Beamtest studies at Fermilab

Shivesh Mandalia (Queen Mary)• Teppei Katori (Queen Mary)

Carlos Argüelles (MIT) • Spencer Axani (MIT) • Janet Conrad (MIT) • Marjon Moulai (MIT) • Perry Sandstrom (WIPAC)

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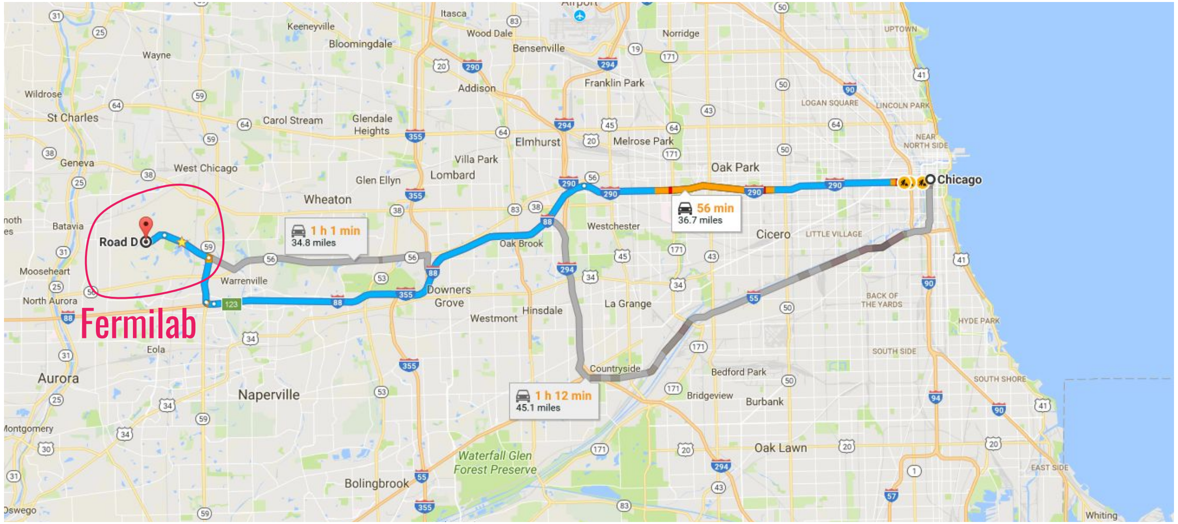
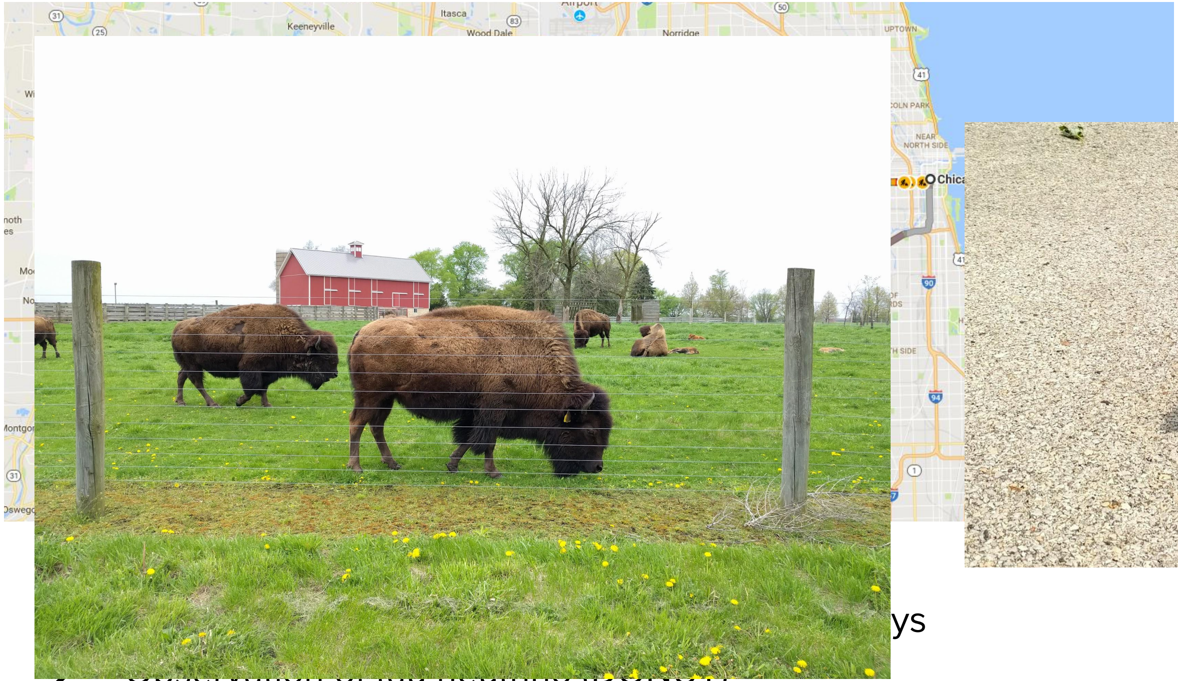
Fermilab



Wilson Hall

- ➔ Discovery of the bottom/top quark
- ➔ Observation of direct CP violation in kaon decays
- ➔ Observation of tau neutrino (DONUT)
- ➔ Headquarters for DUNE

Fermilab



ys

➔ Observation of tau neutrino (DONUT)

➔ Headquarters for DUNE

Wilson Hall

Fermilab

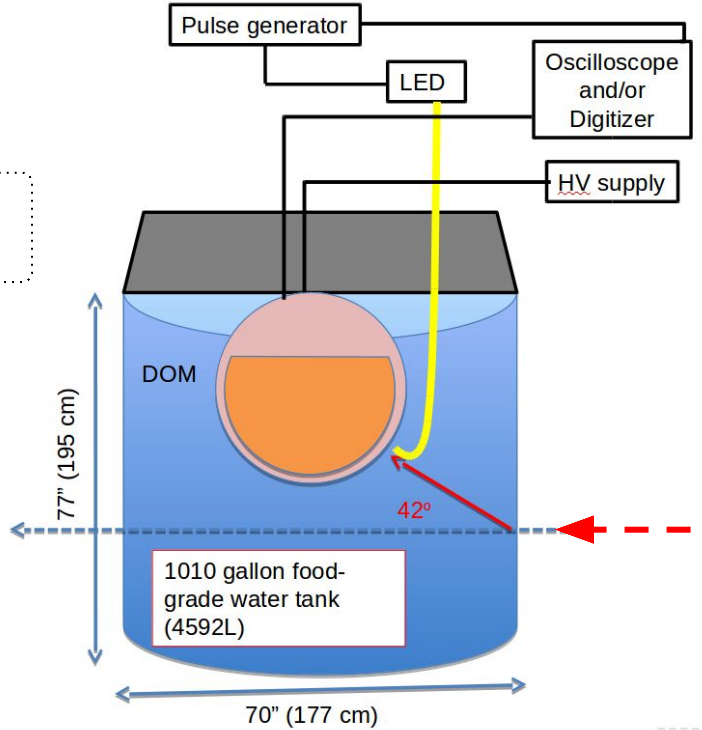
One of the beams at Fermilab is available to users.

From the website: **Fermilab Test Beam Facility (FTBF)**

“The FTBF program provides flexible, equal, and open access to test beams for all detector tests, with relatively low bureaucratic overhead and a guarantee of safety, coordination, and oversight.”

Idea

Tank



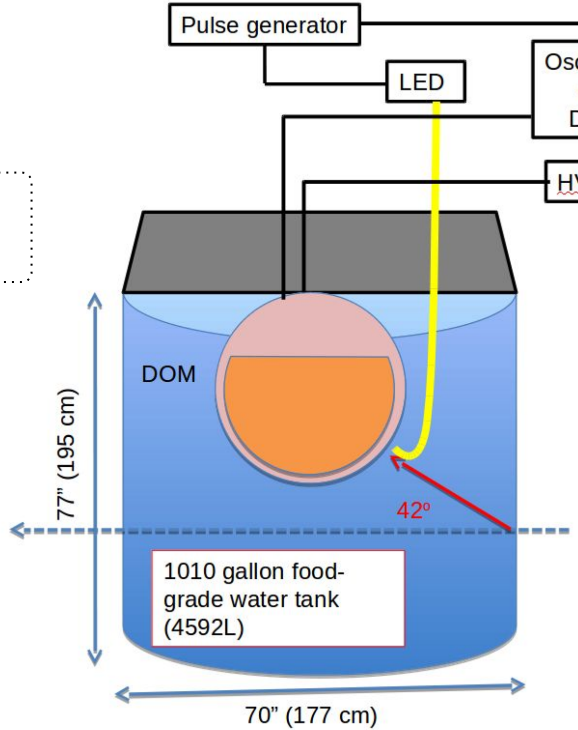
Beam of known particles from **Fermilab Test Beam Facility (FTBF)**
http://ftbf.fnal.gov/

- Black tedlar film coats the inside and outside
- Filled with distilled water

See backup for schematic of tank

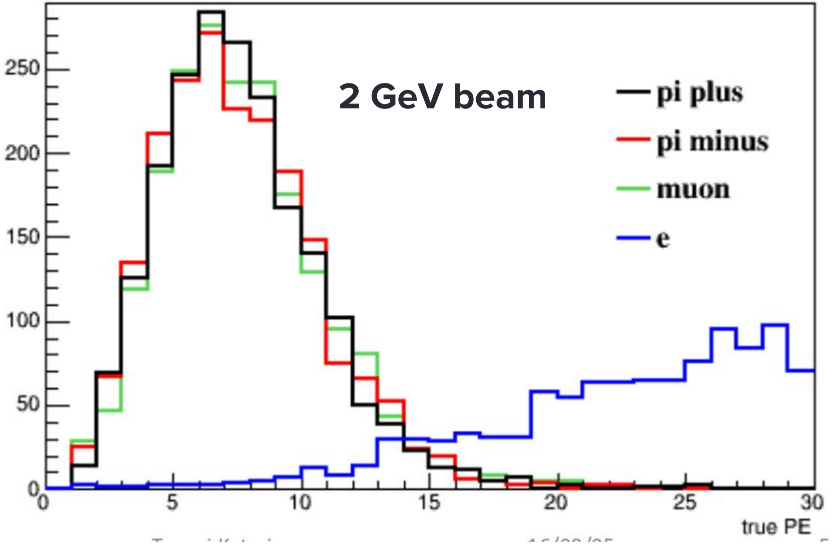
Idea

Tank



Study PID between MIPs vs EM showers using waveforms around a few GeV

True total PE distribution (no efficiency yet)



