ArCS LArTPC: Assembly, Preparation, and Beam Test Study

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Final Presentation for the Italian Summer Program at Fermilab 2024

26th September 2024

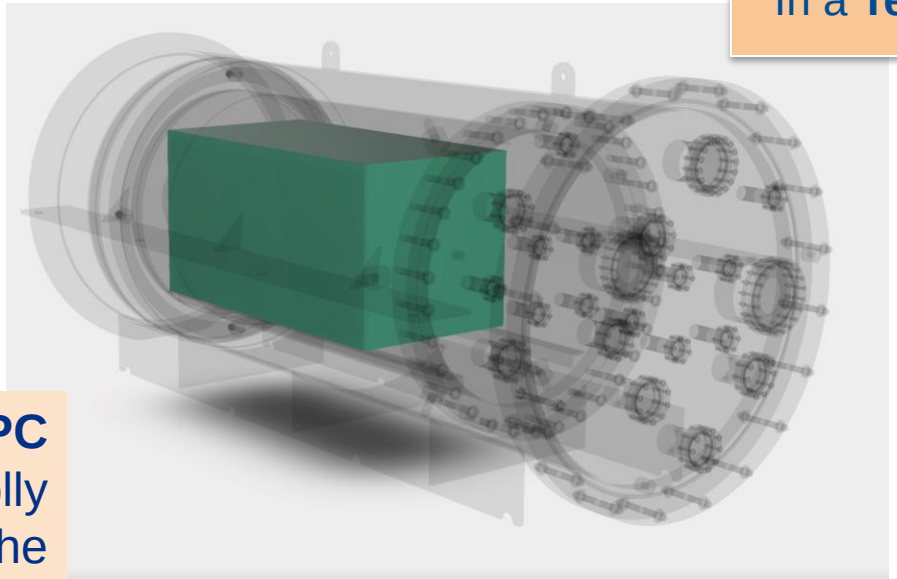
ArCS: Argon detector with Charge Separation

R&D Project

A Liquid Argon Time Projection Chamber in a Magnetic Field [LDRD]

Running a **LArTPC** inside a **magnetic field** (up to 0.7 T)

In a **Test Beam**!



♻ Reusing the **LArIAT TPC** and placing it inside the Jolly Green Giant magnet at the Fermilab's Test Beam Facility.

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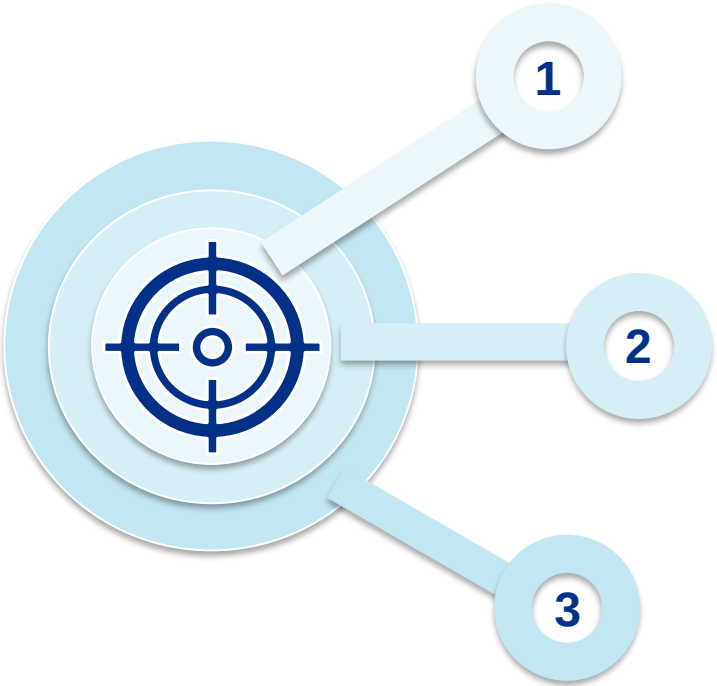
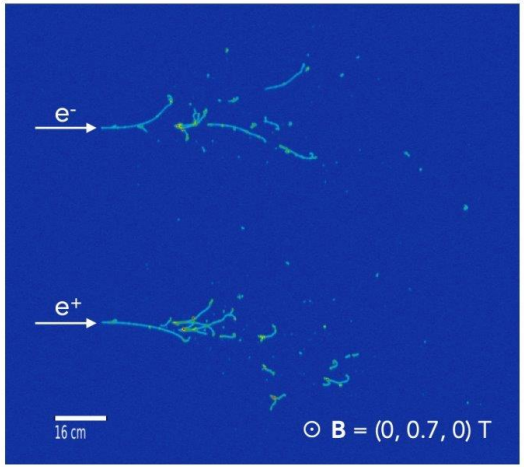
A Liquid Argon Time Projection Chamber in a Magnetic Field [LDRD]



1. Demonstrate **charge sign discrimination** for e^- and e^+
2. Particle **momentum reconstruction** via its curvature
3. Determine **minimum magnetic field** for such measurements



! Charge separation power

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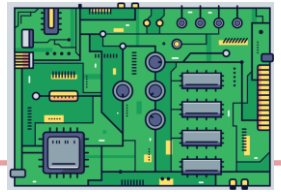
Internship Activities Overview



1 **TESTING the ELECTRONICS**

3 **ASSEMBLY of the LArTPC**

2 **STUDY on the TEST BEAM Simulation**

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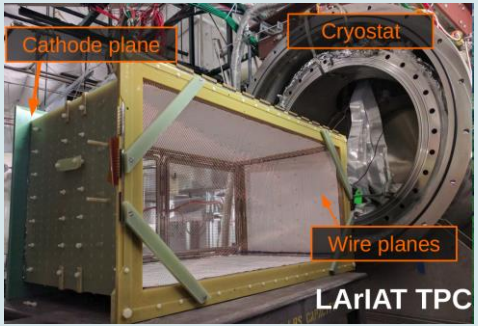
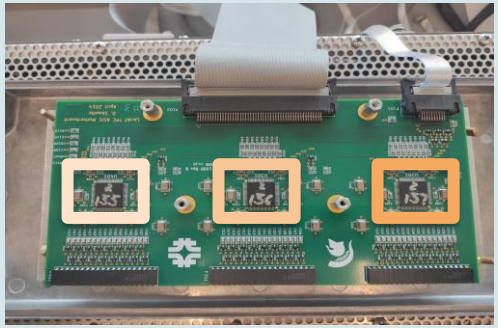
EXPERIMENTAL SETUP

Cold Electronics

TPC

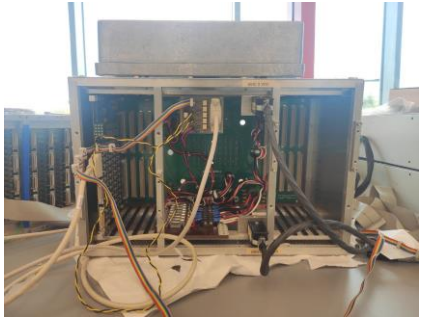


10 CMB
Cold Mother Board



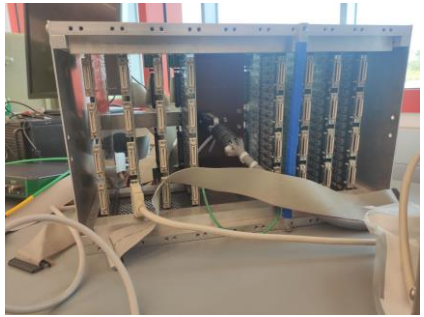
FT

10 WRD
Warm Receiver and Driver



Warm Electronics

8 D2S
Differential To Single-ended



Each CMB comprises **3 16-channel LArASIC**

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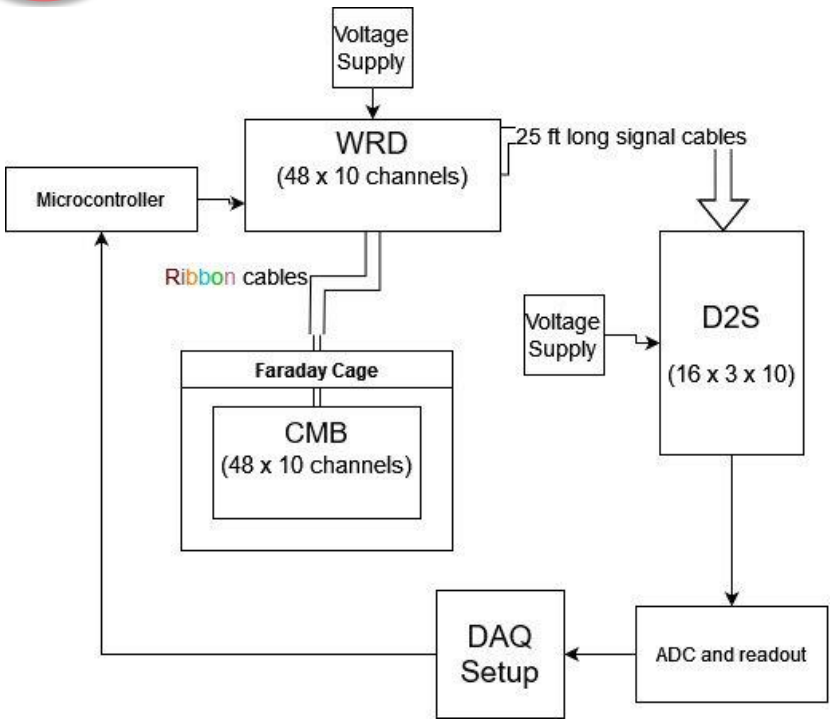
LArIAT Electronics Testing

To **test** the CMBs, one D2S and one WRD are **fixed**. To test the WRDs, one D2S and CMB are fixed. Finally, for the D2S testing, a WRD and a CMB are fixed.



