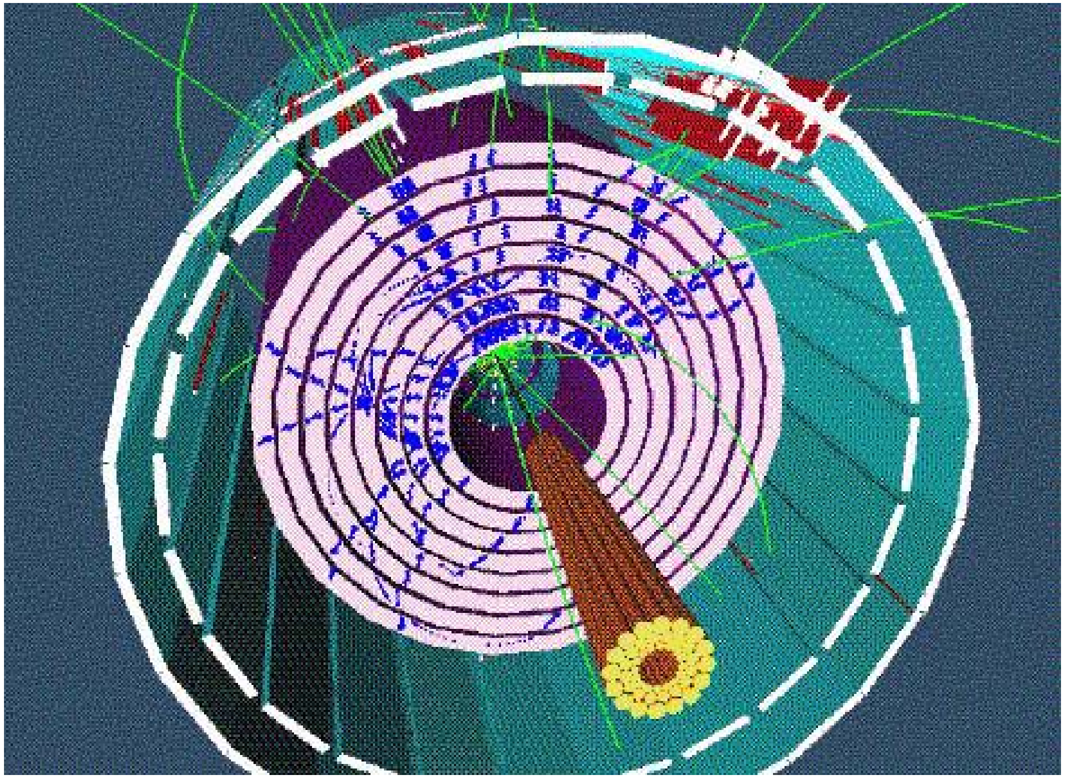
LUCID – A Detector for Measuring Luminosity at ATLAS



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University of Alberta

LUCID Luminosity Determination Interest Group - so far

- University of Alberta (Detector & physics normalization):
  - B. Caron, A. Johnston, W. J. McDonald, J. L. Pinfold (contact person), J. Soukup (contact engineer), W-Y Ting
- University of Lund (Detector only):
  - V. Hedberg (forward shielding)
- University of Montreal (Detector only):
  - C. Leroy, J-P Martin.
- SACLAY (Physics normalization only):
  - L. Chevalier, C. Guyot, J-F Laporte, M. Virchaux

- **NB Great interest from the University of Regina who would consider joining ATLAS with this as an "entry project"**

The LUCID Approach to Luminosity Measurement at ATLAS

- A detector for the measurement of luminosity over the full luminosity range expected at the LHC ($10^{28} \rightarrow 10^{34}$).
- It can be placed in existing free space(?) and requires no intrusion into the beam-pipe or special beam line elements.
- The detector can also be run "independently" in order to:
  - Check beam background conditions,
  - Assess beam quality & beam position.
- The LUCID approach is to use a Cerenkov Luminosity Counter similar to that deployed by CDF
- The LUCID detector exploits the expected Linear dependence (observed by CDF) between # reconstructed particles and # pp interactions (min. bias) to max. ATLAS luminosity ($\sim 10^{34}$ cm^{-2} s^{-1}).

Normalization

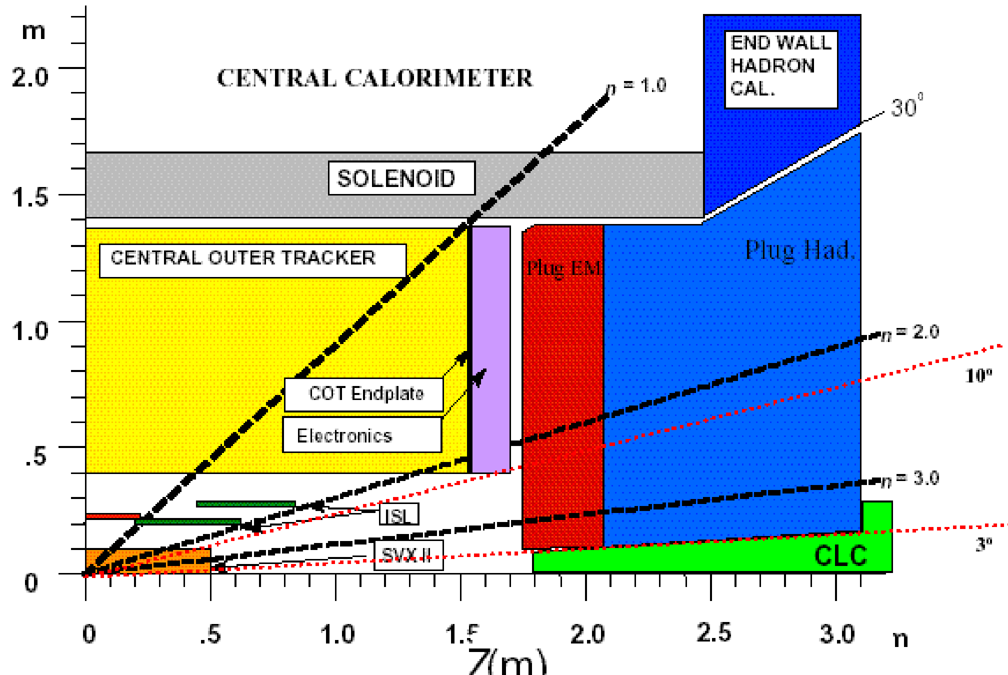
- Alberta/SACLAY & V. Telnov (Novosibirsk) propose to provide an absolute normalization for the measurement using the processes:
  - .$\gamma\gamma \rightarrow \mu^+\mu^-$ -- a QED process, muons are centrally produced with small acoplanarity. ~10K events/day at high lumi, with muon Pt >3 GeV (1.5K with Pt>6 GeV)
  - W/Z counting -- $W \rightarrow l\nu$ rate 60Hz at hi lumi with analysis cuts. ΔL limited by $\sigma_{W/Z}$.
- CDF is also using the process $W \rightarrow l\nu$ for absolute norm.
- ATLAS is also planning to measure absolute luminosity using Coulomb normalization with special beta-star=3500 m optics.