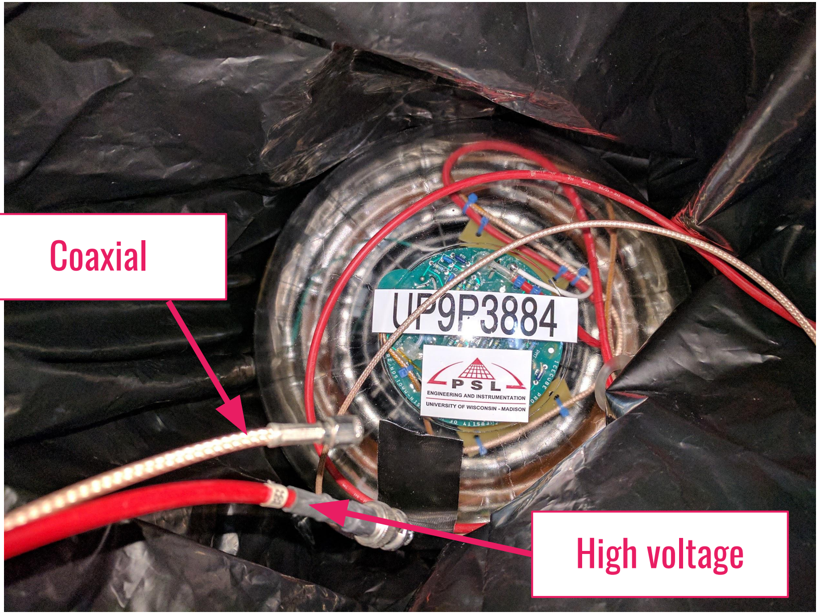
- ➔ Black tedlar film coats the inside
- ➔ Filled with distilled water

See backup for schematic of tank

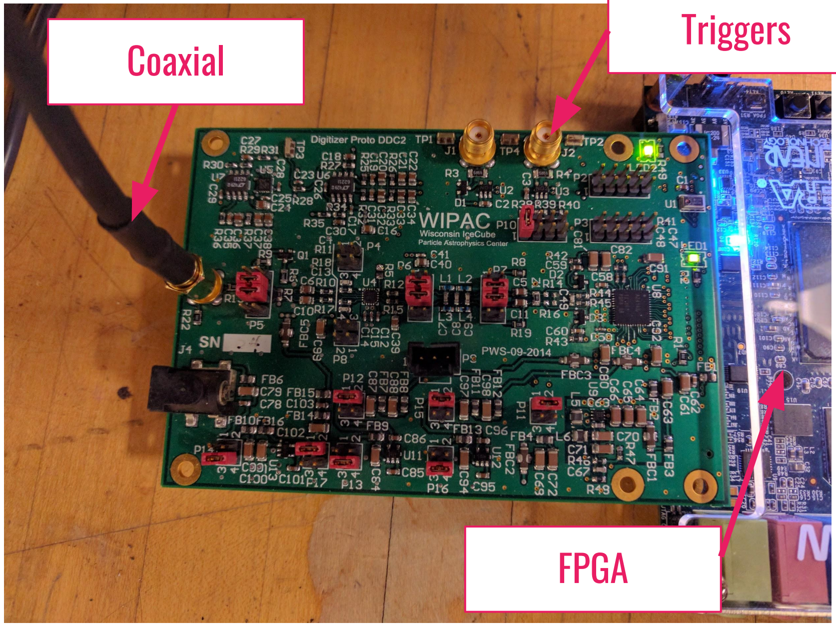
- ➔ Clear e vs MIP separation

Hardware

PMT



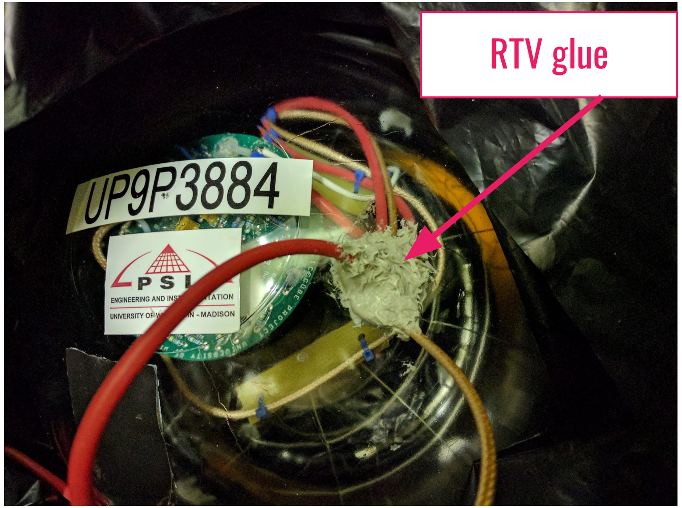
Digitiser



Setup

PMT

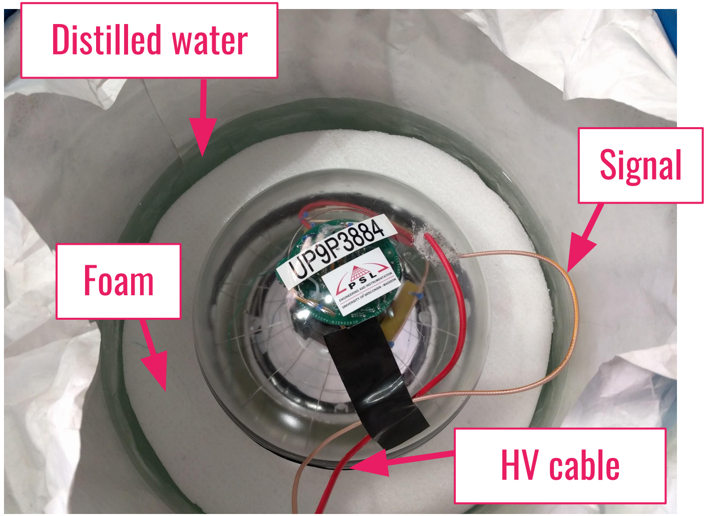
- ➔ PMT enclosure must be made water-tight
- ➔ Penetrator was closed up by using grey RTV glue

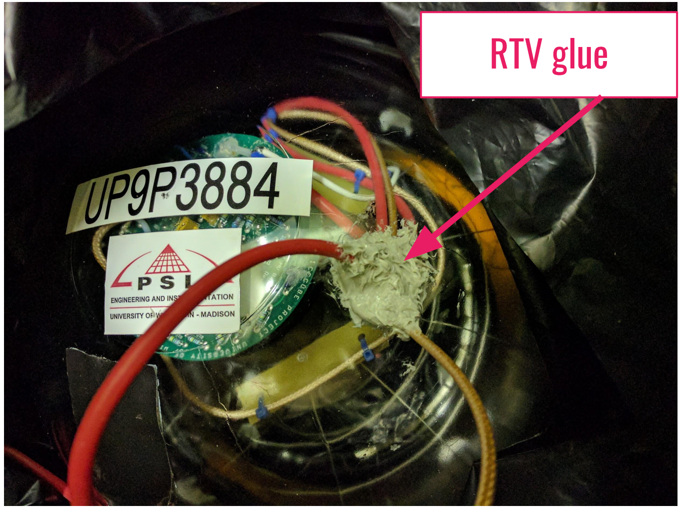


Setup

PMT

- ➔ PMT enclosure must be made water-tight
- ➔ Penetrator was closed up by using grey RTV glue
- ➔ Used a 55-gallon drum filled with distilled water to test this



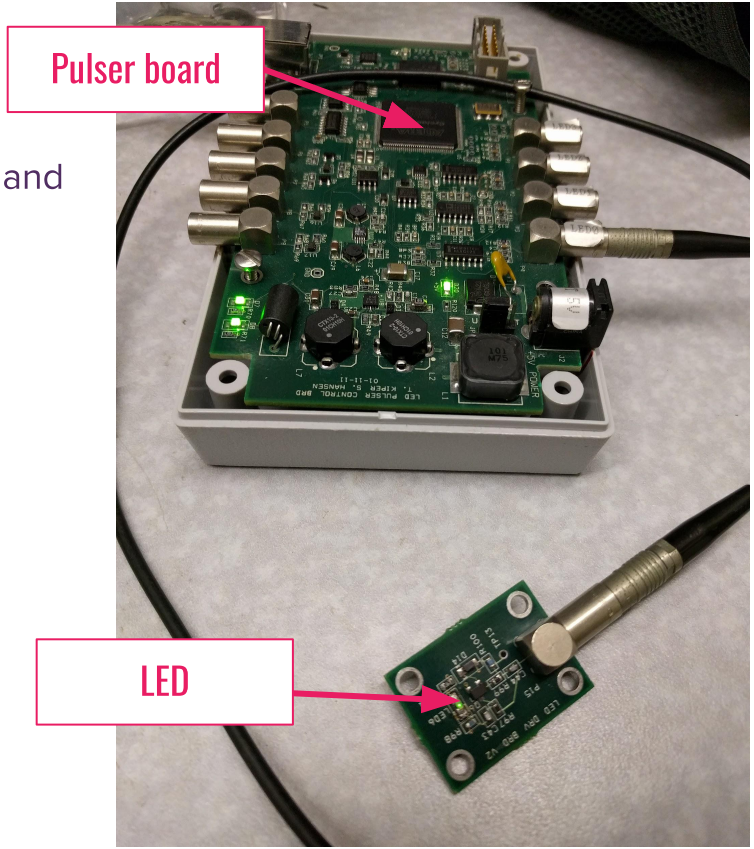


- ➔ DOM is very buoyant!
- ➔ For stability we made a foam structure which houses the DOM - “floating island”

Setup

LED

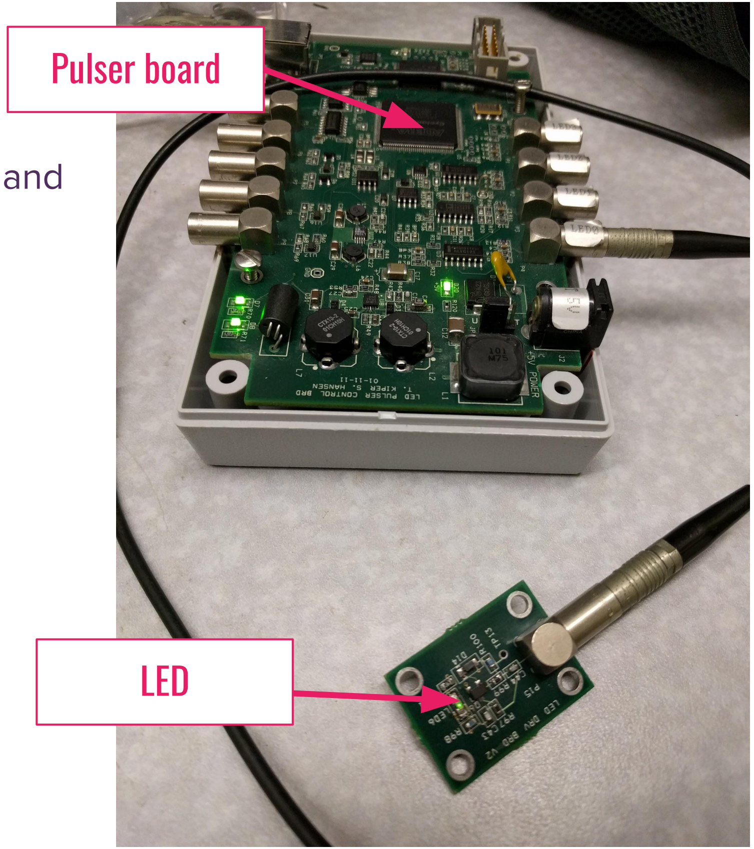
- ➔ Use a well-defined LED pulses to test DOM is operational and produces the expected signal waveform
- ➔ FPGA board allows dynamic control of the LED