Waveforms, FFTs, Gain and Voltage…

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LArIAT Electronics Testing

To **test** the CMBs, one D2S and one WRD are **fixed**. To test the WRDs, one D2S MB are fixed. Finally, e D2S testing, a WRD CMB are fixed.

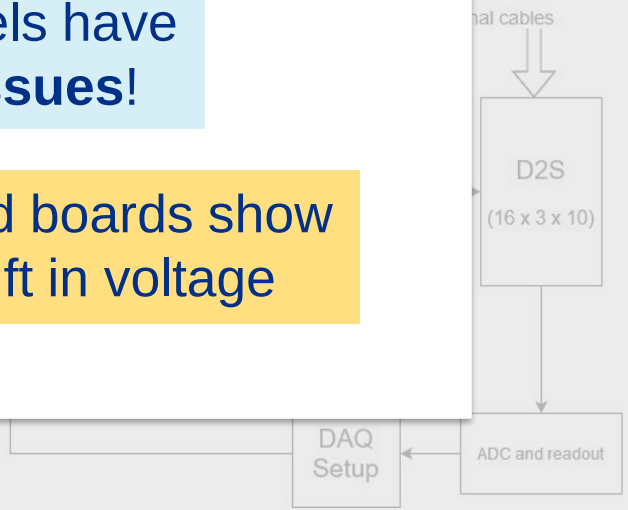
Waveforms

FOR CALIBRATION

Characterization of the CMBs

! 11/576 channels have **gain issues**!

4 out of 11 cold boards show a sistematic shift in voltage



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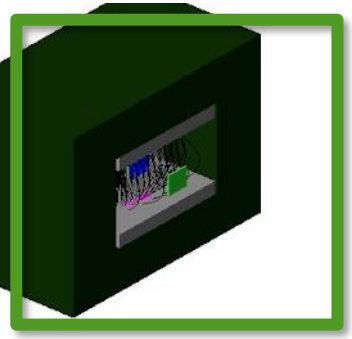
Study on FTBF Simulation

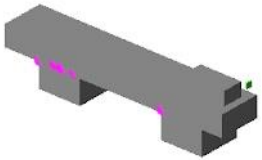
There are different beam **operating modes**. The nominal one considered has a pion spill of **2.5×10^5**.

- Each event simulates a **π^+** from the secondary beam of the FTBF impinging on a **Cu target**, thus generating the **tertiary beam** (as in LArIAT configuration).
- The beam is defined as a Gaussian-distributed one with an energy of **64 GeV**.



JGG Magnet

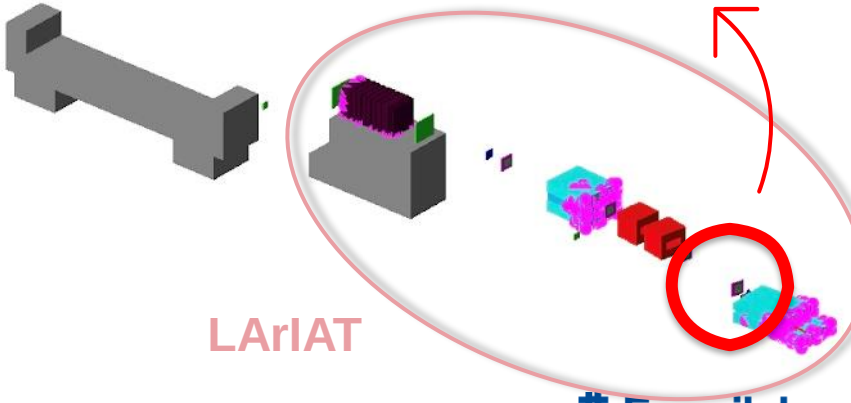
ON-AXIS



The previous LArIAT configuration was *different*

Start Line

OFF-AXIS



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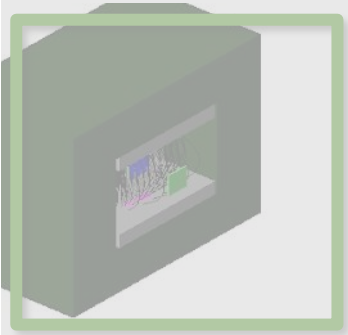
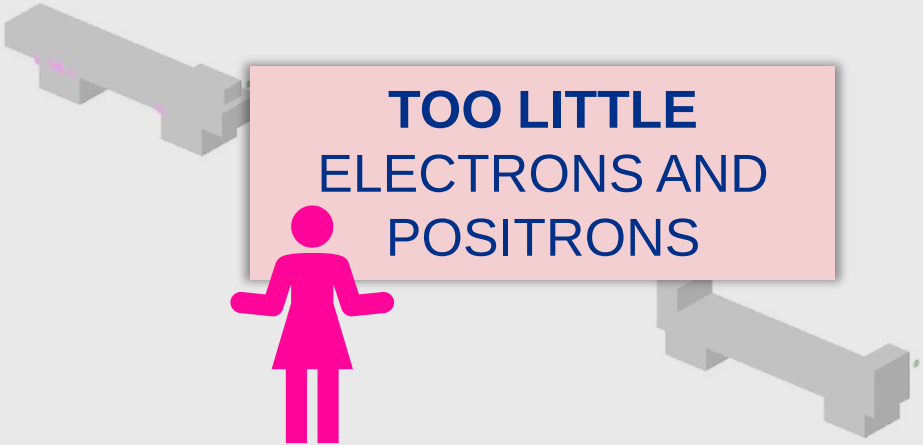


JGG Magnet

ON-AXIS

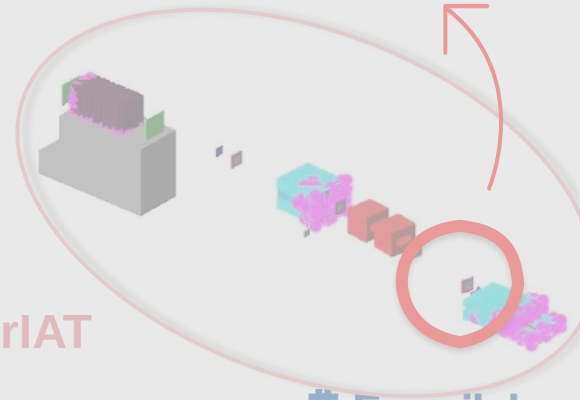
PROBLEM from previous LArIAT configuration



TOO LITTLE
ELECTRONS AND POSITRONS

Start Line

OFF-AXIS



LArIAT

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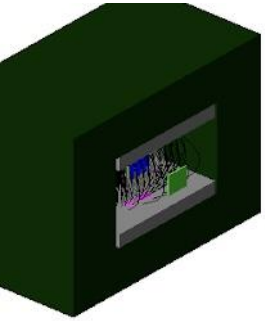
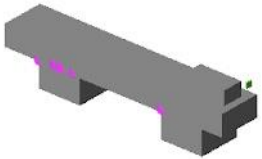
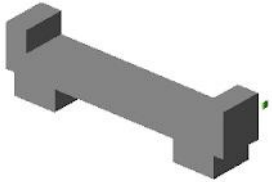
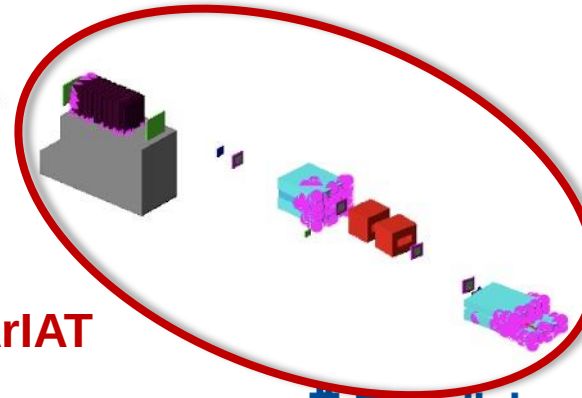
My contribution…

- I updated the existing geometry with **2 US detectors** (virtual WCs) to trigger on;
- I added the **concrete blocks** and the **muon range stack** from the FTBF;
- This detector geometry was used to study 3 main configurations.