Preliminary Assessment of the CLC Technique at CDF

- Sensitive to right particles -- Much more light from primary particles than secondaries & soft particles:
  - Shorter paths (secondaries moving across detector)
  - Cerenkov thresholds
- No Landau fluctuations for Cerenkov Light emission..expect a narrow single particle peak (SPP)
- Excellent amplitude resolution
  - One can count particles
  - No saturation (occ.<0.25 for 0.5 amp. thr), linear
- Excellent time resolution (~140ps)
  - Distinguish number of interactions by time.
- Radiation hard, low mass
- Disadvantage, need gas system

The Cerenkov Luminosity Counter (CLC) at CDF (1)

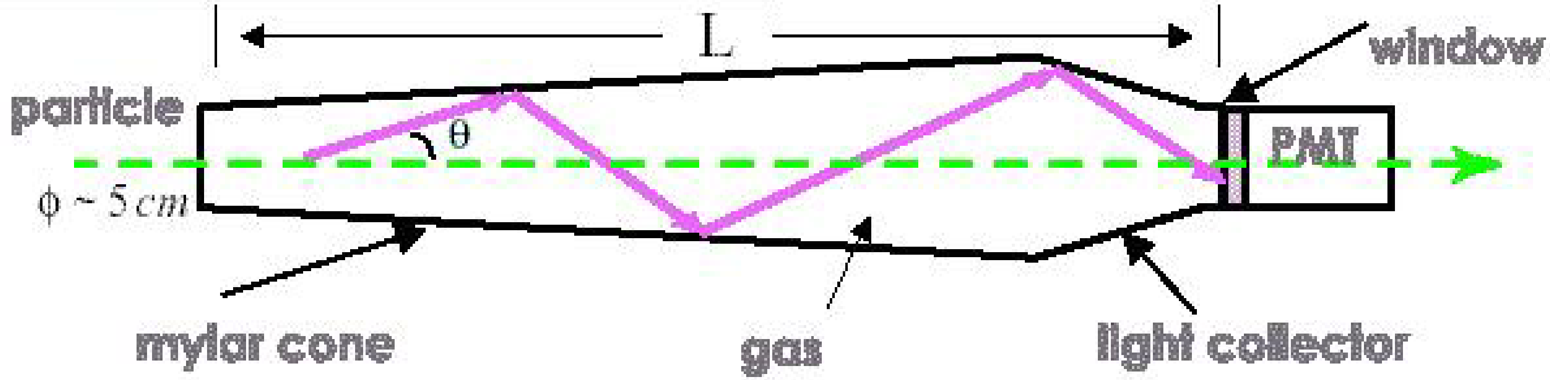
- The existing CDF CLC detector counts primary particles from forward, inelastic ppbar events, up to a Luminosity of 2×10^{32} cm^{-2} s^{-1}



- Two CLC modules in the CDF detector, installed at small angles with eta coverage 3.75→ 4.75

The Cerenkov Luminosity Counter (CLC) at CDF (2)

Light emitted if $\beta > 1/n$ UV dominated



Cherenkov radiation

- $\cos\theta = 1/(n\beta)$
- $N_{pe} = N_o L \langle \sin^2\theta \rangle$
- $N_0 = 370\ cm^{-1} eV^{-1} \int \mathcal{E}_{col}(E)\mathcal{E}_{det}(E)\, dE$

$\mathcal{E}_{col}$ - light collection efficiency

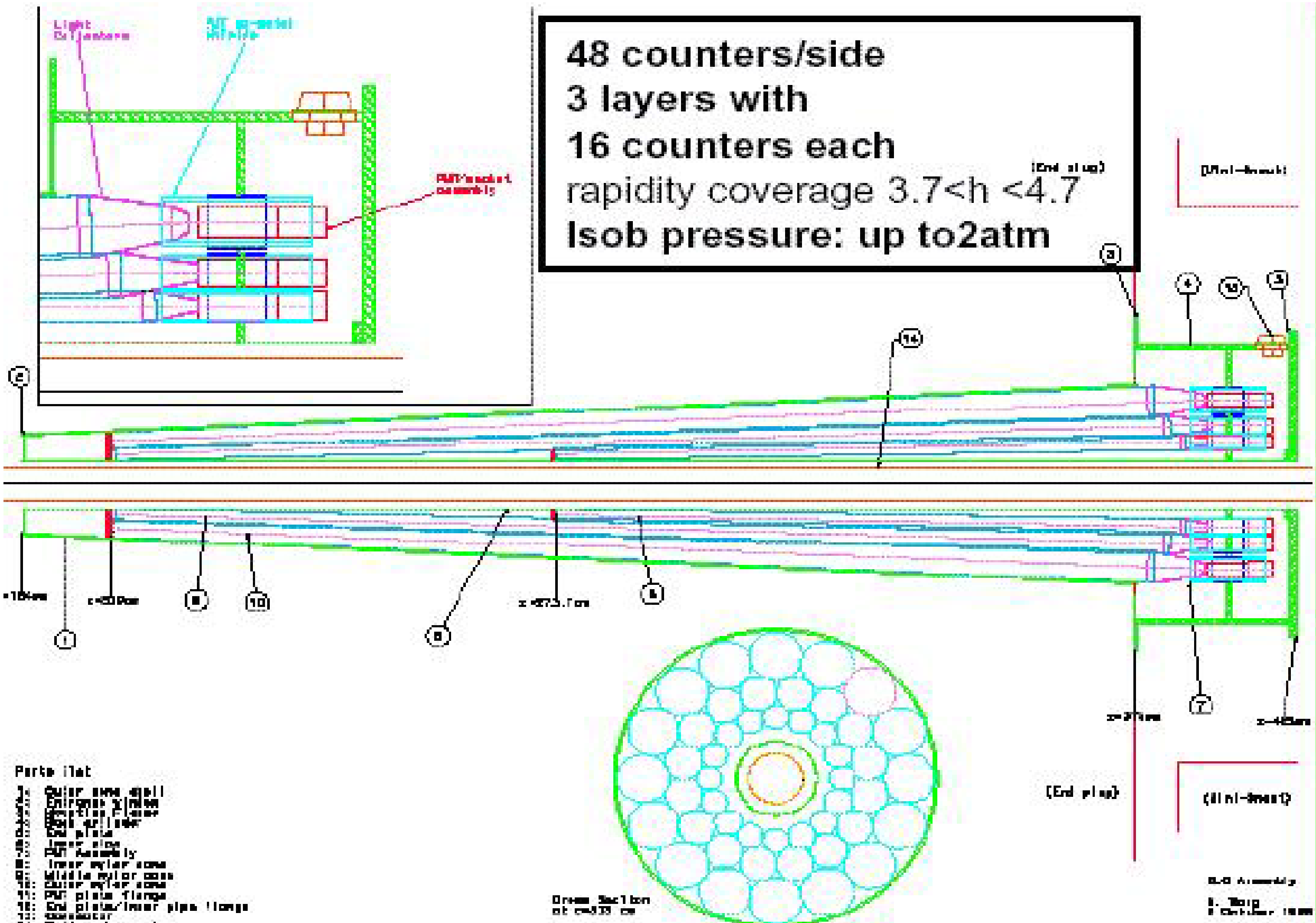
$\mathcal{E}_{det}$ - PMT quantum efficiency

