DarkLight: Welcome to the Other Side

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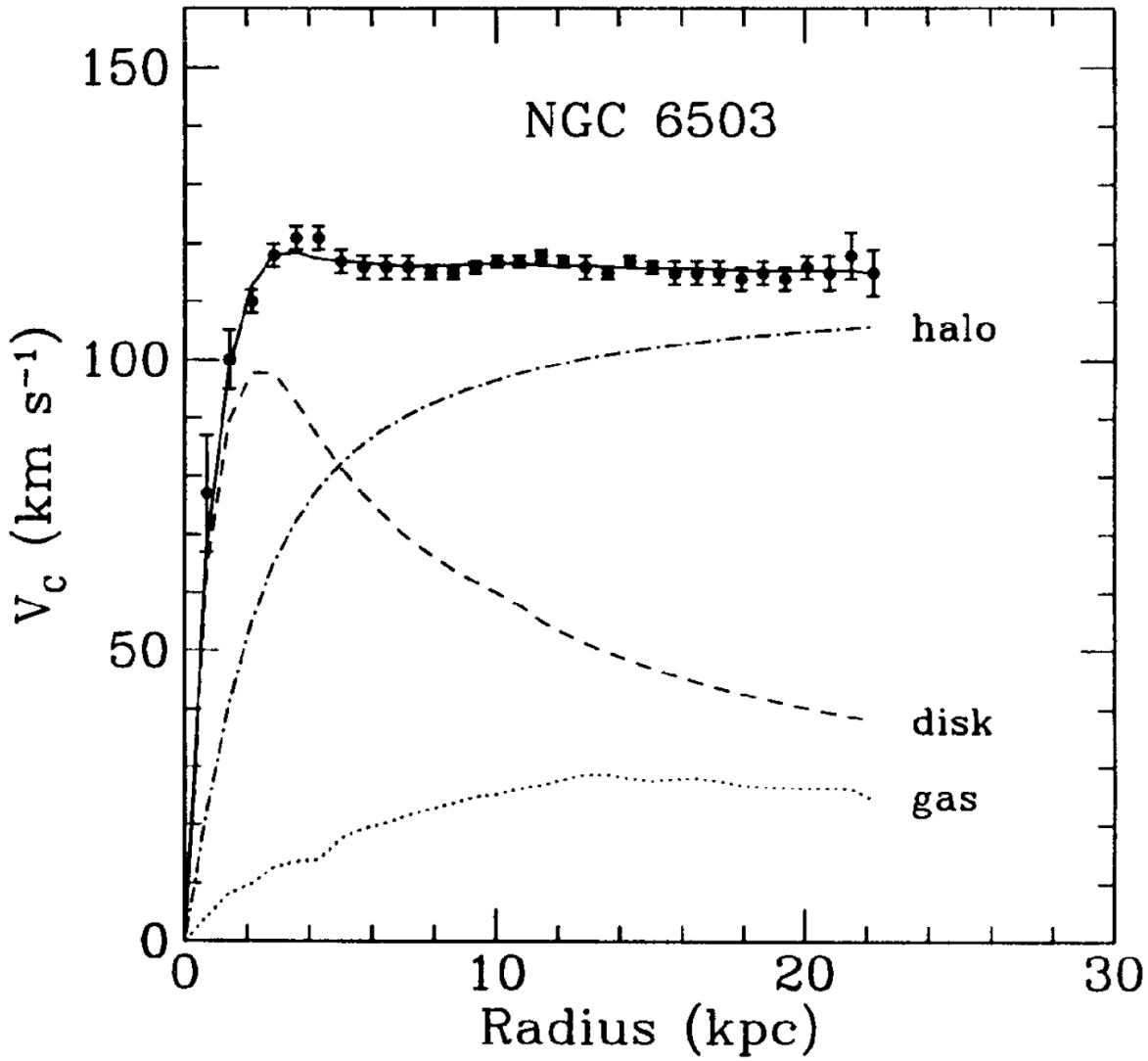