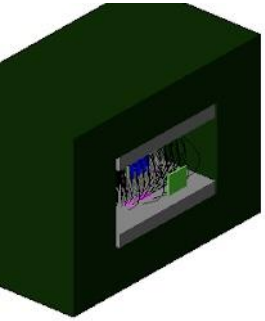


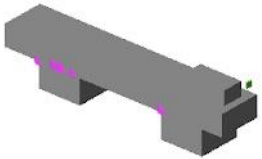




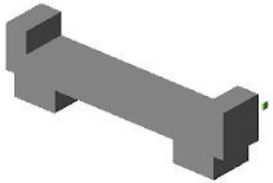
LArIAT

Fermilab

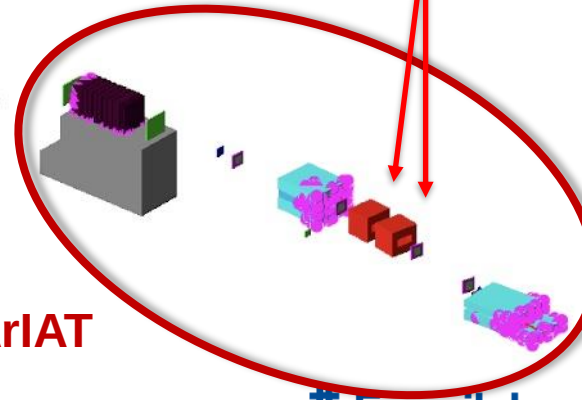




z

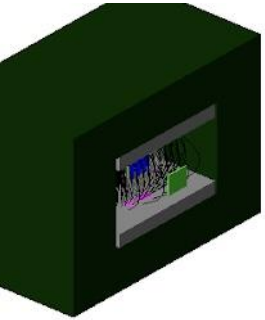


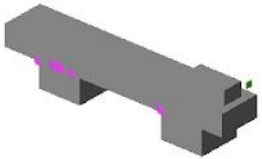
LArIAT Magnets
(B1 and B2)



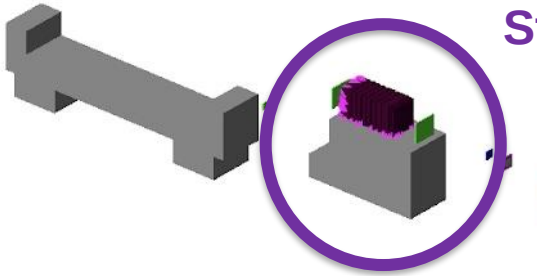
LArIAT

Fermilab





Muon Range Stack



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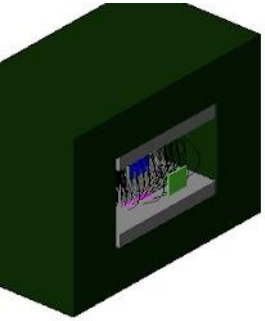
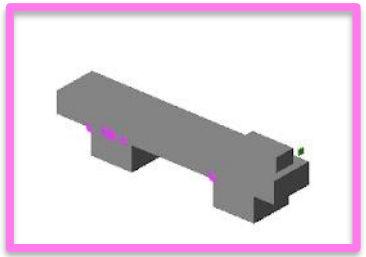
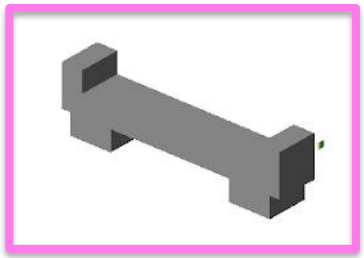
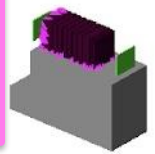