Isobutane @ 1atm

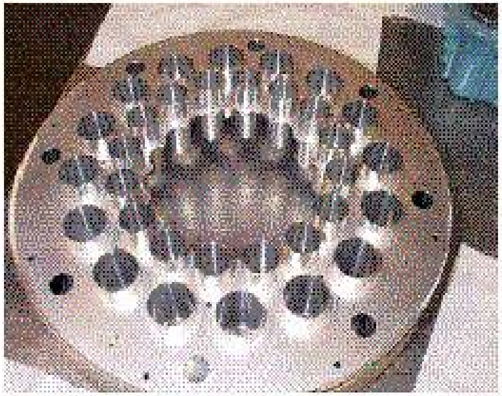
- $n=1.00143$
- $\theta = 3.1^o$
- $\sin^2\theta \sim 0.0027$
- $\langle \varepsilon_{col} \rangle \sim 0.80 \times 0.80 = 0.64$
- $\int \varepsilon_{det}(E)\, dE \sim 0.84$ (quartz window)
- $No \sim 200$

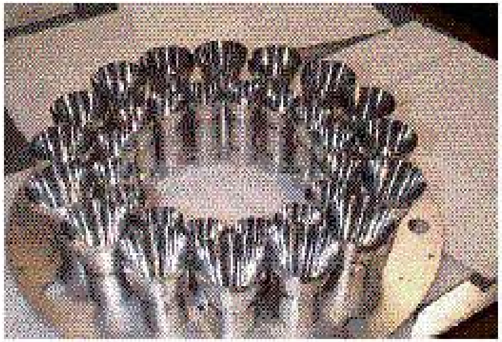
Pions > 2 GeV & Electrons > ~9 MeV ⇒ *Np.e.~110* (L=200cm)

The Cerenkov Luminosity Counter (CLC) at CDF (3)



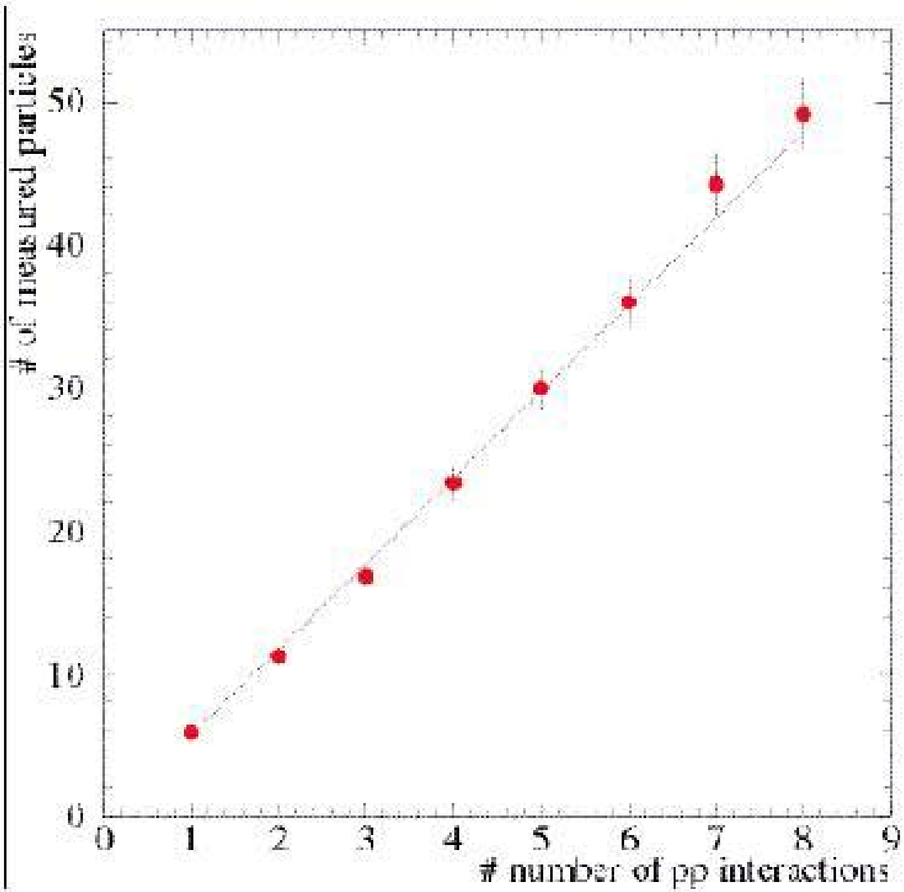
The Cerenkov Luminosity Counter Modules at CDF

