCHF
- Contingency = 21 kCHF

The LUCID detector read-out is estimated to cost about 400 kCHF to build:

- 2800 fibres @ 10 CHF/m = 70 kCHF
- Fibre connectors, testing etc = 50 kCHF
- 44 multi-anode PMTs = 50 kCHF
- Fast co-ax ribbon cables = 40 kCHF
- Electronics = 120 kCHF (very provisional)
- Contingency = 70 kCHF

Summary

LUCID is a 400 channel Cherenkov detector made of aluminium tubes and read out by quartz fibres.

The purpose of the detector is to monitor the luminosity in ATLAS.

It should also be able to run independently from the main ATLAS DAQ so that it can assess the beam background conditions and provide luminosity to the LHC if so required.

A similar detector is in operation at the CDF experiment.

A good time resolution makes it possible to follow individual bunches.

A measurement of the pulseheight can be used to determine when several particles goes through one tube. No saturation is expected at even the highest LHC luminosity.