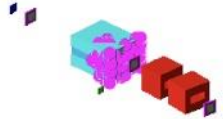


Concrete Blocks

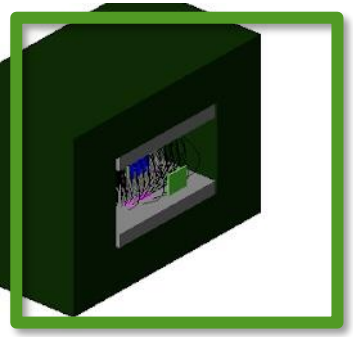
z



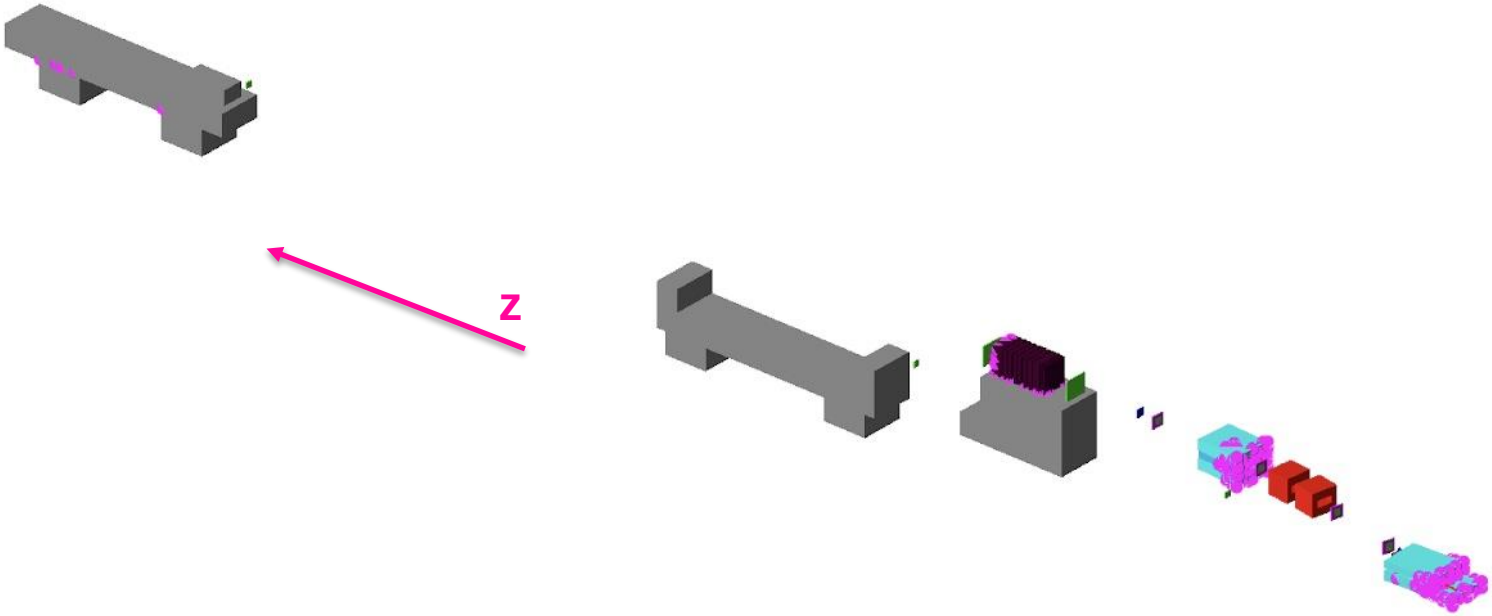




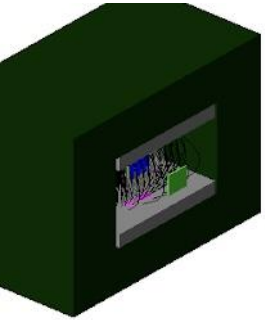
Fermilab

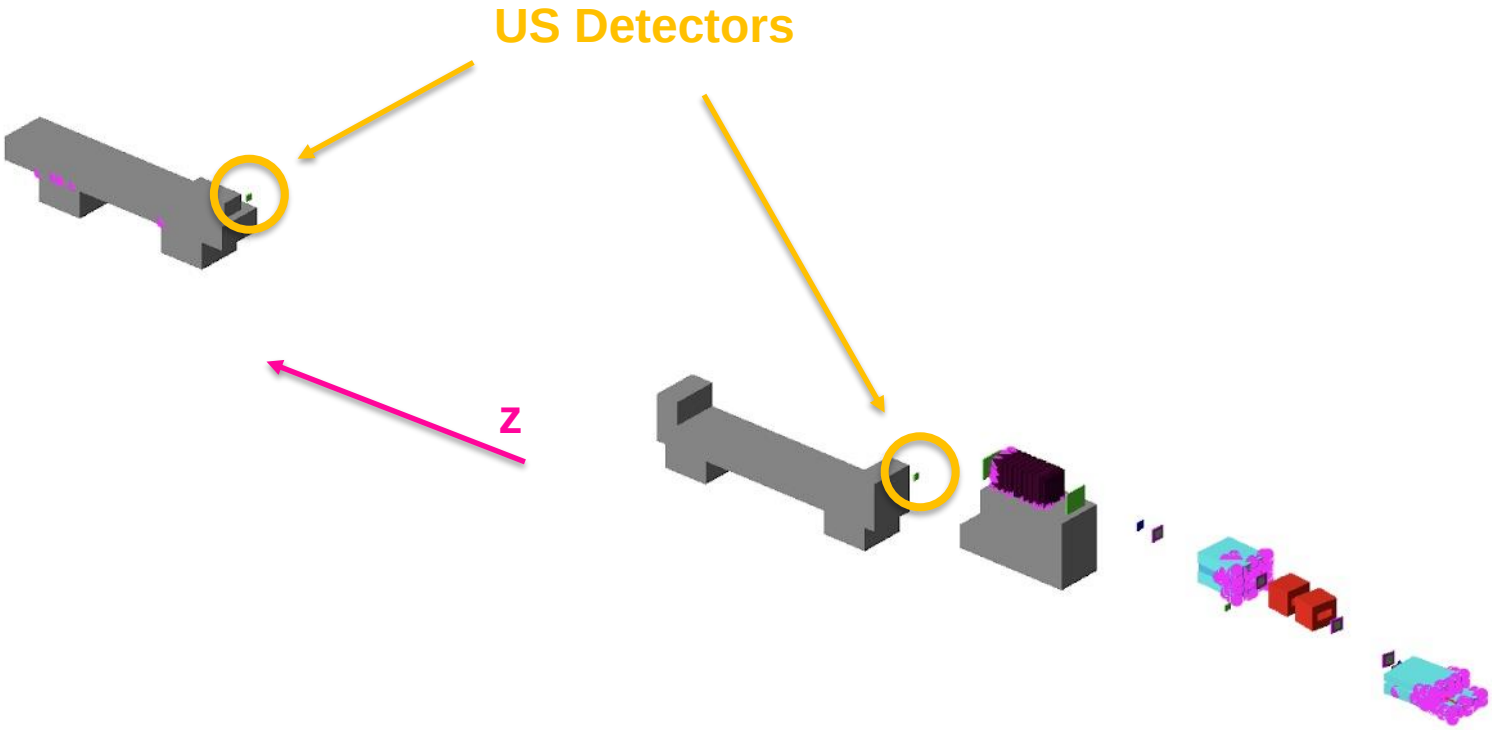


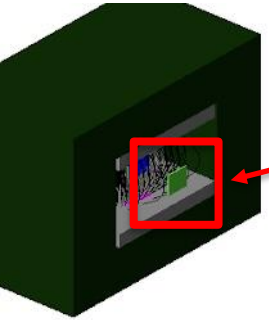
JGG Magnet



Fermilab



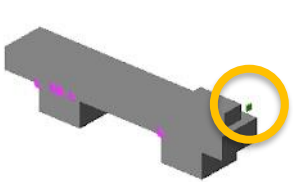

US Detectors
z

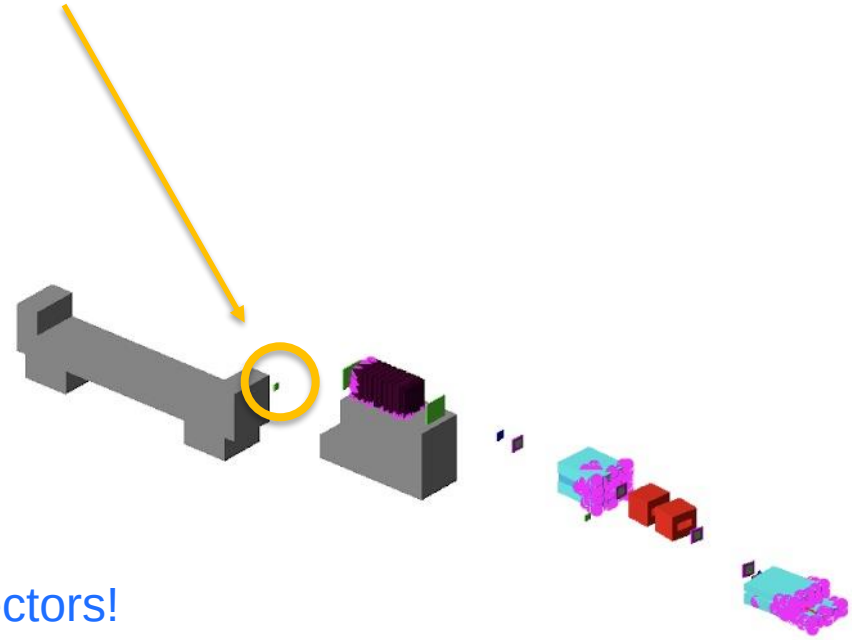


Det7

US Detectors

z





I performed the **triggering** upon such detectors!

3 Main Configurations

JGG Magnet **ON**

LArIAT Magnets (B1 and B2) **OFF**

JGG Magnet **ON**

LArIAT Magnets (B1 and B2) **ON**

- Pos 60 Amps
- Neg 60 Amps

JGG Magnet **OFF**

LArIAT Magnets (B1 and B2) **OFF**

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For each configuration…

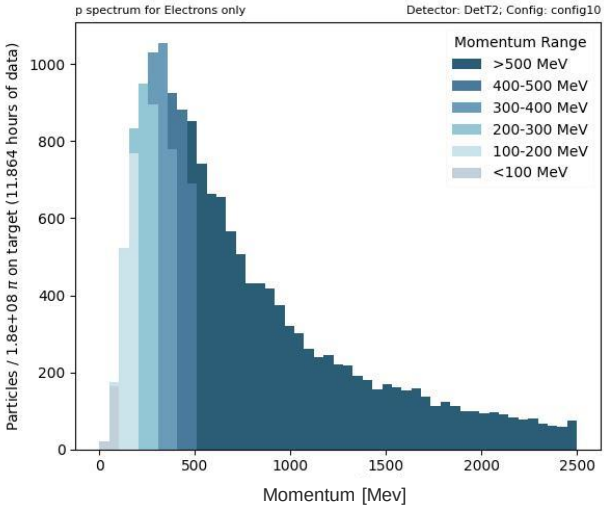
- I **triggered** on DetT1, DetT2 (US), and Det7;
- I studied the **spectra of all particles** across such detectors *(momentum, polar and azimuthal angles),* focussing on **electrons** and **positrons***;*
- I studied the **flux characteristics** with respect to the detectors' surface;
- I counted the **occurrences** for each particle type.

DetT2

Example Plot: Momentum Spectra of **Electrons**

JGG Magnet **ON**

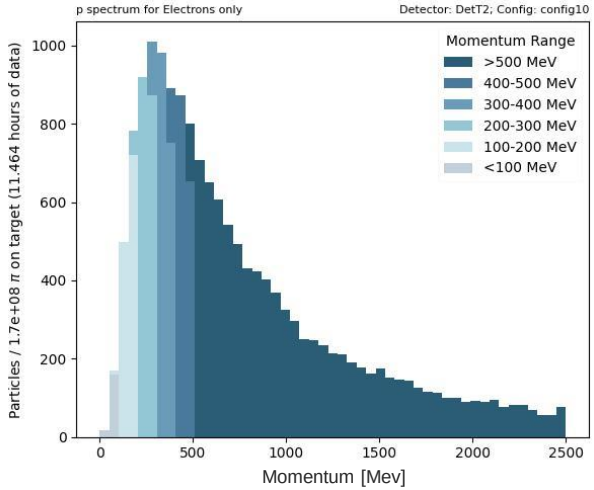
LArIAT Magnets (B1 and B2) **OFF**



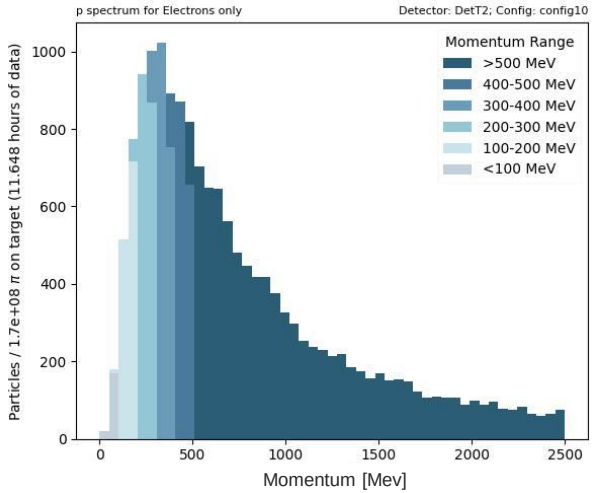
JGG Magnet **ON**

LArIAT Magnets (B1 and B2) **ON**

pos 60 Amps



neg 60 Amps



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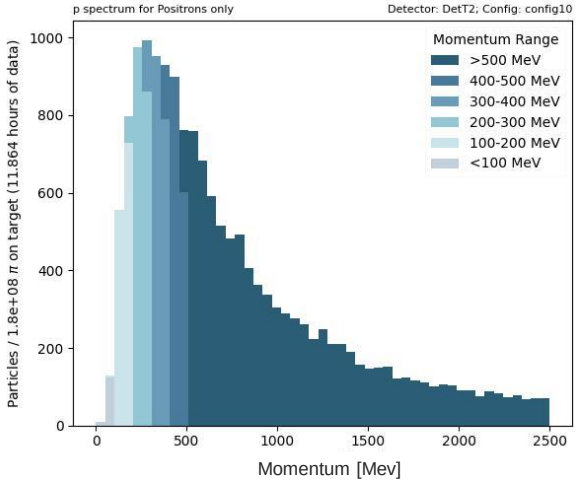
DetT2