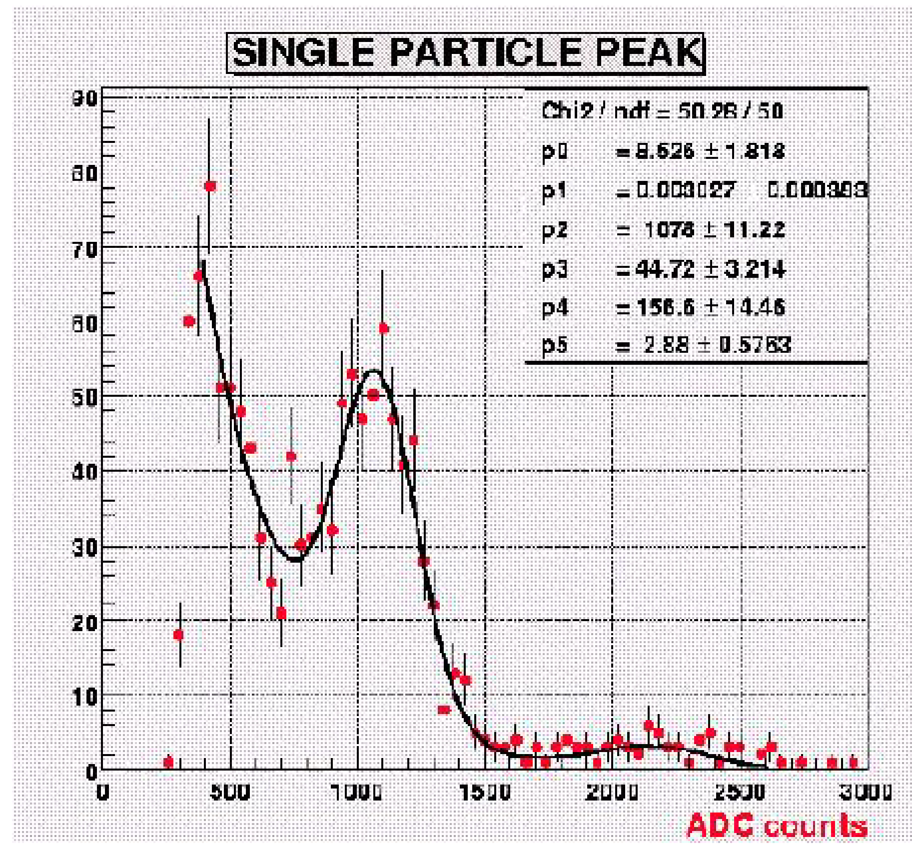




Preliminary Assessment of the CLC Technique at CDF

Operate @ L=2*10**32 @ ~6 interactions/beam crossing



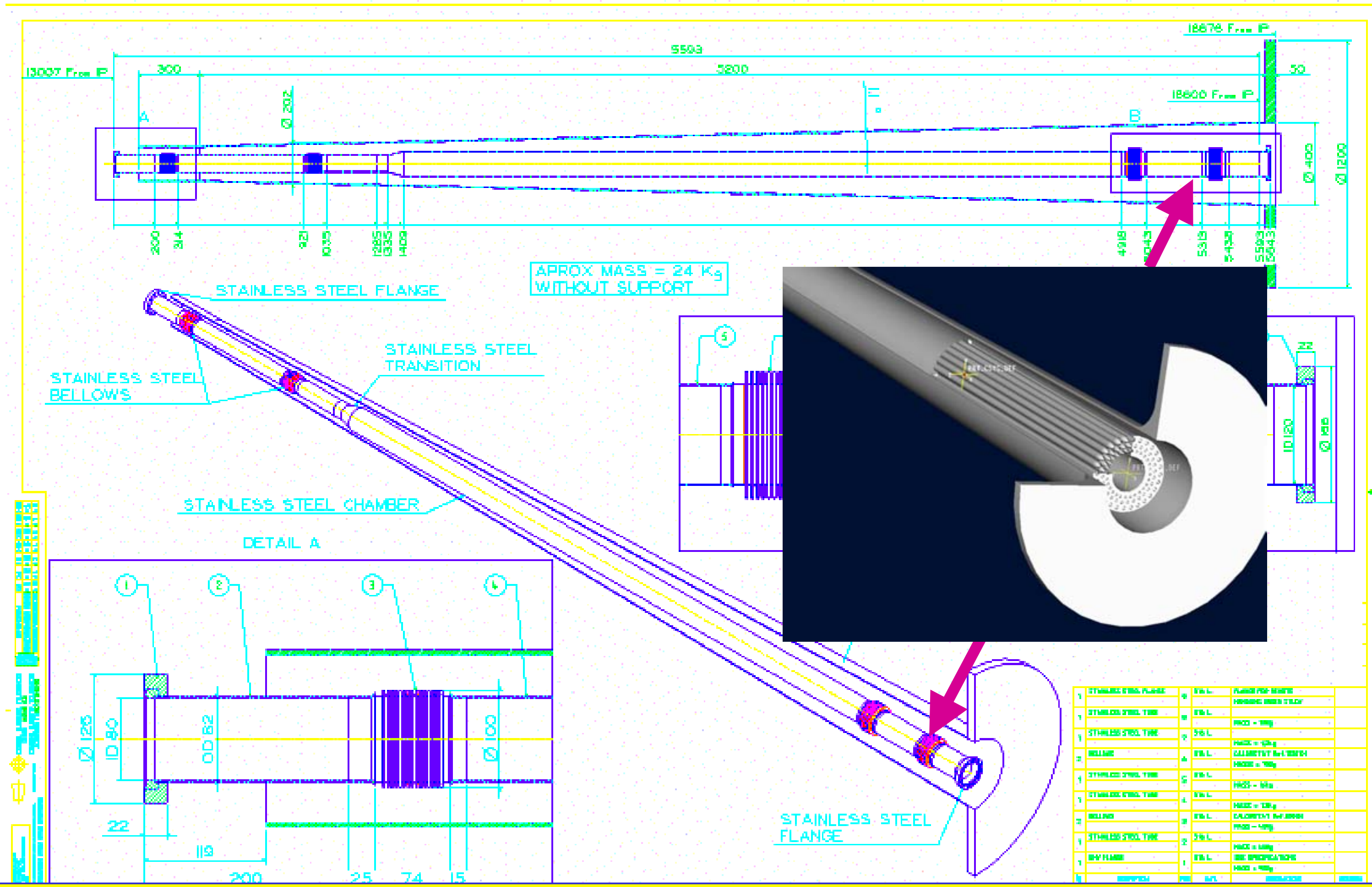


LUCID - A CLC for ATLAS Luminosity Detection

- Requirements for ATLAS luminosity (same as CDF/D0?), for the full ATLAS luminosity range:
  - Offline precision < 5% to highest luminosity
  - Online precision < 10% (every second)
  - Bunch-by-Bunch measurement
- The CLC technique is now measuring CDF lumi at 2×10^{32} with a luminosity uncertainty of 10% which is expected to fall to < 5%.
- Can the CDF CLC technique fit the bill for ATLAS Luminosity measurement?
- Two big problems:
  - Inaccessibility (buried in the forward shielding)
  - Radiation levels (10^5 Gy/yr, 10^{14} n/(cm^2.yr))