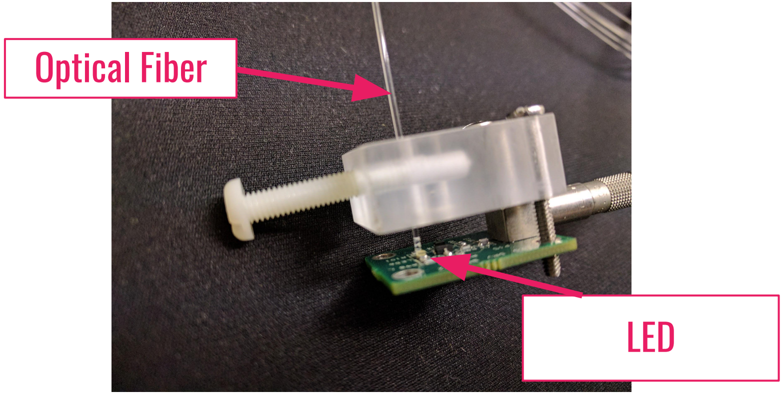


Setup

LED

- Use a well-defined LED pulses to test DOM is operational and produces the expected signal waveform
- FPGA board allows dynamic control of the LED
- We couple the LED light pulse to an optical fiber

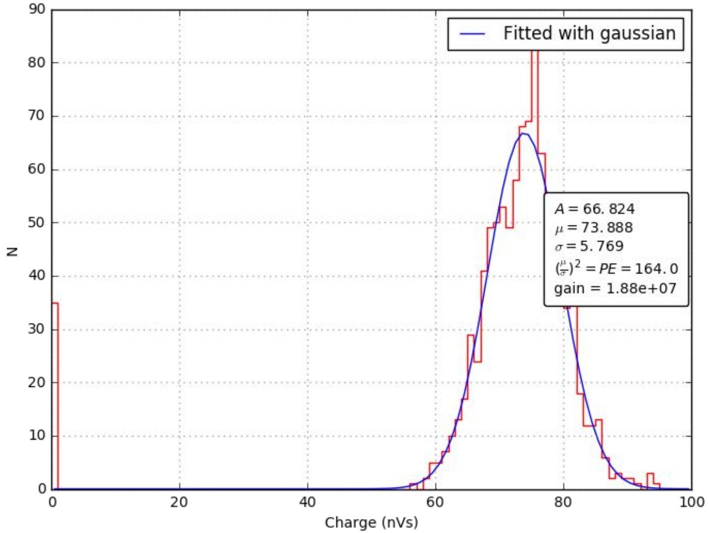




Setup

LED

- We can monitor the **gain** of the PMT by using the LED
  - Fit the charge distribution to a gaussian
  - Using poisson statistics, the number of PE hits and gain can be calculated
- This is useful to test the degradation of the water over the days when we have beam
  - Degradation of distilled water (i.e. changes in the water transparency) will affect the gain we measure on the PMT



Setup

Tank

- ➔ Delivered to FTBF
- ➔ Wrong colour! We were expecting a black tank

Setup

Tank

- Delivered to FTBF
- Wrong colour! We were expecting a black tank
- We coated the inside and outside layers of the tank in a black Tedlar film

Wires get fed through hole in the lid

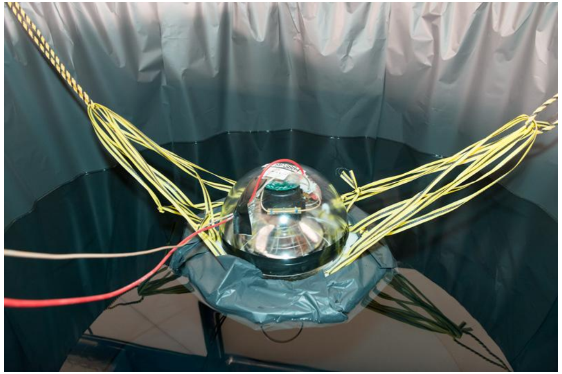
Setup

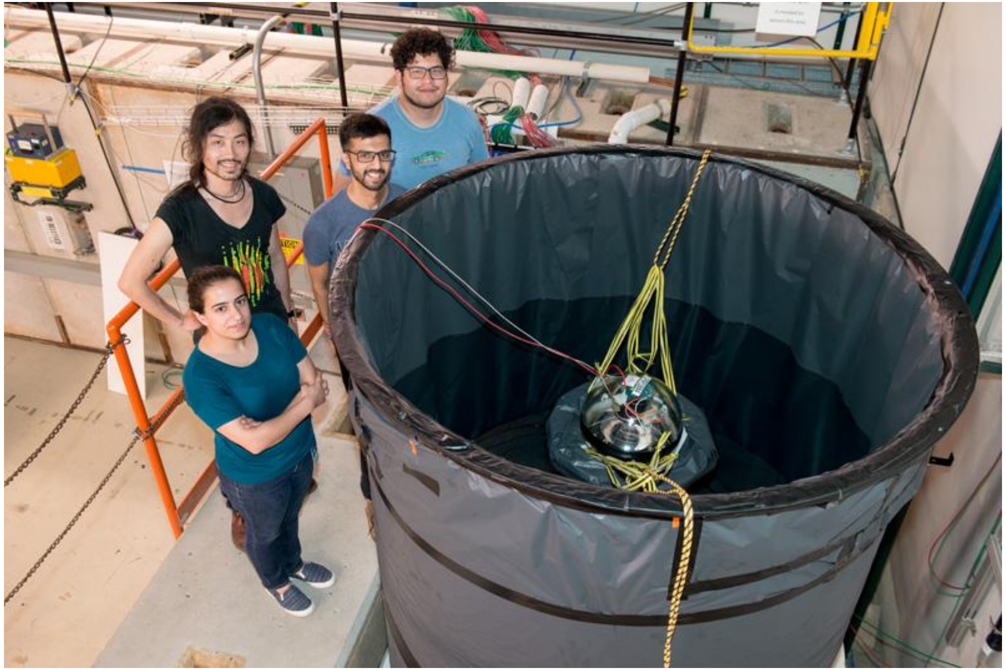
Tank

→ Moved the tank into the MT6.2 enclosure

Setup

- ➔ Tank was filled with ~ 700 gallons of distilled water
- ➔ DOM was placed at the centre of the tank using ropes

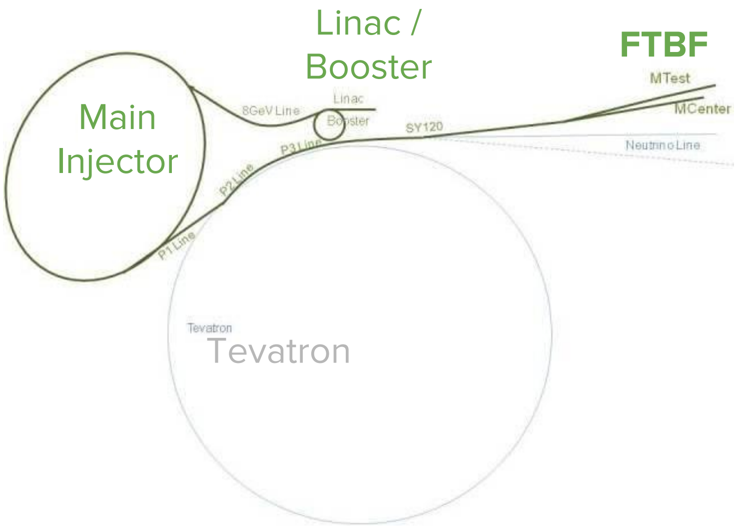




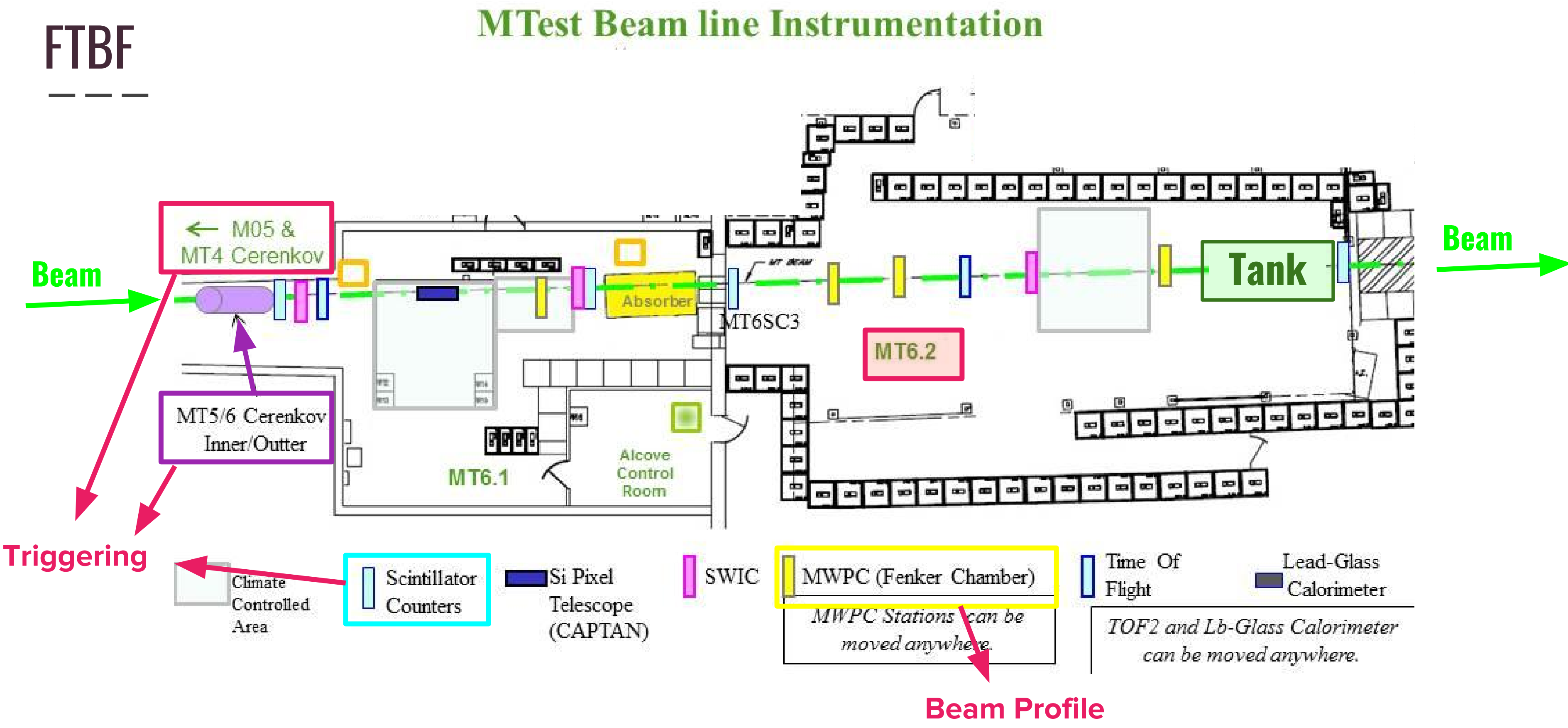
FTBF

Beam details:

- Using the secondary beamline at “MTest”
  - **(120 GeV**: Protons - primary beam from Main Injector)
  - **8 - 60 GeV**: Pions, (some protons possible)
  - **1 - 32 GeV**: Pions, electrons, kaons, or broadband muons
- 4 second spill every 60 seconds
- Tunable rate (100 Hz - 100,000 Hz), beam available 24/7
- At 4GeV pions make up ~30% of the beam
  - This fraction gets smaller as energy is decreased
- Full details can be found:
  - http://ftbf.fnal.gov/beam-overview/

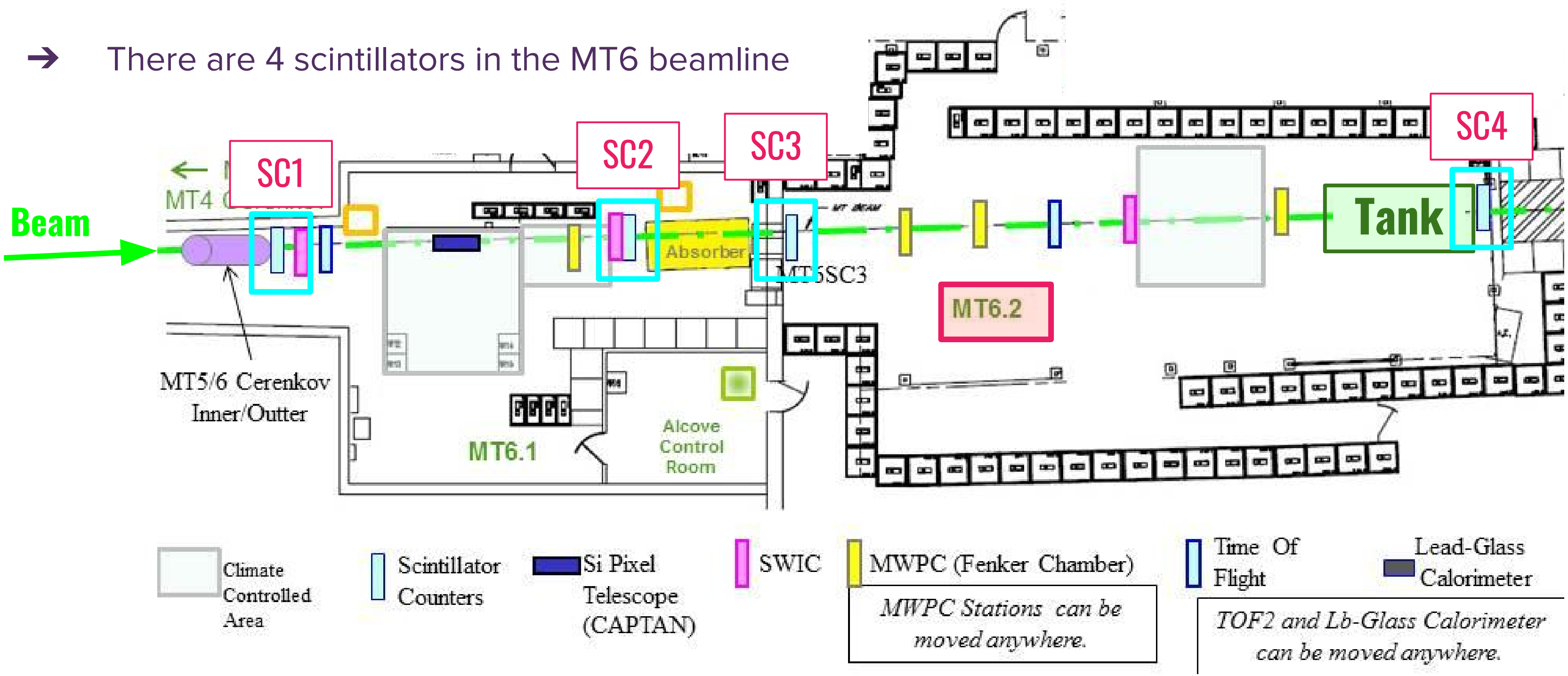


FTBF


MTest Beam line Instrumentation
Beam
← M05 & MT4 Cerenkov
MT5/6 Cerenkov Inner/Outter
Absorber
MT6SC3
MT6.2
Tank
Beam
MT6.1
Alcove Control Room
Triggering
Climate Controlled Area
Scintillator Counters
Si Pixel Telescope (CAPTAN)
SWIC
MWPC (Fenker Chamber)
MWPC Stations can be moved anywhere.
Time Of Flight
Lead-Glass Calorimeter
TOF2 and Lb-Glass Calorimeter can be moved anywhere.
Beam Profile

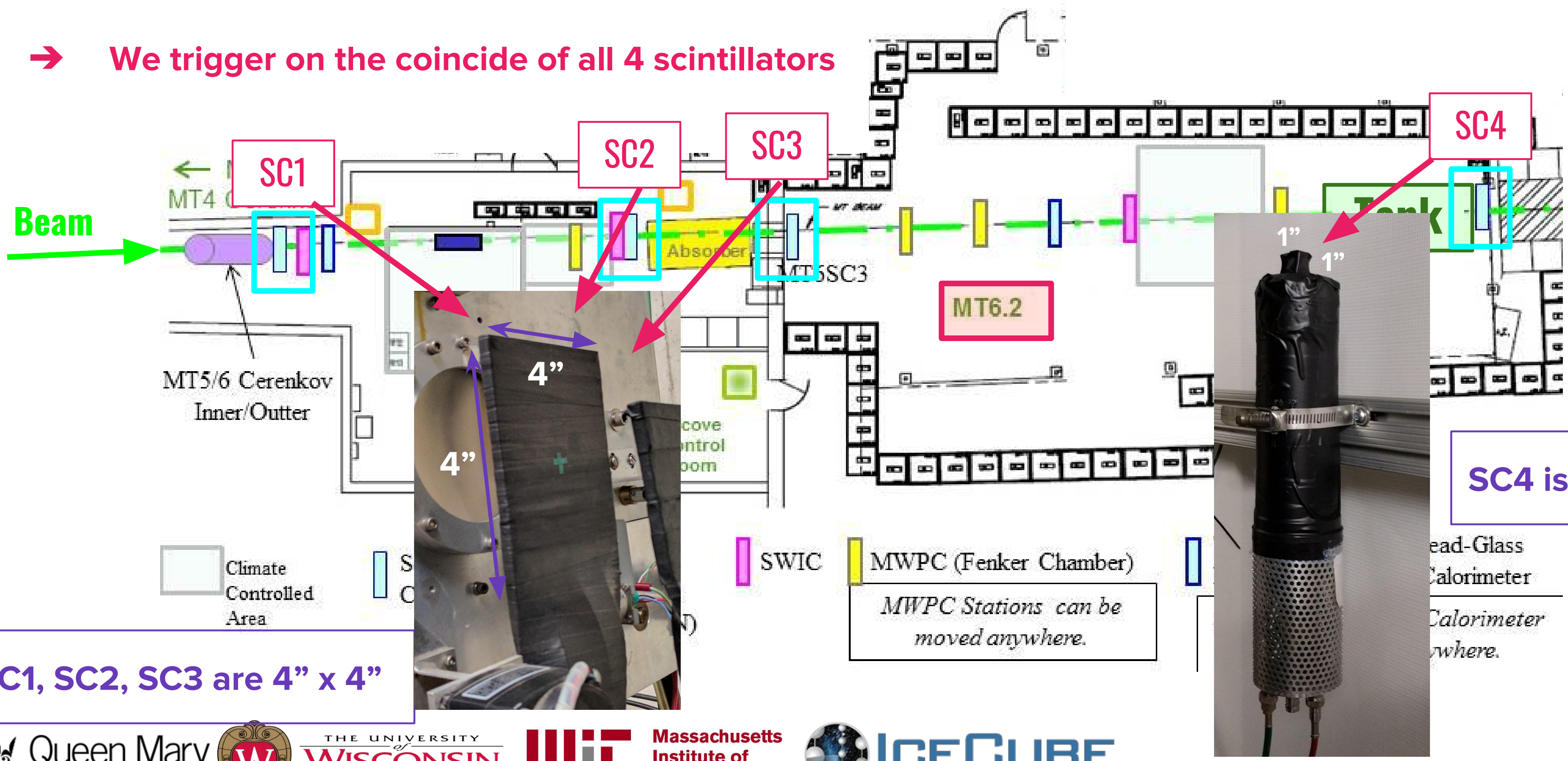
Triggering

➔ There are 4 scintillators in the MT6 beamline



Triggering

➔ **We trigger on the coincide of all 4 scintillators**

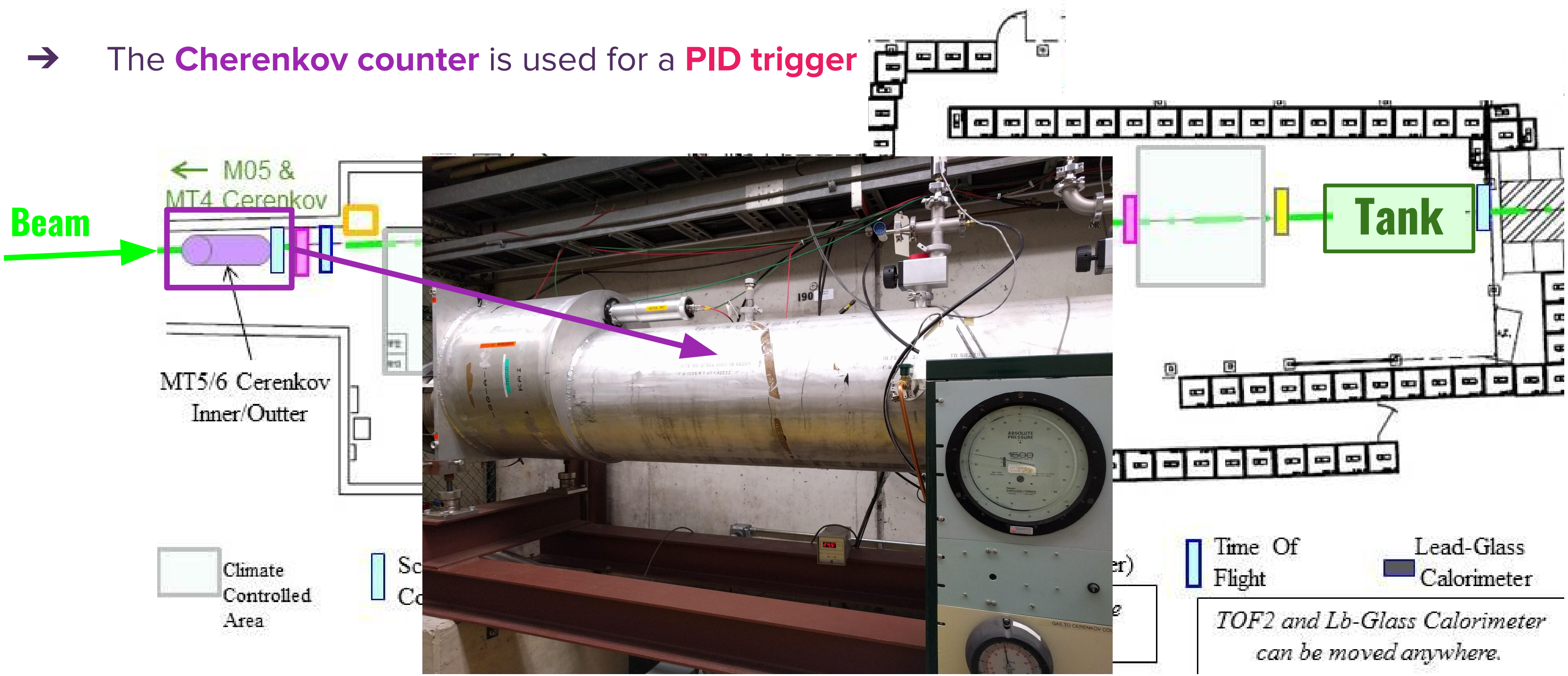


SC1, SC2, SC3 are 4” x 4”