Example Plot: Momentum Spectra of **Positrons**

JGG Magnet **ON**

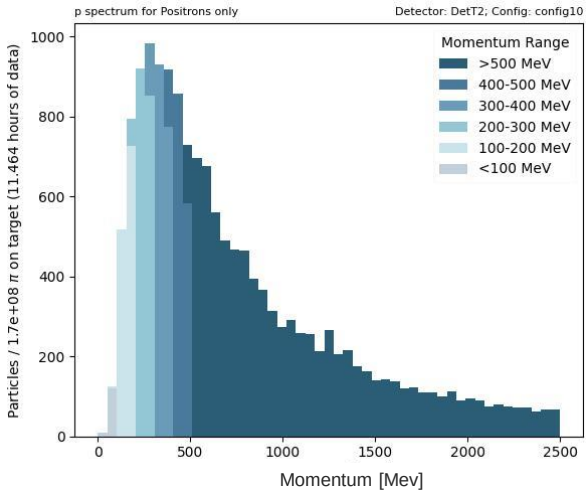
LArIAT Magnets (B1 and B2) **OFF**



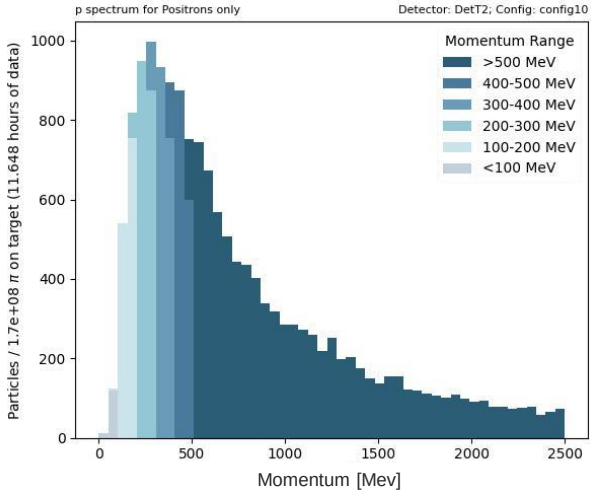
JGG Magnet **ON**

LArIAT Magnets (B1 and B2) **ON**

pos 60 Amps



neg 60 Amps



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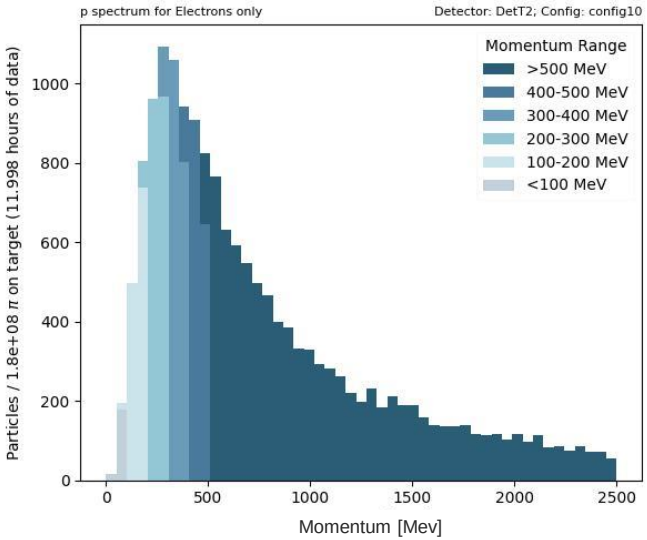
DetT2

Example Plot: Momentum Spectra of **Electrons** and of **Positrons**

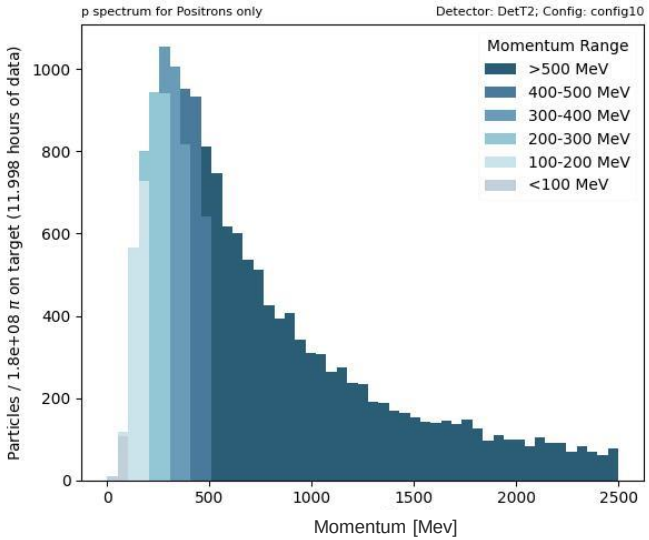
JGG Magnet **OFF**

LArIAT Magnets (B1 and B2) **OFF**

Electrons



Positrons



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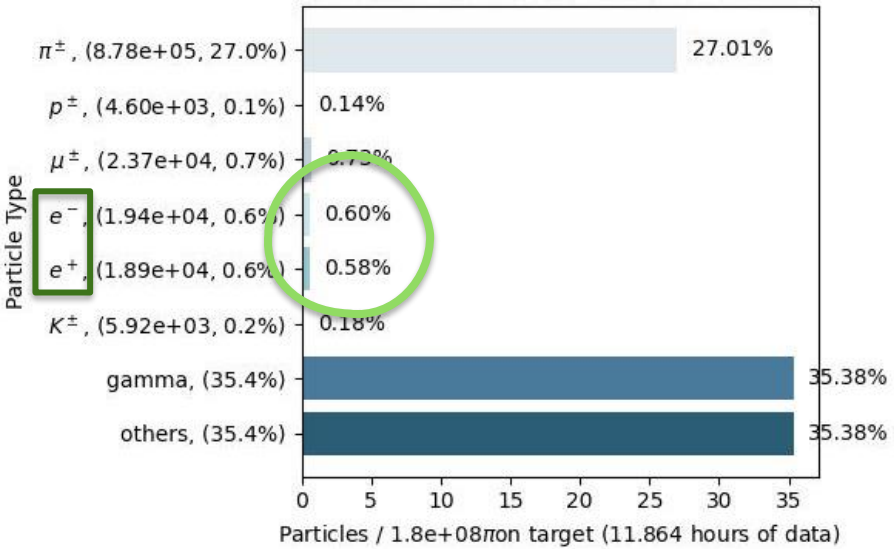
Example Plot: Particle ID