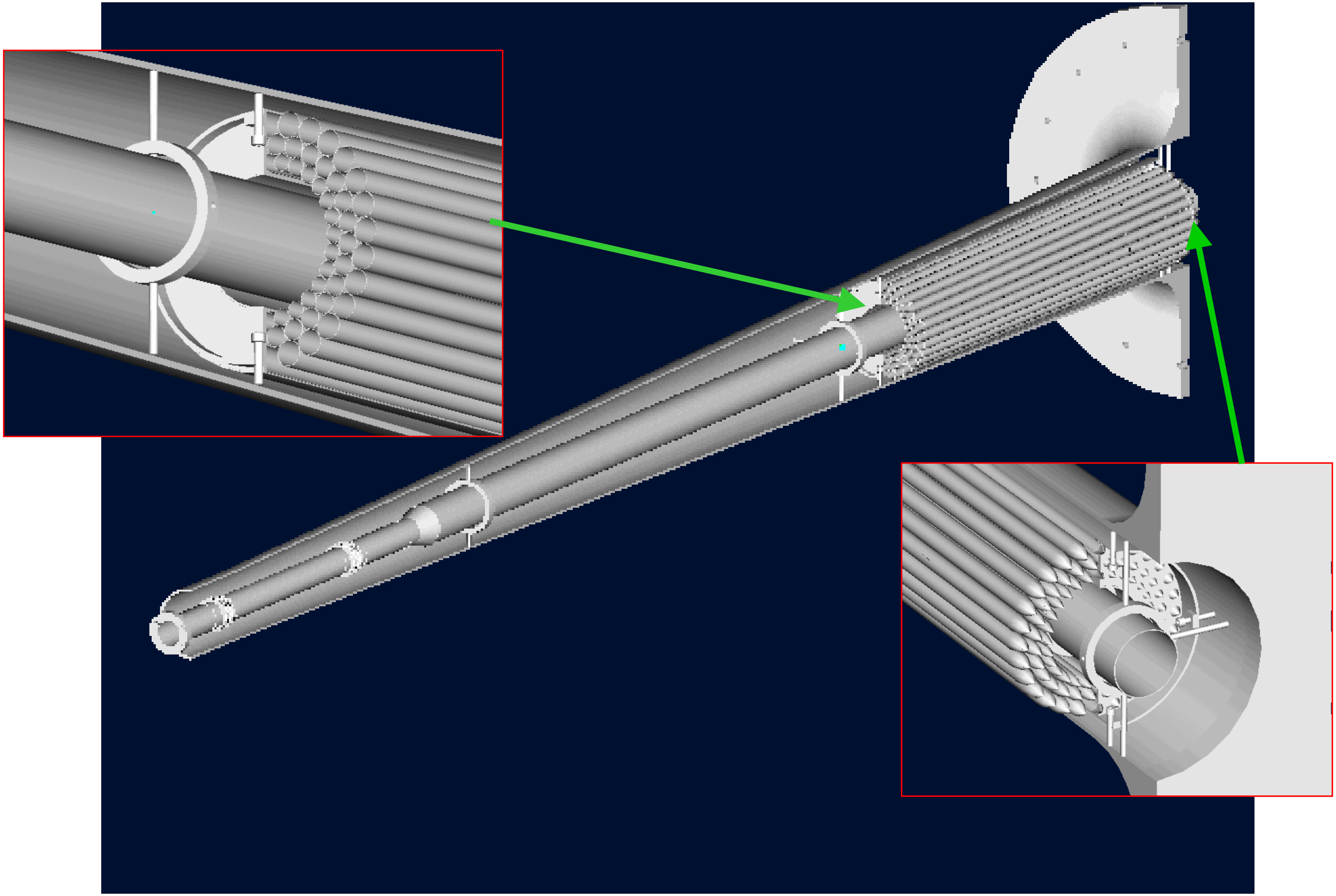
Position for LUCID ~17-19m from the IP

- Acceptance (in pseudorapidity): 5.2 → 6.6

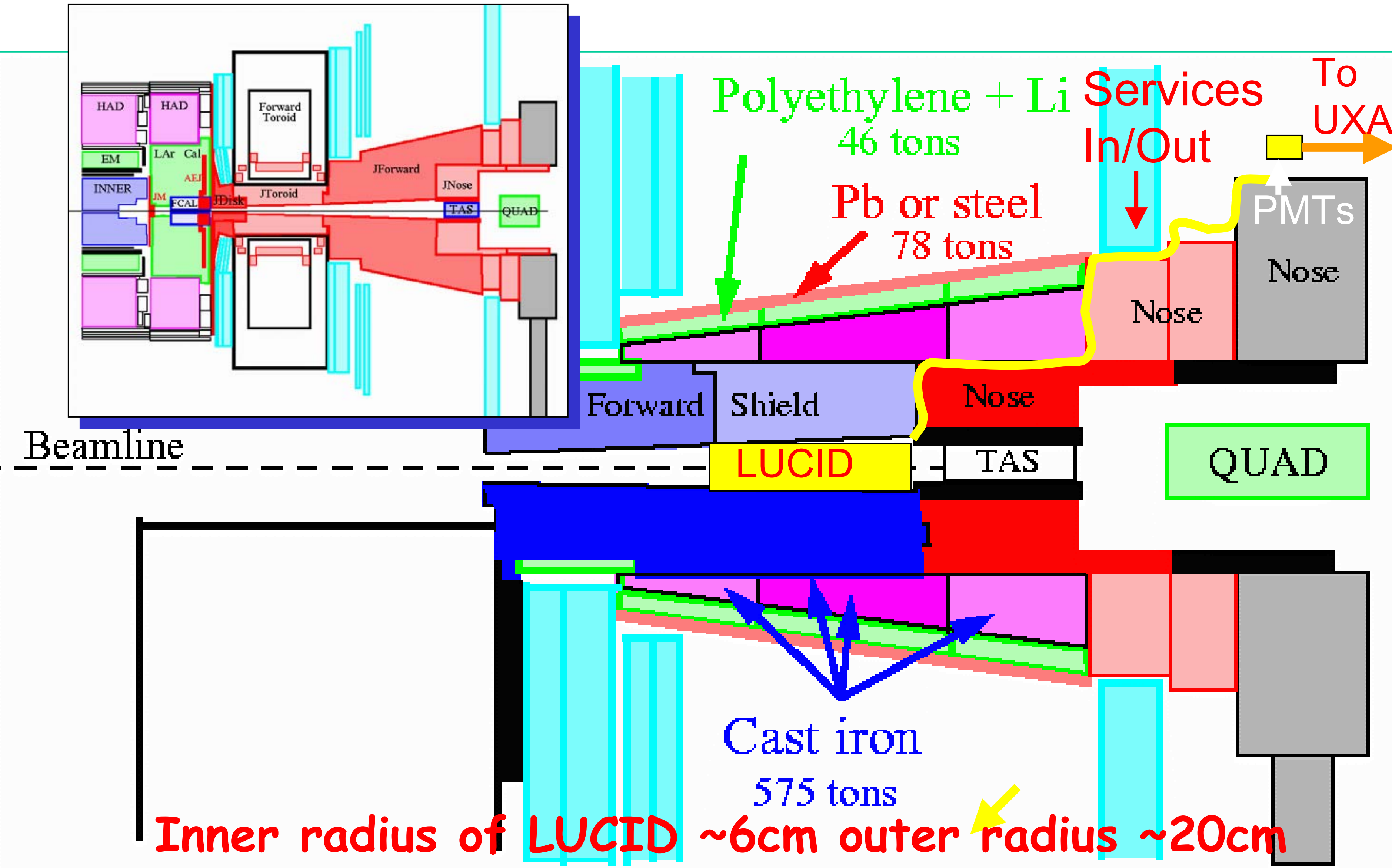


Position LUCID between Vacuum Support Structure & beam pipe in the vicinity of the forward shielding