SC4 is 1” x 1”

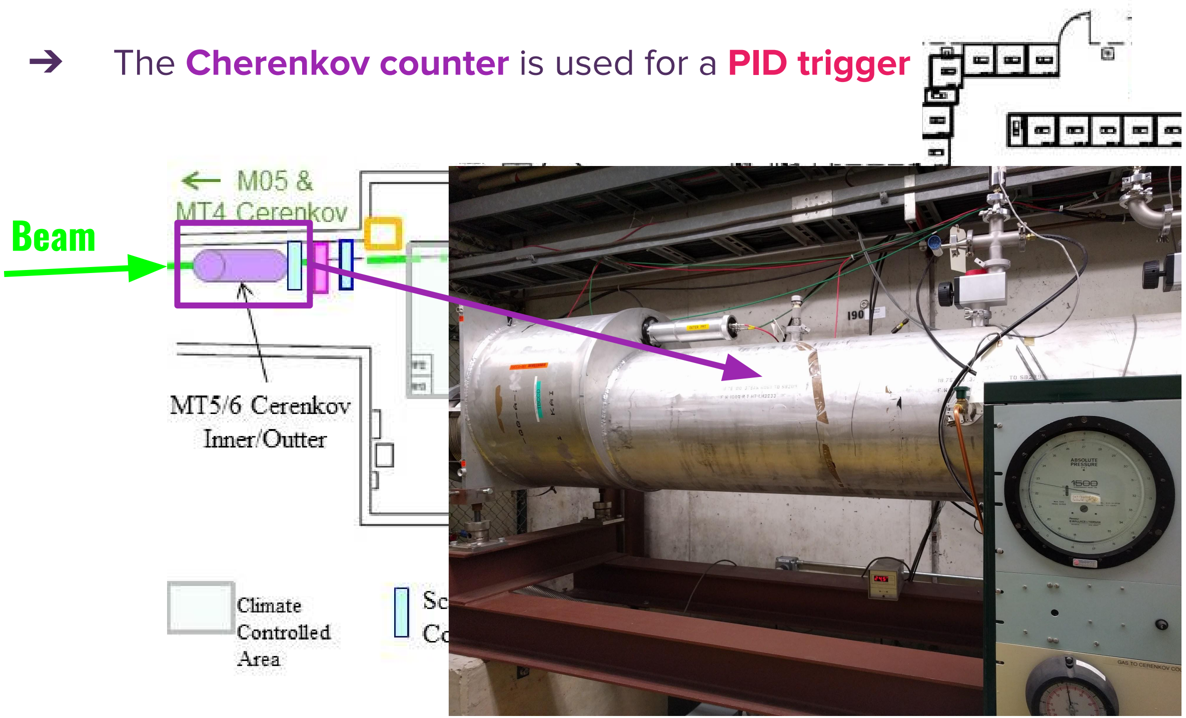
Triggering

- The **Cherenkov counter** is used for a **PID trigger**



Triggering

➔ The **Cherenkov counter** is used for a **PID trigger**



➔ We trigger on the Cherenkov counter to select **electrons**

➔ We can also do an **anti-coincidence** to trigger on everything **but electrons i.e. MIPs**

➔ We use this in (anti-) coincidence with the **4 scintillators** for the final trigger

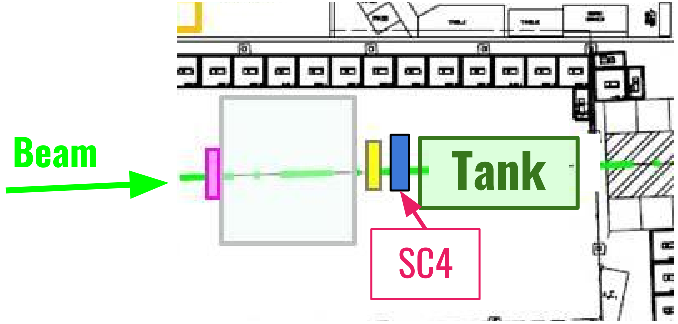
Beam Profile

➔ For the incoming beam we focused on the following configurations:

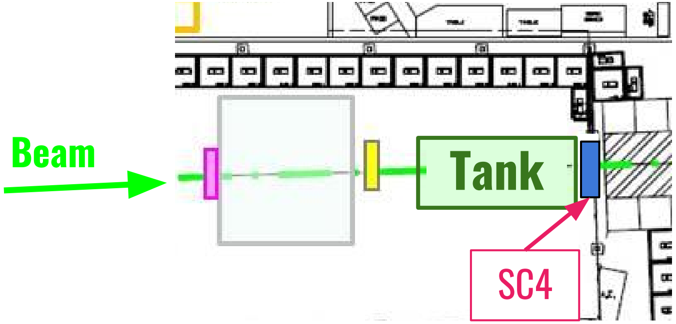
- 8 GeV - electrons, MIPs
- 6 GeV - electrons, MIPs
- 4 GeV - electrons, MIPs
- 2 GeV - electrons

Beam Profile

- For the incoming beam we focused on the following configurations:
  - 8 GeV - electrons, MIPs
  - 4 GeV - electrons, MIPs
  - 6 GeV - electrons, MIPs
  - 2 GeV - electrons
- We also have 2 configurations for SC4 - a forward and backward configuration



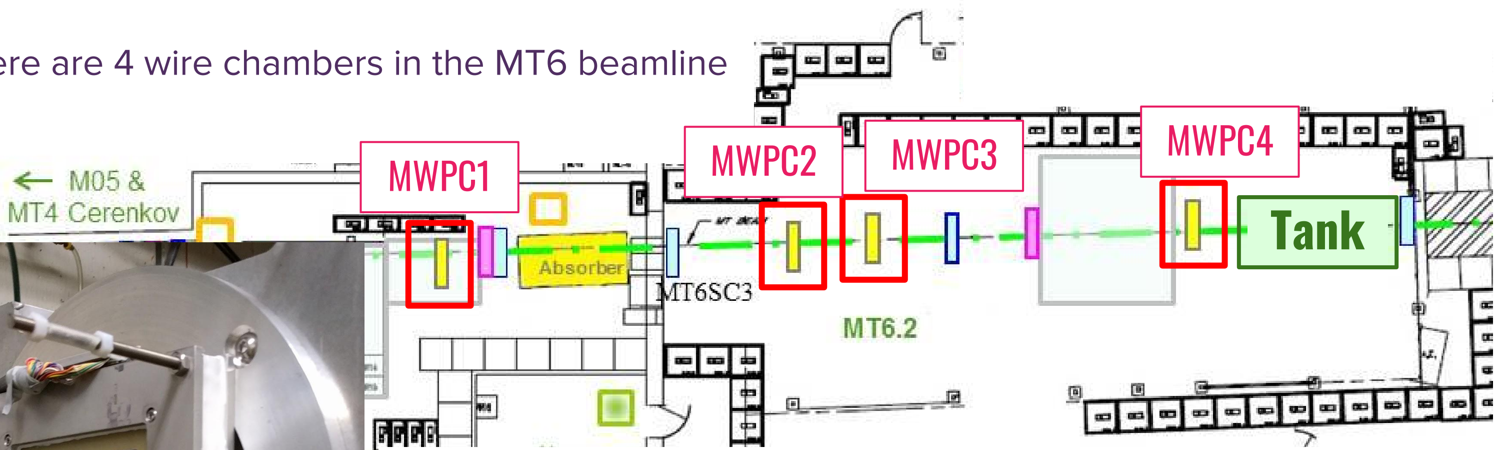
Forward configuration

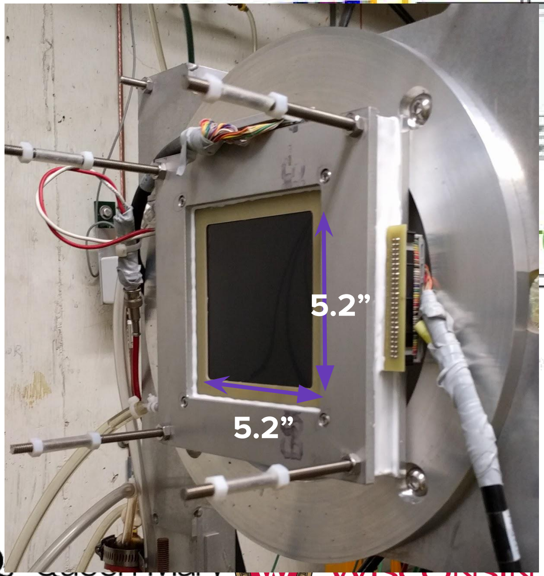


Background configuration

Beam Profile

➔ There are 4 wire chambers in the MT6 beamline





➔ Each MWPC has a dimension 5.2” x 5.2”