JGG Magnet **ON**

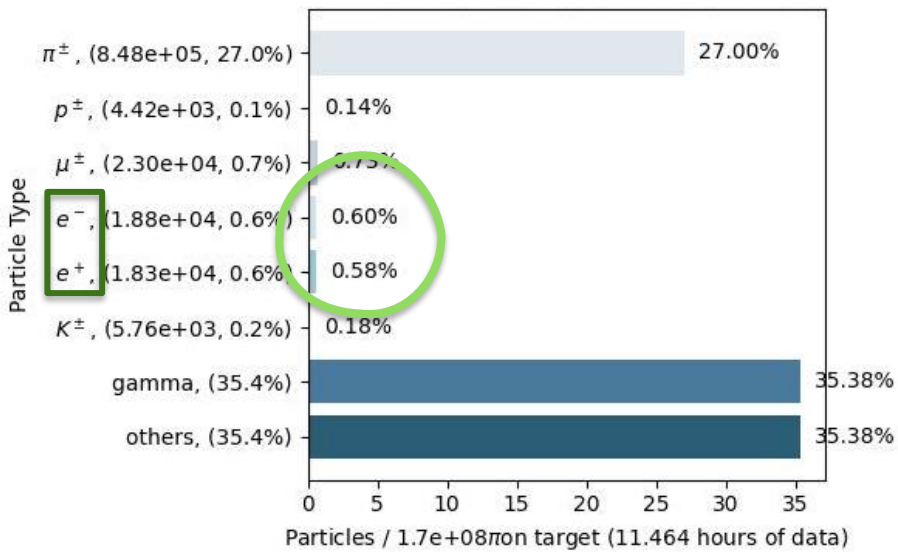
LArIAT Magnets (B1 and B2) **OFF**



JGG Magnet **ON**

LArIAT Magnets (B1 and B2) **ON**

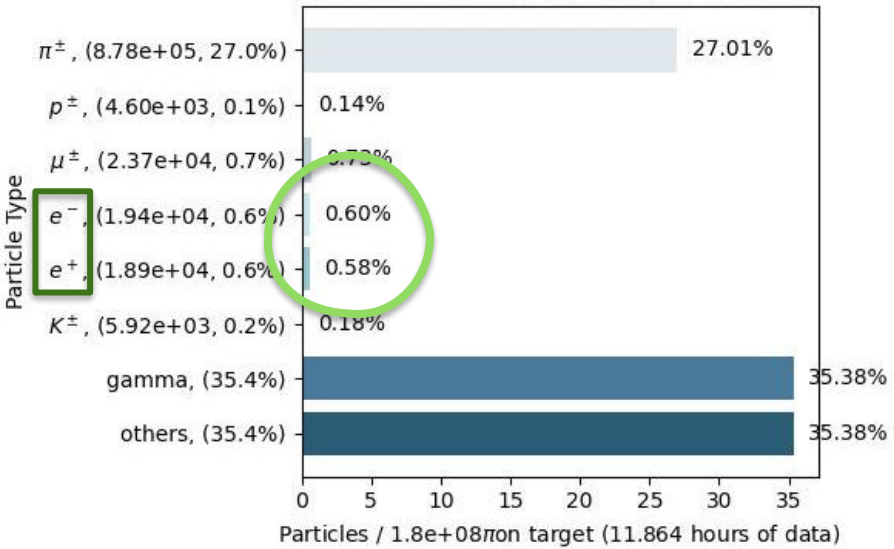
pos 60 Amps



Example Plot: Particle ID

JGG Magnet **ON**

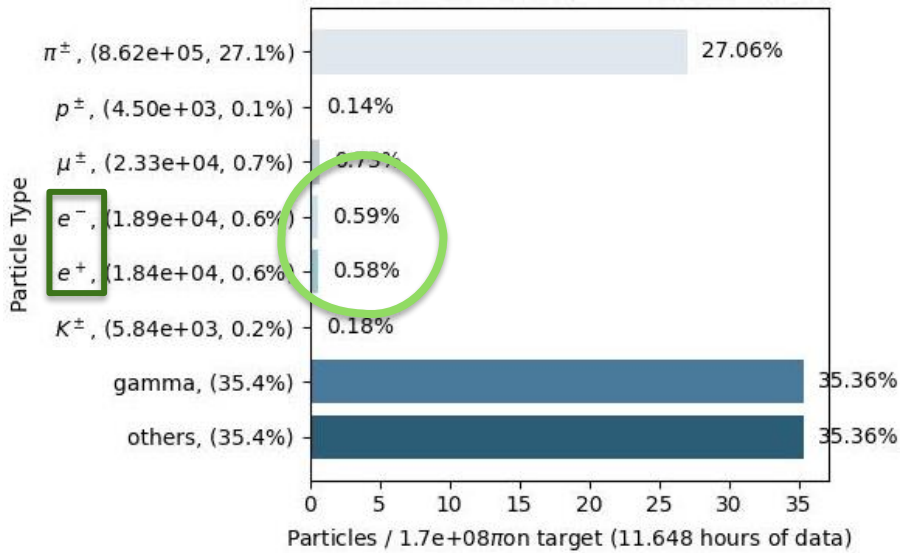
LArIAT Magnets (B1 and B2) **OFF**



JGG Magnet **ON**

LArIAT Magnets (B1 and B2) **ON**

neg 60 Amps

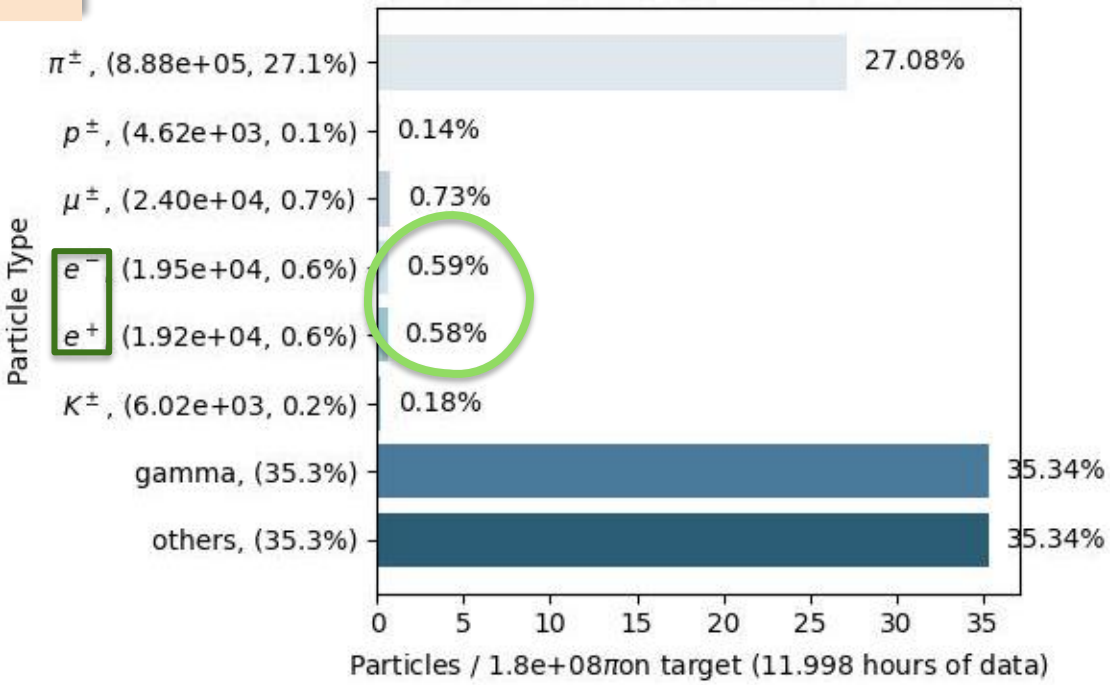


Fermilab

JGG Magnet **OFF**

LArIAT Magnets (B1 and B2) **OFF**

Example Plot: Particle ID



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Triggering with detectors more **US**, considering the direction **on-axis** with the **secondary beam** led to…

Rate of detection
≈ 27 electrons/**min**
≈ 26 positrons/**min**

≈ 19 400 **electrons**
≈ 18 900 **positrons**

In less than **12 hours** of **data-taking**

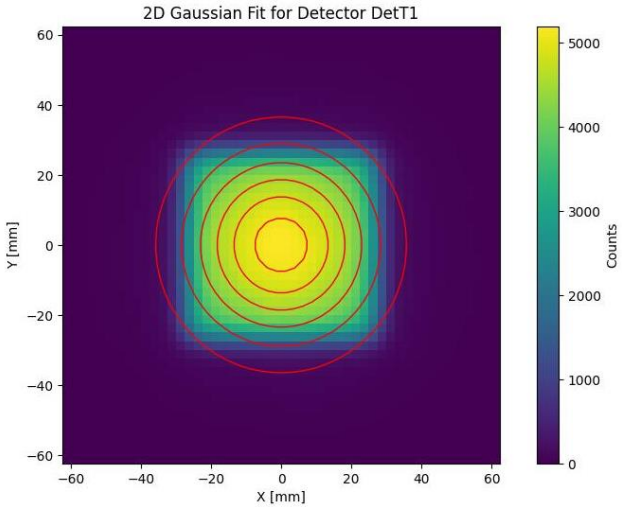
! **CONSISTENT** through all the configurations

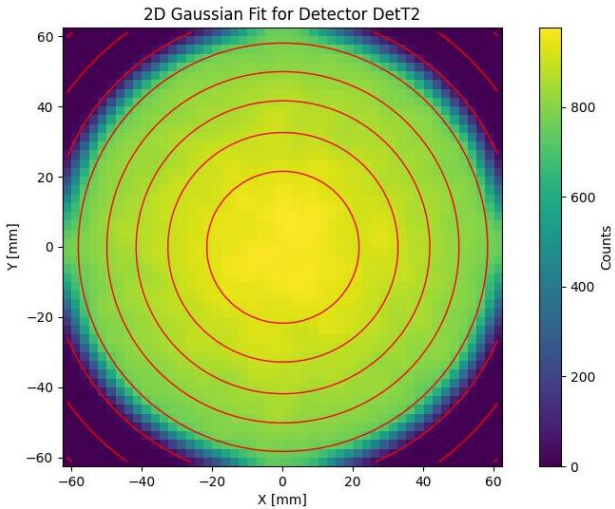
Flux Characteristics

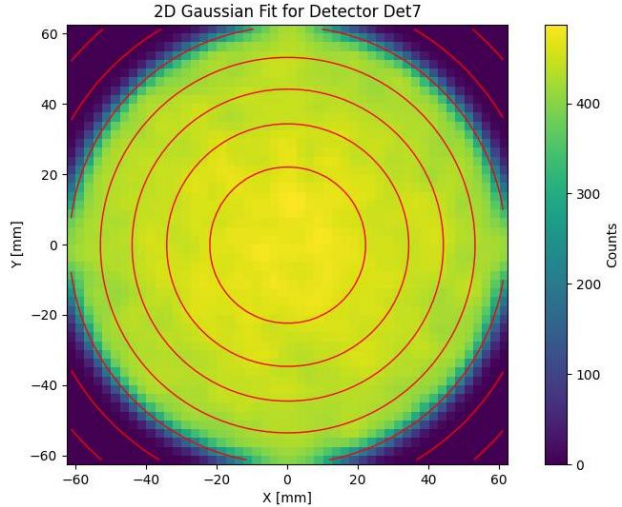
JGG Magnet **ON**

LArIAT Magnets (B1 and B2) **OFF**

US → **DS**







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LArTPC Assembly

- Removed the **WLS foils** from the **cathode**;
- Replaced a **faulty resistor** in the divider chain;
- Cleaned the chamber;
- Installed **wire planes**;
- Placed the external **frame** to tension the wires;
- Soldered different **connectors** for various purposes ***(FT, HV, level probes, bias filter boards)***;
- Completed **wiring** for FT and HV.

The **first** days…

The **last** days…

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Conclusions

- Cold and Warm Boards were tested. *CMBs are now properly connected to the LArTPC*.

- The detector was cleaned and restored. All the needed cabling and wiring were completed, although some cables still need to be connected (shortly!).

- Beam studies proved that a high statistic for electrons and positrons can be achieved when considering the secondary beam.