The LUCID Detector In Situ

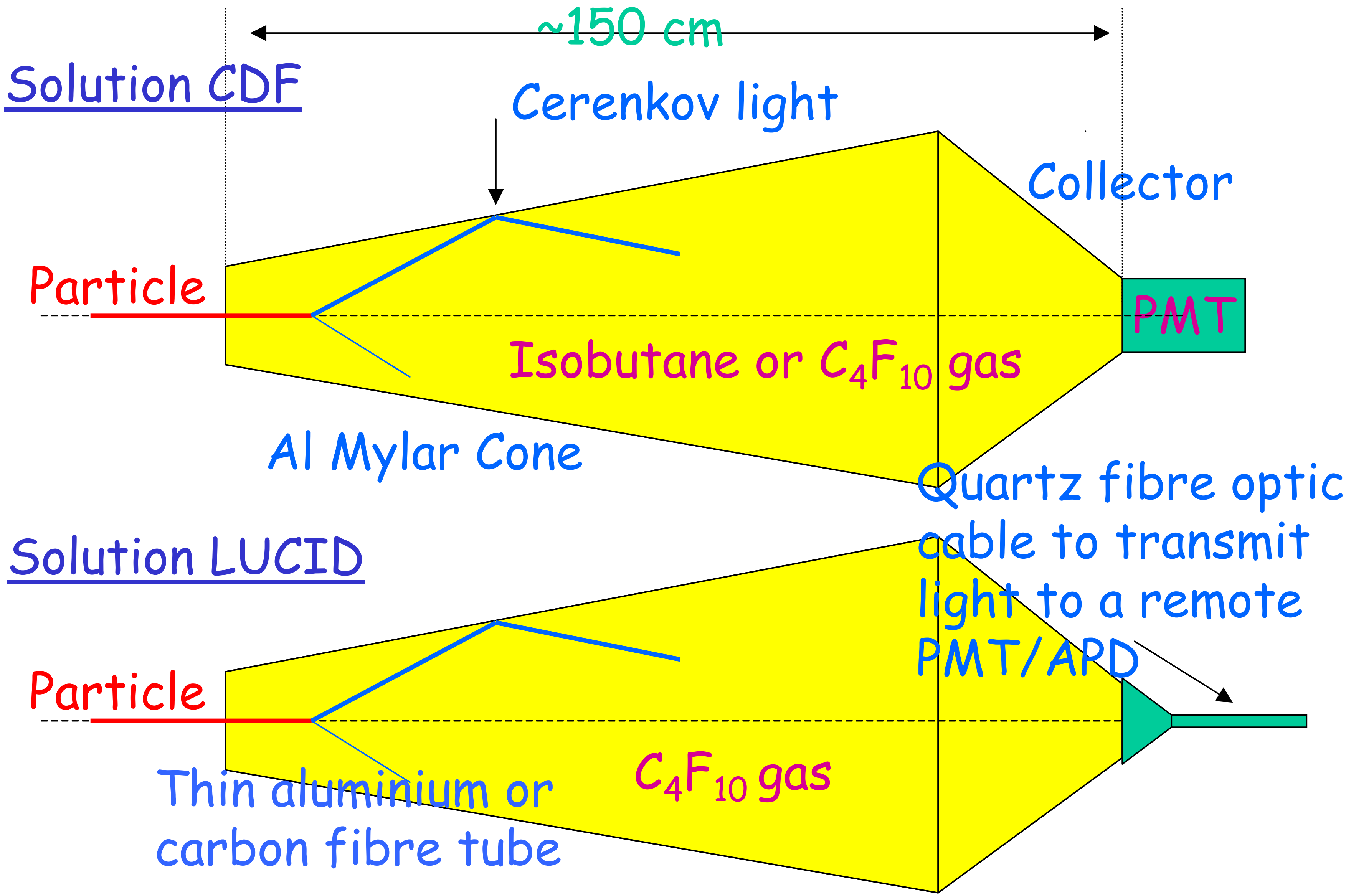


Routing of Cables + Gas Supply



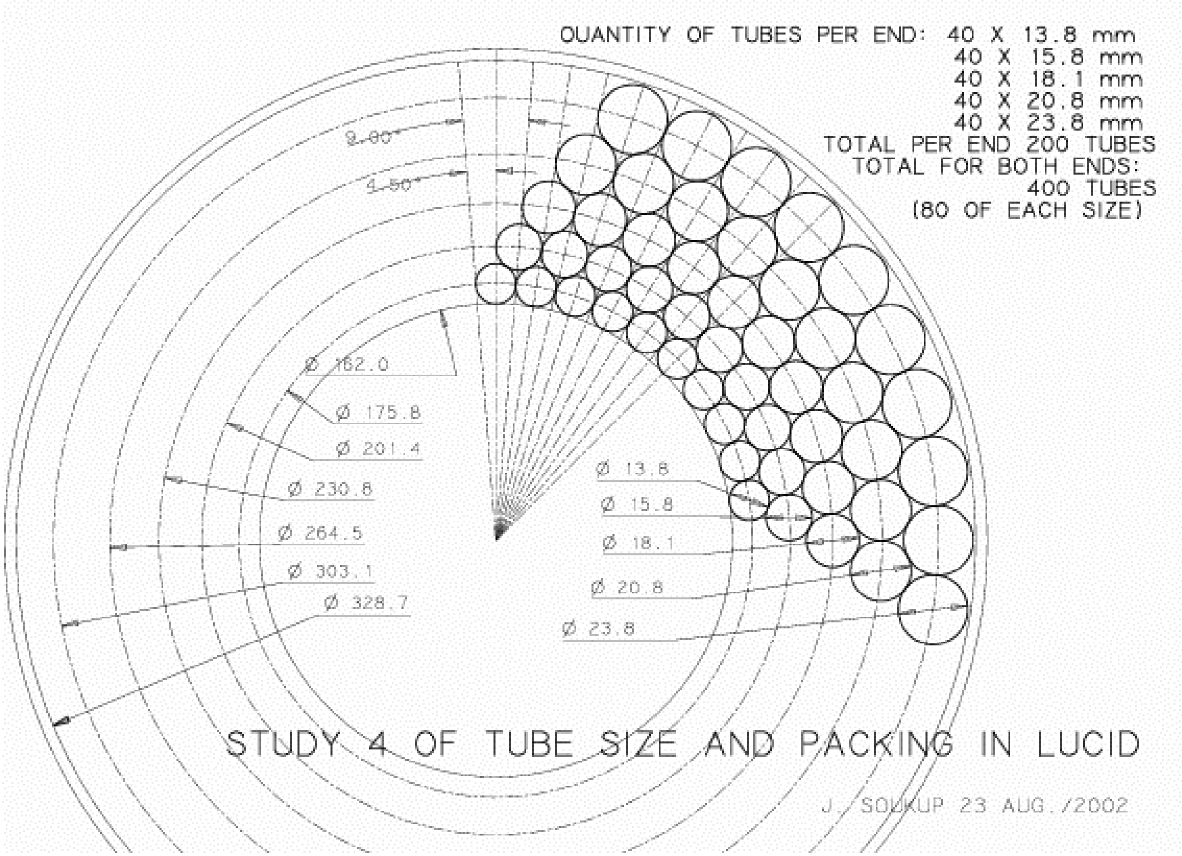
Inner radius of LUCID ~6cm outer radius ~20cm

CDF-like CLC of LUCID

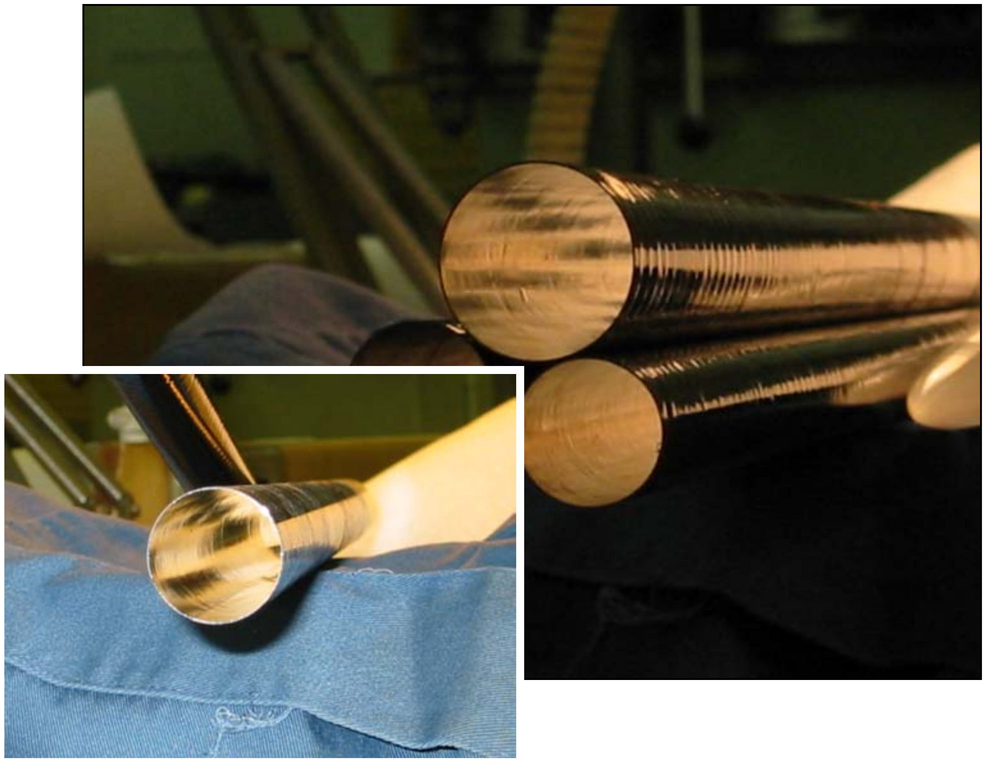


A Cross-Section Through LUCID

- There are 200 Cerenkov tubes per end.
- Use Al lined Carbon fibre Cerenkov tubes for heat resistance.
- The tubes are deployed in 5 layers of increasing diameter each row has 40 tubes.
- Allows some position sensitivity