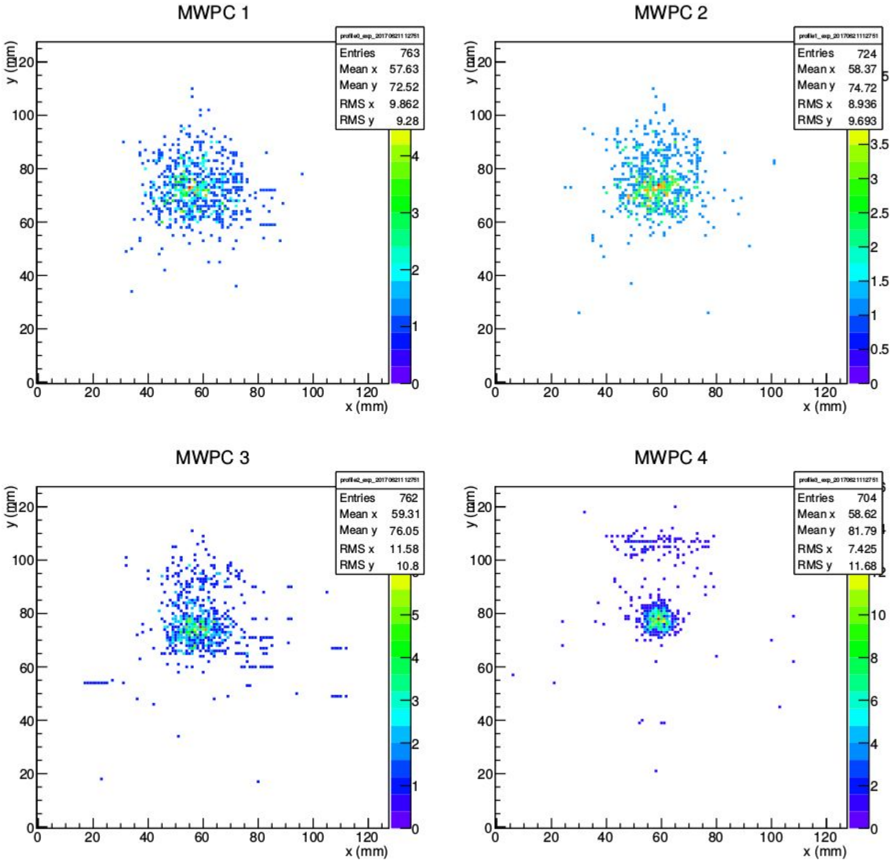
➔ These MWPCs provide **x-y information**

➔ We use our trigger on these to **profile the x-y spread** of the beam

➔ This is useful to diagnose any problems with the incoming beam

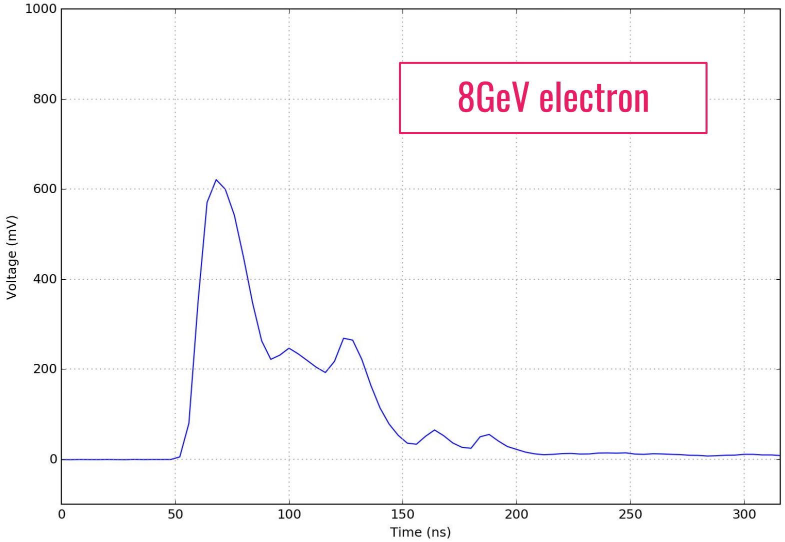
Beam Profile

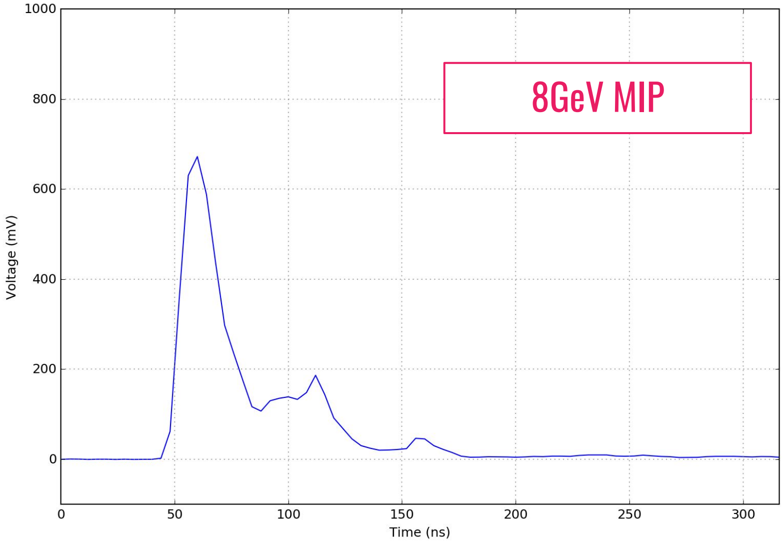
Example:
➔ 8GeV MIP beam



Results

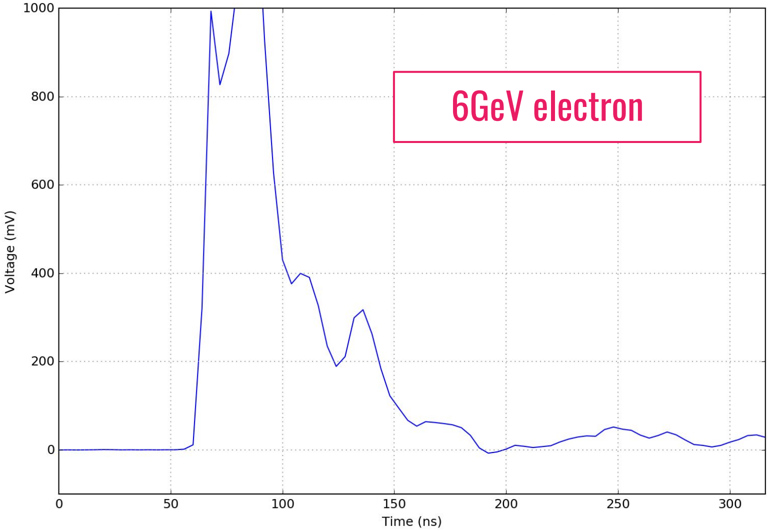
- Data taking completed from June14th - June 27th!
- Waveforms for each configuration obtained, example:

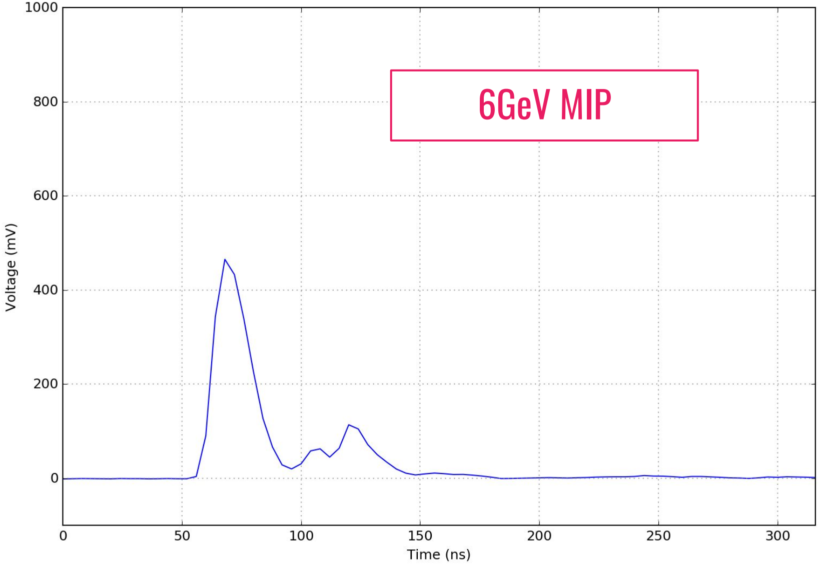




Results

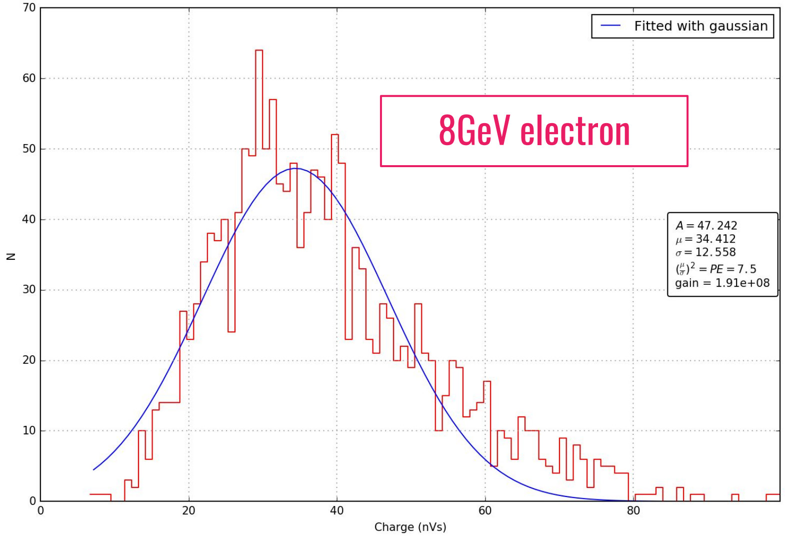
- Data taking completed from June14th - June 27th!
- Waveforms for each configuration obtained, example (for forward configuration):

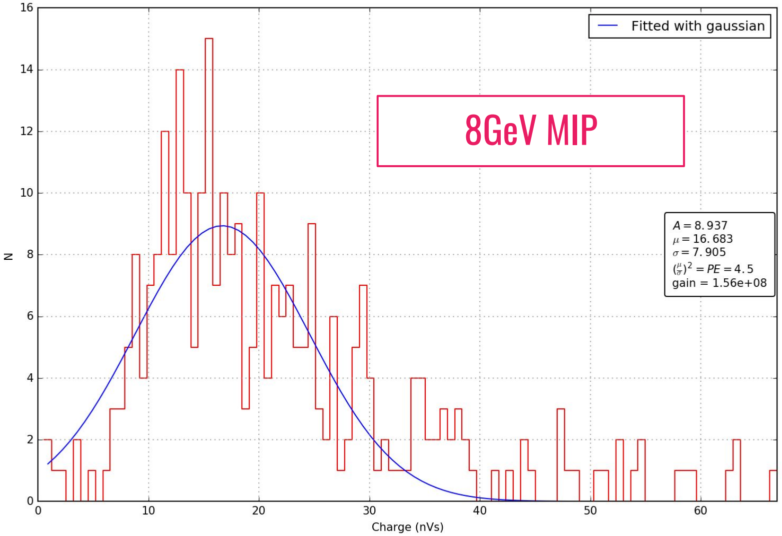




Results

- ➔ Data taking completed from June14th - June 27th!
- ➔ Charge plots:





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Results

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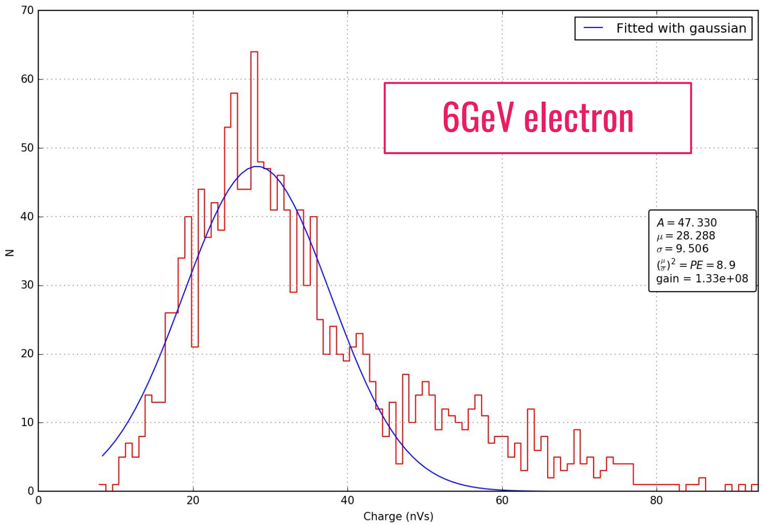
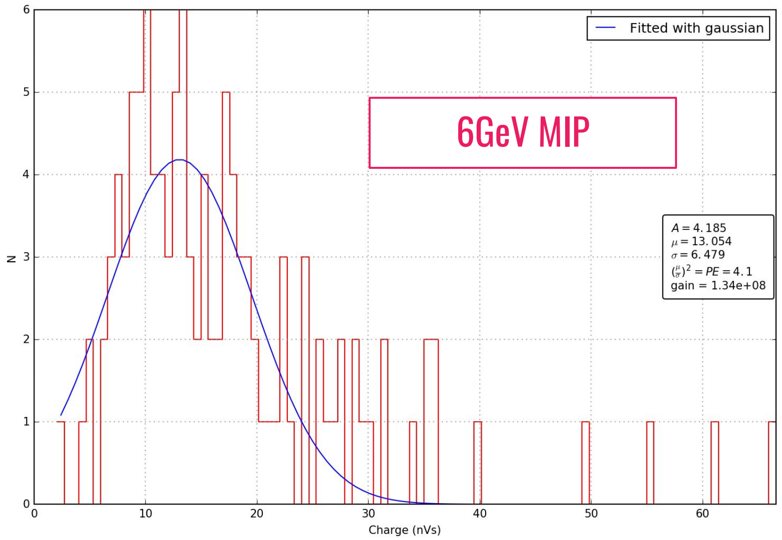
➔ Charge plots:





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Results

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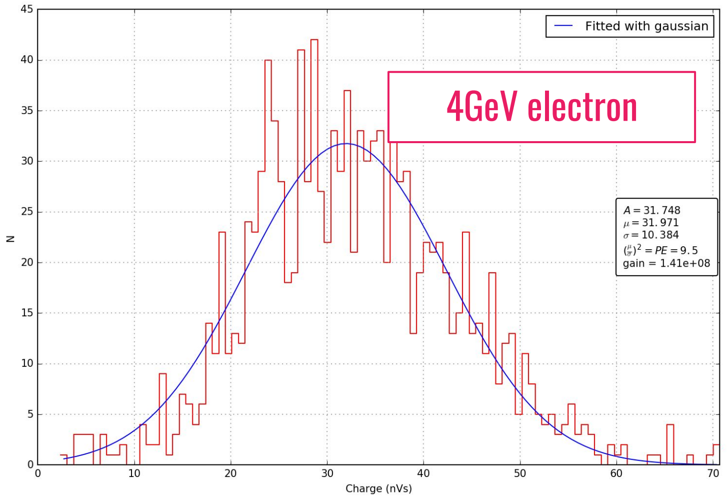
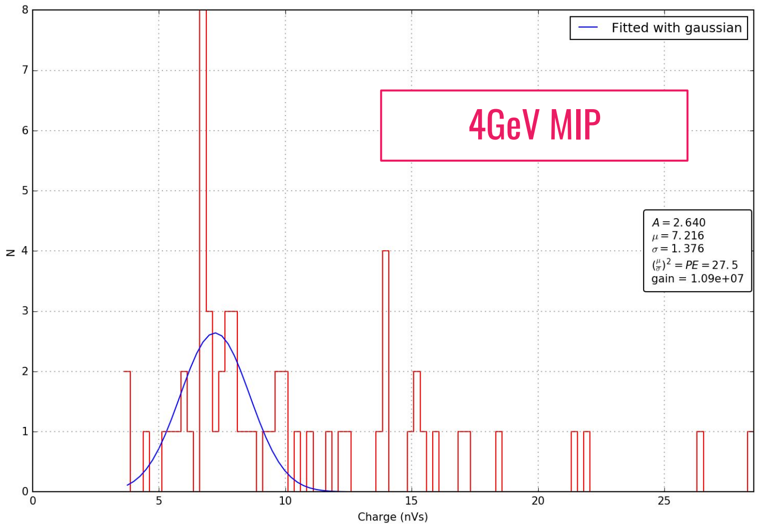
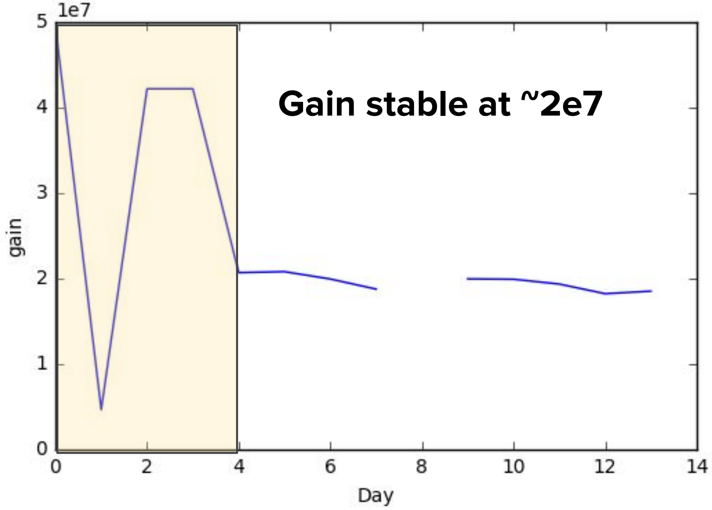


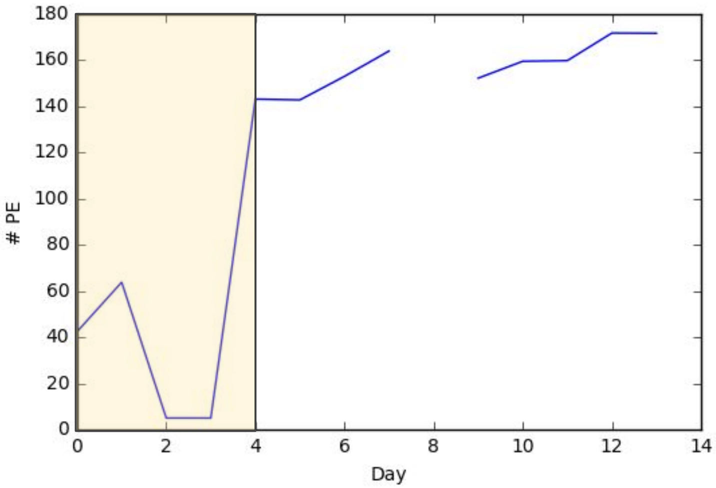


Results

- Data taking completed from June14th - June 27th!
- PMT gain plot using LED:



- Number of photoelectrons plot:



LED was misbehaving for the first 4 days (the condensation from the water made it damp)

Next steps

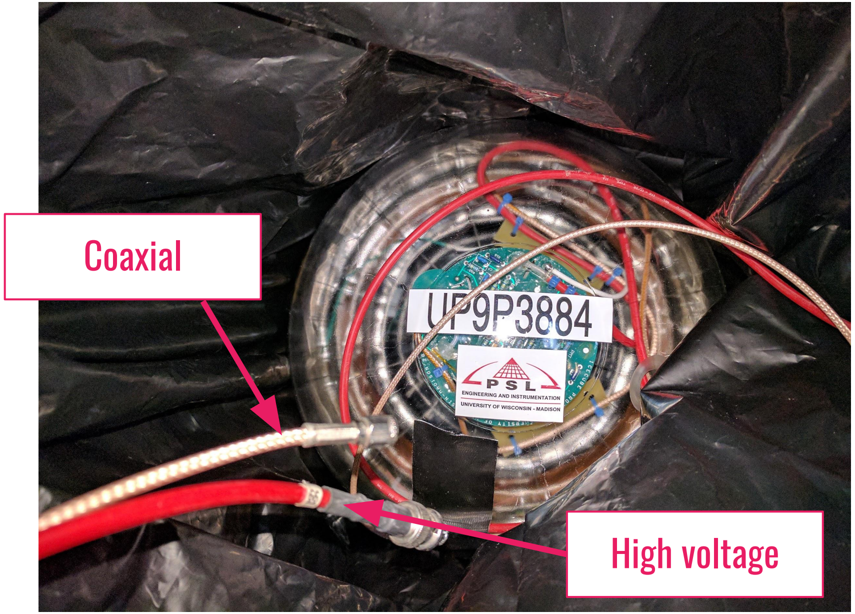
- Simulations of the beamtest
  - Build experiment setup in Geant4
  - Simulate the beamline (using the MWPC profile as input)
  - Simulate the waveforms from the number of PMT hits
- Decommission the equipment at the FTBF
  - Need to get water tested before we dispose of it
  - Tank will be left at the FTBF - can be used for future DOM beamtests!
- The result will be published in NIM or JINST

Backup

Sven Lidstrom, NSF

Recap

DOM



Thanks to Chris Wendt!

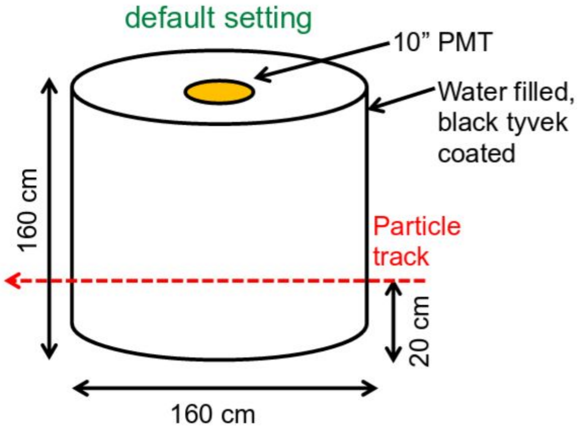
- “Wintery_Mix”
- Main board has been removed
- Bypass the DOMHub

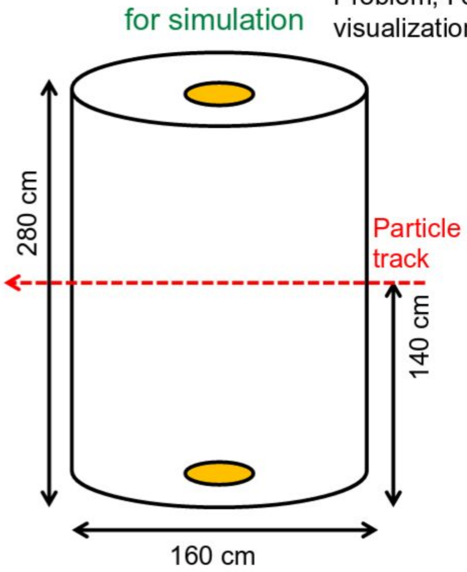
https://github.com/wcsim/

1. WCSim

WCSim for DUSEL → Hyper-K
- Developed by Duke
- Water Cherenkov detector simulators
- Classes are pre-defined (PMT geometries, noises)
- Widely used by accelerator-based neutrino experimentalists