Also, thank you Claudio, Marco, and Angela!
THANK YOU
FOR YOUR
ATTENTION

Backup Slides

Giulia Cicogna

Final Presentation for the Italian Summer Program at Fermilab 2024

26th September 2024

DetT2

Example Plot: Momentum Spectra of **All Particles**

JGG Magnet **ON**

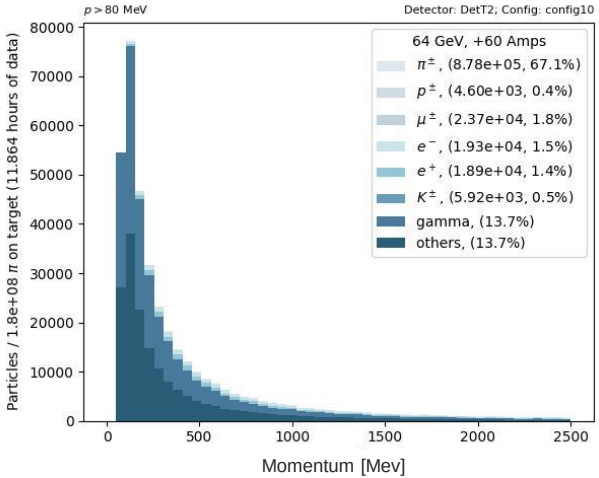
LArIAT Magnets (B1 and B2) **OFF**

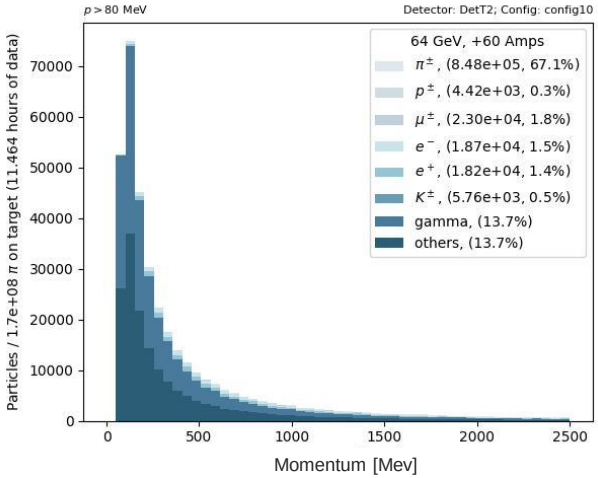
pos 60 Amps

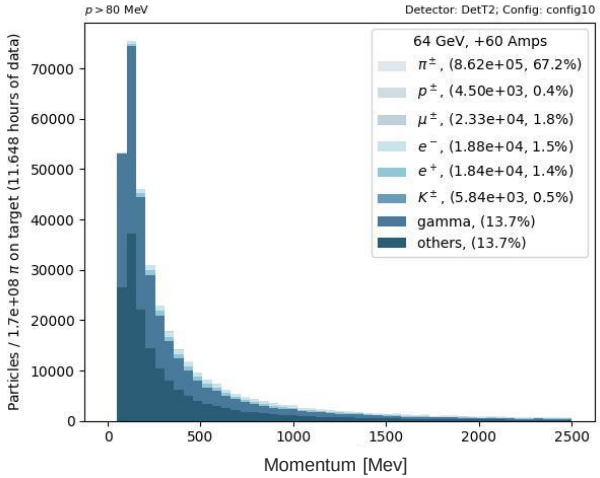
JGG Magnet **ON**

LArIAT Magnets (B1 and B2) **ON**

neg 60 Amps







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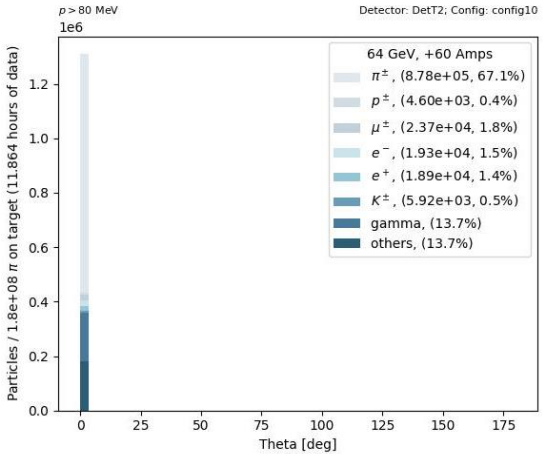
DetT2

Example Plot: Angular (polar) Spectra of **All Particles**

JGG Magnet **ON**

LArIAT Magnets (B1 and B2) **OFF**

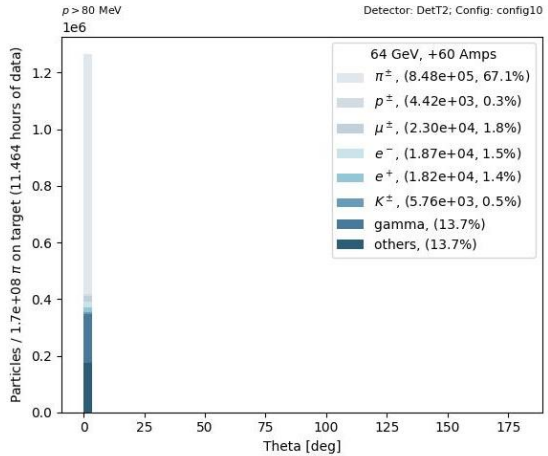
pos 60 Amps

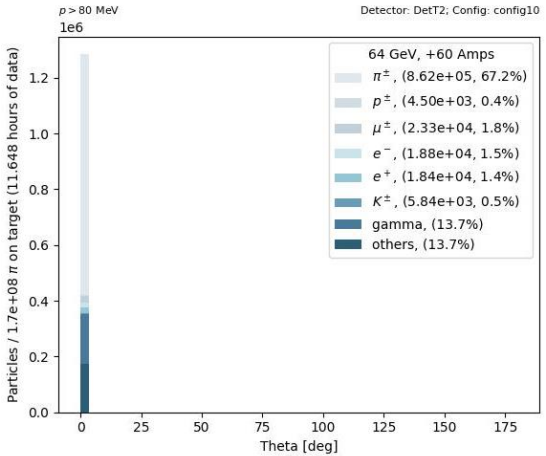


JGG Magnet **ON**

LArIAT Magnets (B1 and B2) **ON**

neg 60 Amps





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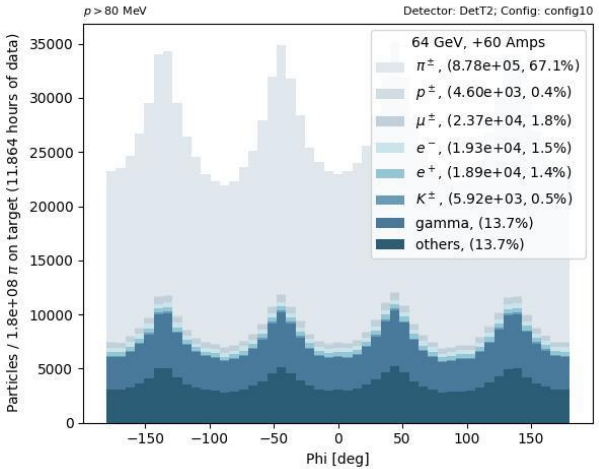
DetT2