Prototype Al Lined Carbon-Fibre Cerenkov Tubes + Al Winston Cones



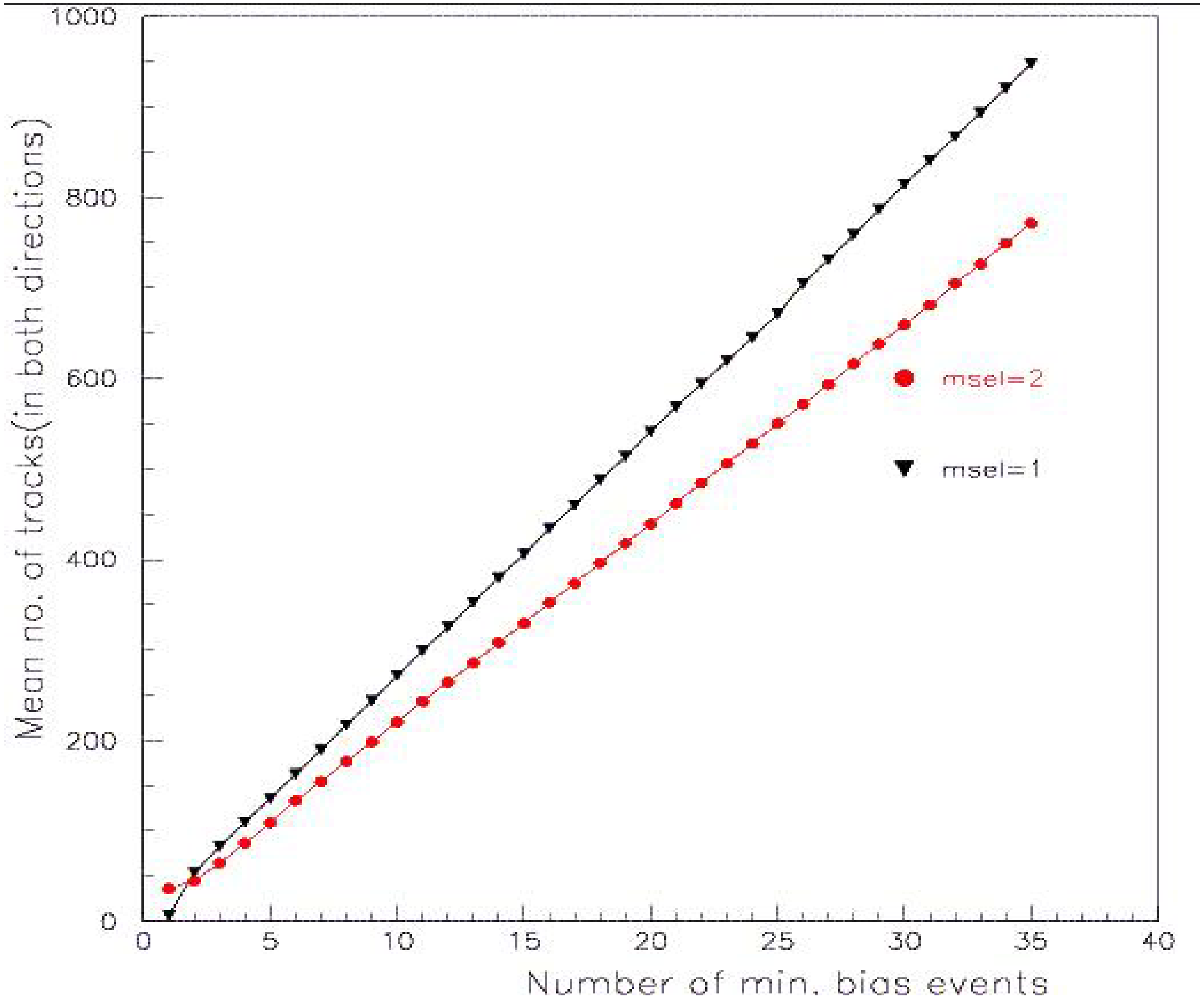
Carbon fibres tubes with wall thickness 0.5 mm and 50 micron Al liner

Plastic models of Winston Cones used to concentrate Light into the fibre readout The cones will be fabricated Out of 0.5m thick aluminium

Primary Particle flux in LUCID

- 20,000 events used (ATLFAST). An initial simulation with no detailed simulation of the detector.
- Primary particle flux into acceptance of the detector (one end)
  - ~11 tracks/MinBias event
  - At low lumi ~ 30 MinBias tracks per bunch xing
  - At high lumi ~300 MinBias tracks per bunch xing
- Roughly 25% of MinBias events will give no tracks in either LUCID detector.
- At low luminosity only a few percent of crossings will give no primary tracks in LUCID from primary tracks
- At high luminosity essentially no crossing will give zero primary tracks in LUCID

Variation of Detected Multiplicity with #Pileup Events (1st look)



Milestones Reached

1. Appoint contact engineer (J. Soukup) ✓
2. Start and continue discussions with forward shielding and beampipe responsibles ✓
3. Space reserved for LUCID services ✓
4. Preliminary meeting with ATLAS integration (Marzio) ✓
5. Fabricate CDF-like cerenkov cones ✓
6. MC of secondary particle fluxes in the LUCID region ✓
7. ATLFAST study of physics normalization processes: $\gamma\gamma \rightarrow \mu^+\mu^-$ & W/Z counting (PhD Bryan Caron) ✓
8. Preliminary meeting with ATLAS EB ✓

Milestones Leading to a TP?

1. Prepare full simulation (G3→G4) of detector including secondary particles fluxes at LUCID - in progress
2. Prepare full set of engineering drawings - in progress
3. Construct full-scale mock-up of the LUCID region to explore routing of services, start within one month
4. Prepare FULLSIM studies of physics normalization processes and study low Pt muon trigger (Alberta/SACLAY) - in progress
5. Prepare prototype for muon beam tests at TRIUMF - in progress (test this winter)
6. Radiation test of LUCID elements - to be done

Cons - an Initial Look (1)

- CONS
  - LUCID will be placed in an inaccessible region and will need optical fibre readout and a gas supply
  - Will experience radiation levels much higher than at CDF.
  - Will need to be able to take the temperature of a beampipe bakeout jacket (hence carbon fibre construction)
  - Is a new detector that will cost money (estimate ~$500K US, based on CDF experience).

Pros - an Initial Look (2)

- **LUCID provides a luminosity measurement that:**
  - Has a response Linearly proportional to # bunches over full range - providing a lumi measurement over full range.
  - Fast enough to track individual bunches(eg"bad" bunches)
  - Less susceptible to low energy and/or secondary particle fluxes than "conventional" lumi detectors
  - Should provide a measurement over the full Lumi range.
- **LUCID can also:**
  - Be triggered independently from ATLAS and switched on before ATLAS to provide feedback to machine people.
  - Extends eta coverage to 6.6, useful in forward physics?
- **The LUCID detector:**
  - Can fit in existing space OUTSIDE of beampipe.
  - Is low mass (~6Kg/end) & can be supported from the existing beam pipe support cone.
  - Is in principle rad. hard
  - Based on already functioning detector technology (CDF).