This makes it twice faster.
Problem, I cannot activate visualization option…





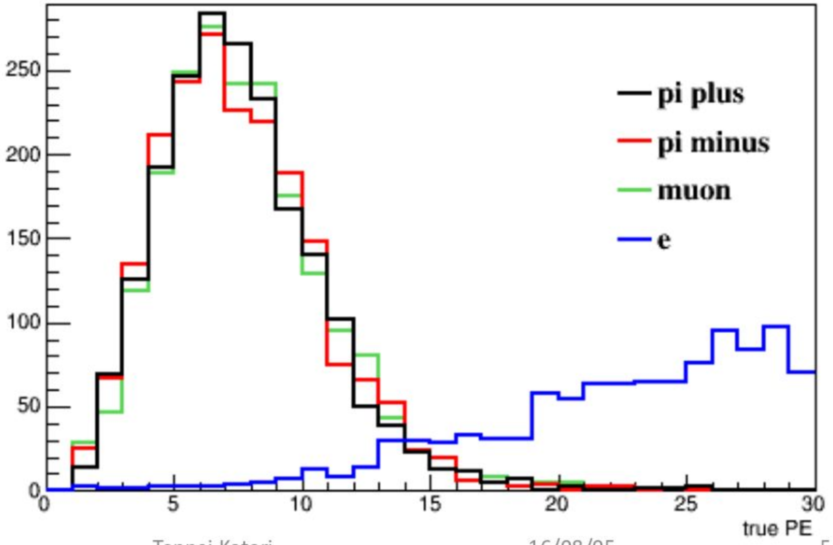
Teppei Katori 16/08/05 4

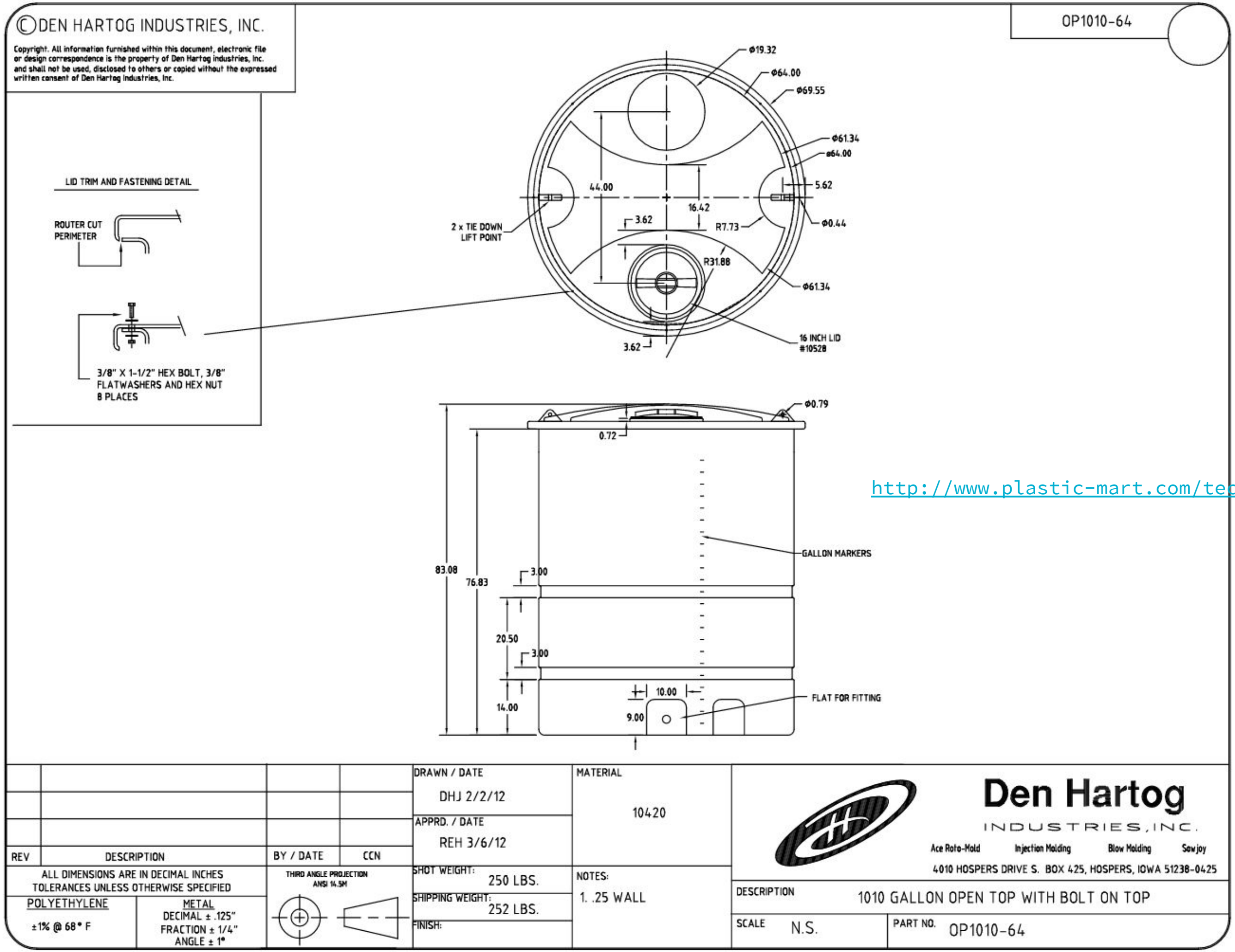
Queen Mary University of London

1. WCSim

Simulation setup
- run 1000 events (→2000 events for real experiment)
- Measure true total PE distribution (no efficiency yet)
- π^+, π^-, μ^-, e^- beams

2 GeV beam
- clear e vs MIP separation
- All MIPs look same

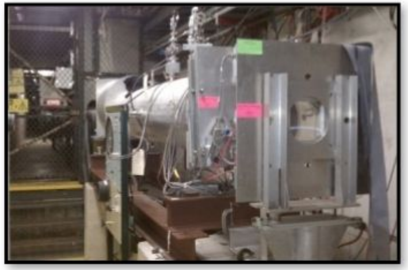


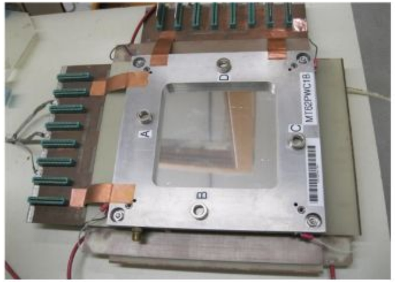


http://www.plastic-mart.com/tech_drawings/ace/op1010-64.pdf

Facility Instrumentation (MTest)

- 2 Cerenkov Detectors
- 1 Pixel Telescope
- 4 MWPC Tracking Chambers
- Lead Glass Calorimeters
- Assorted Trigger scintillators





Dr. Mandy Rimonsky - ICHEP 2016

Facility Manager/Coordinator at the FTBF

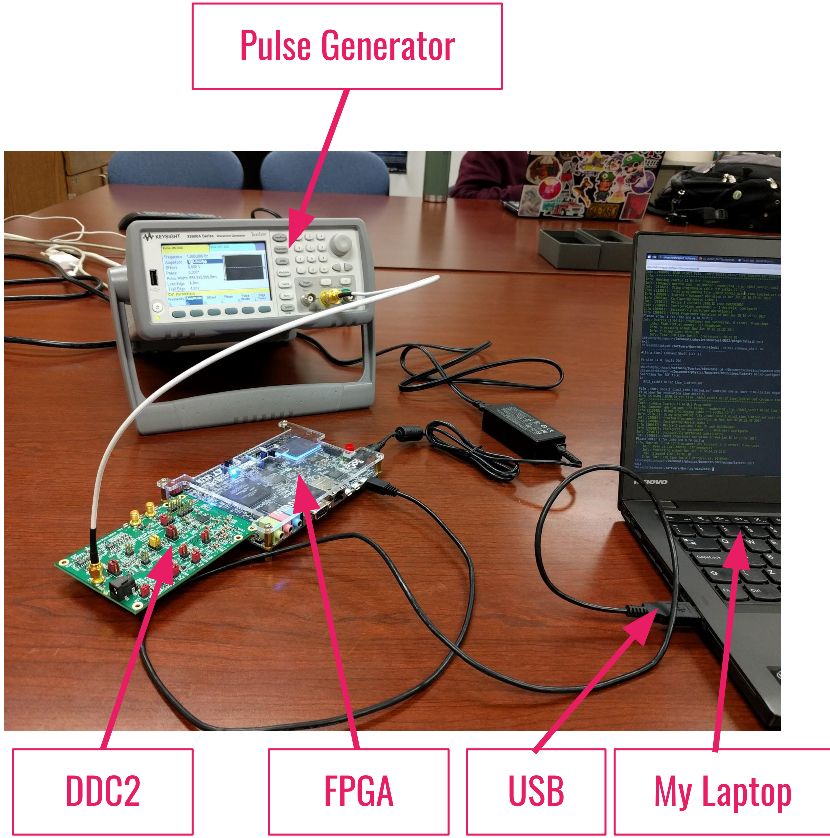
Hardware tests

We tested the DOM and DDC2

DDC2 conclusions (more details found in gen2-hw talks)

- → DDC2 was tested with a pulse generator
  - ◆ Response at varying frequencies, amplitude and pulse widths verified
- → Input impedance found to be **150** Ω
- → LSB found to be **0.312mV** (needs to be re-calculated)
- → AC Dropoff (knee) frequency at 10MHz, however
- → To preserve waveform shape we extended the dropoff by removing the **low-pass filter**
- → Past talks:
  - https://docushare.icecube.wisc.edu/dsweb/Get/Document-79234/SM_gen2-hw_170209.pdf
  - https://docushare.icecube.wisc.edu/dsweb/Get/Document-79549/SM_gen2-hw_170323.pdf

Big thanks to Bunheng Ty!

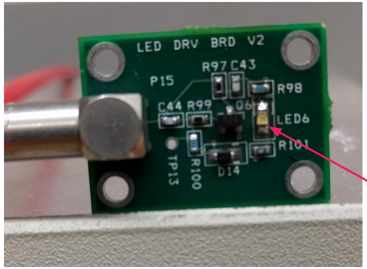


Hardware tests

We tested the DOM and DDC2

DOM conclusions

- ➔ SPE peak plot from noise
- ➔ Use an LED to test the DOM response:



- ➔ Details of setup in the last ice-cal talk:
  - https://docushare.icecube.wisc.edu/dsweb/Get/Document-79086/SM_icecal_170120.pdf
- ➔ Updated: now using a pulser board to control LED
  - (pic in backup slides)

Big thanks to Bunheng Ty!

Gain = 1.5 kV