Example Plot: Angular (azimuthal) Spectra of **All Particles**

JGG Magnet **ON**

LArIAT Magnets (B1 and B2) **OFF**

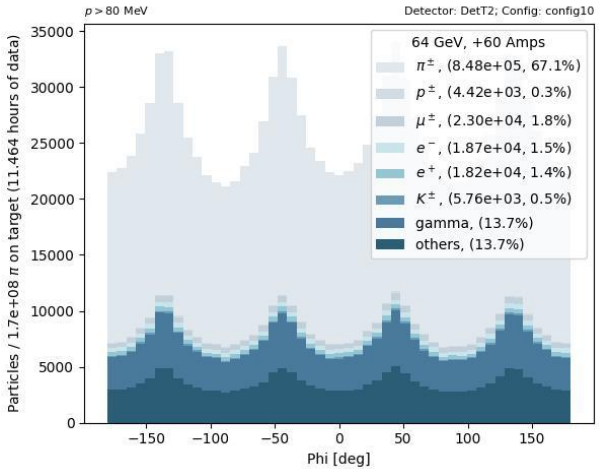
pos 60 Amps

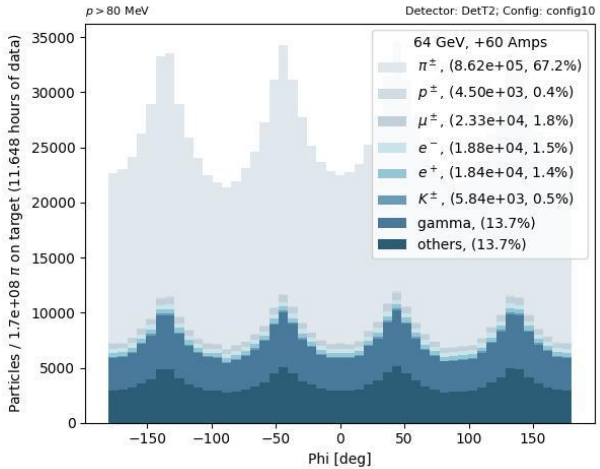


JGG Magnet **ON**

LArIAT Magnets (B1 and B2) **ON**

neg 60 Amps



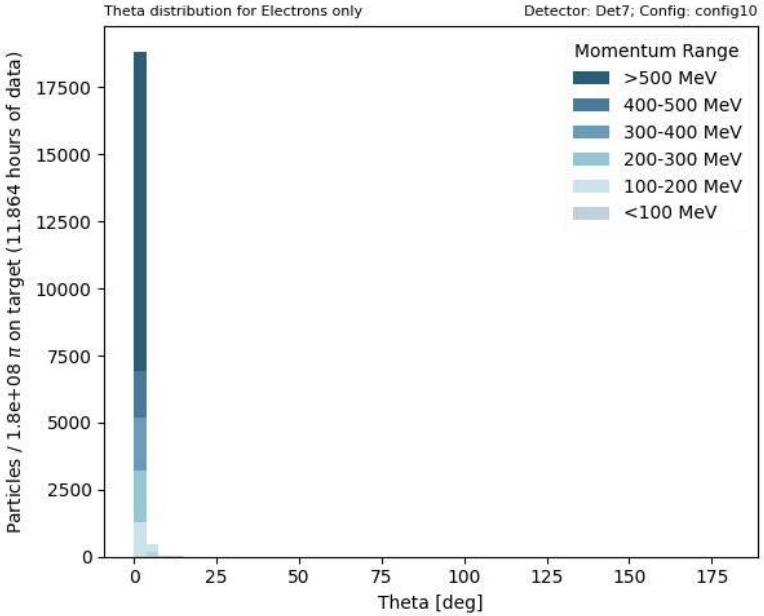


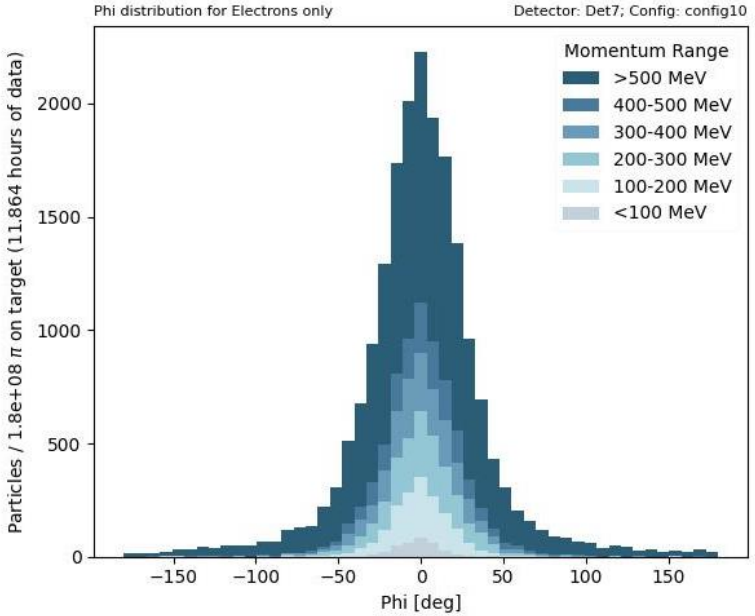
Fermilab

Det7

Example Plot: Angular Spectra of **Electrons**

JGG ON **LArIAT OFF**



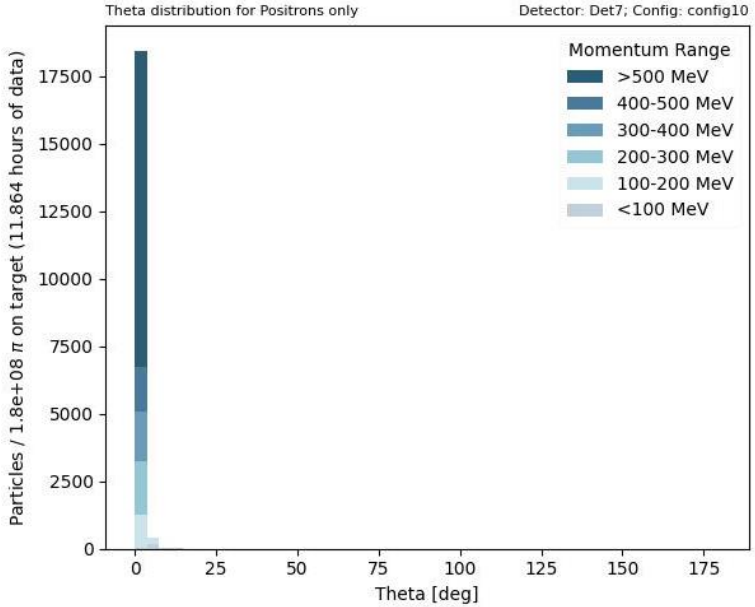


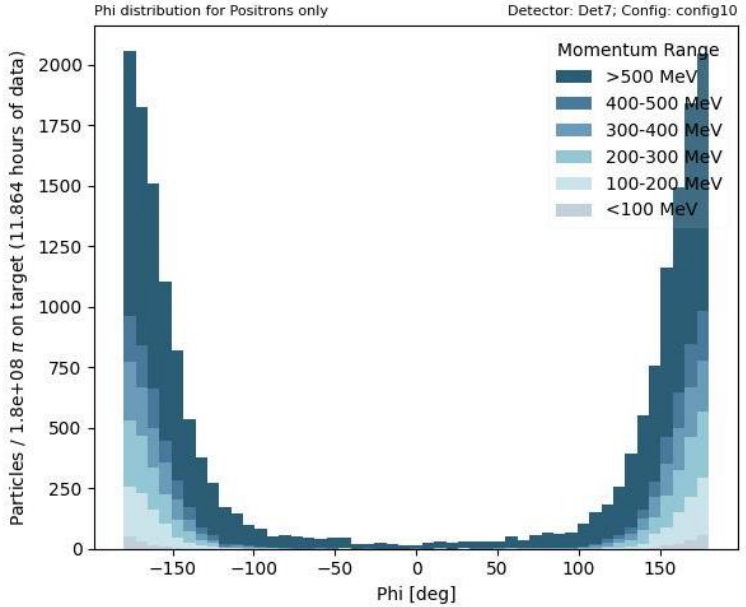
Fermilab

Det7

Example Plot: Angular Spectra of **Positrons**

JGG ON **LArIAT OFF**





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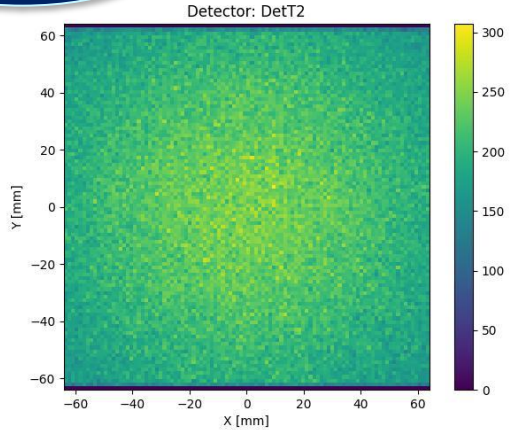
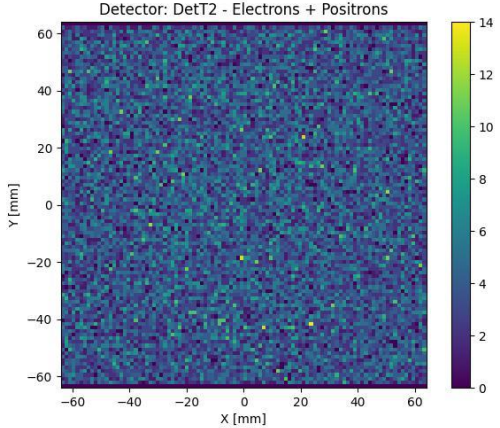
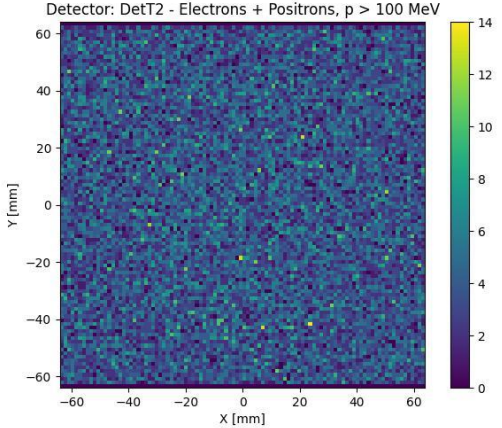
DetT2

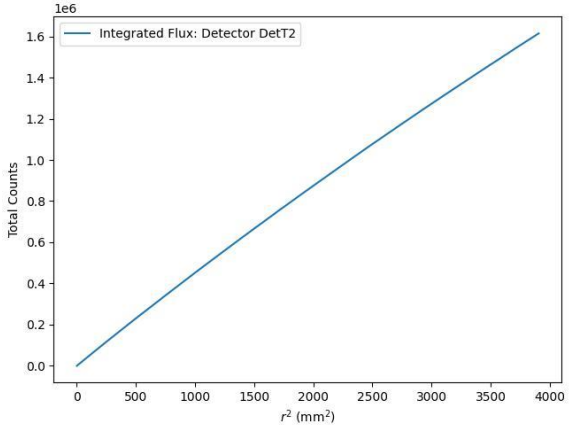
Flux Characteristics

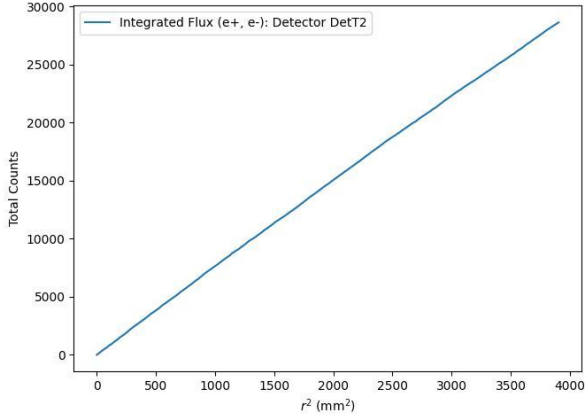
JGG ON **LArIAT OFF**

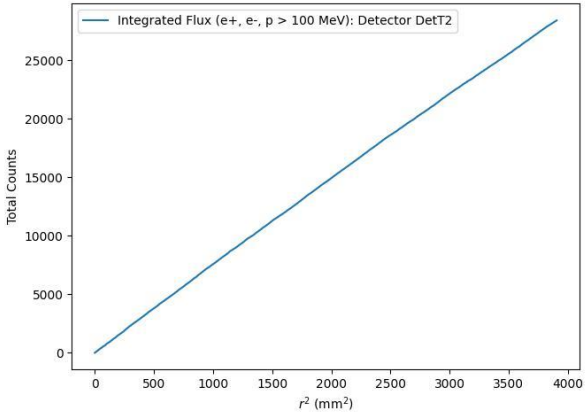












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