Overture

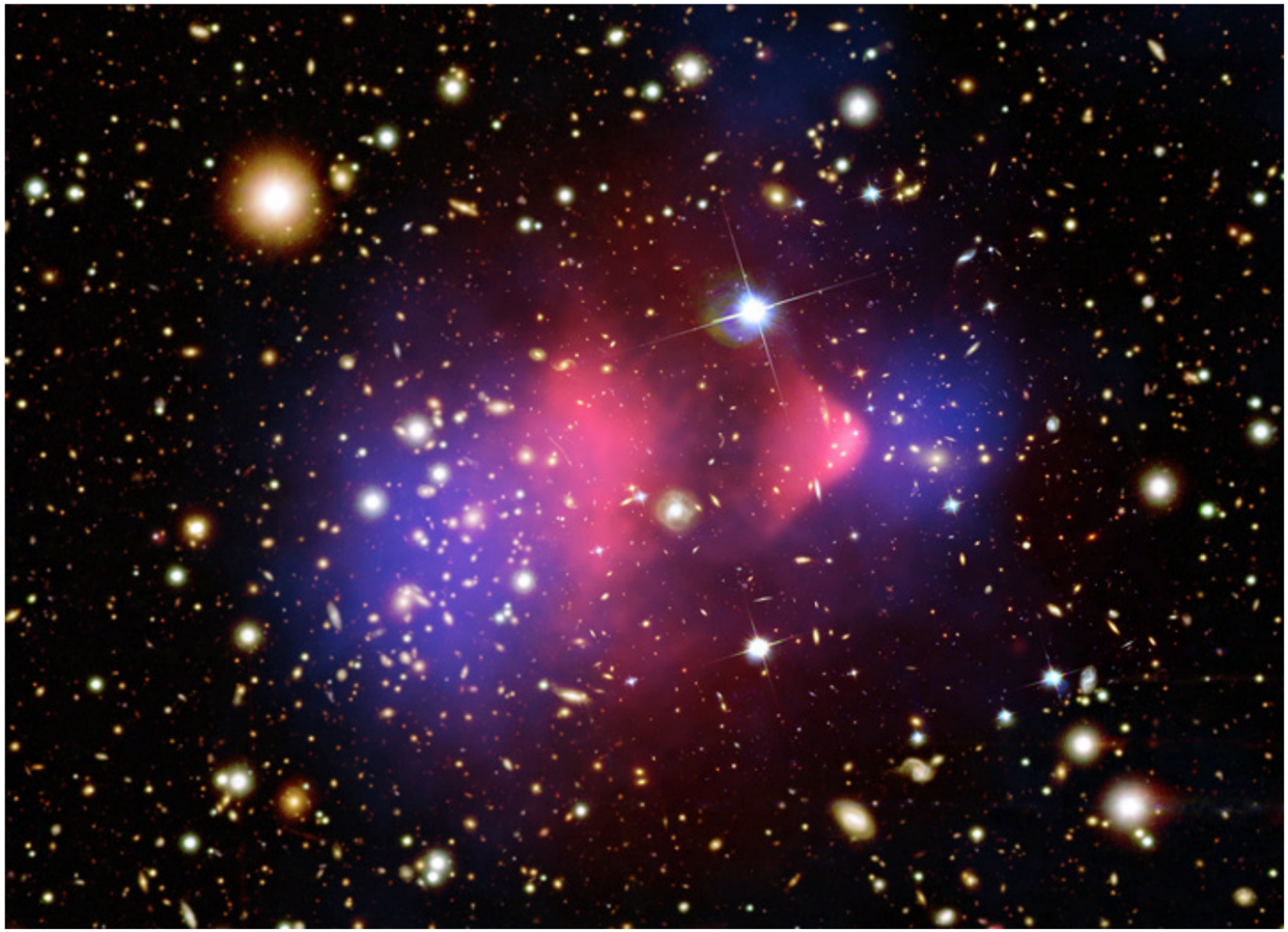
1. Preliminaries
   - Experimental Set-up
   - History
2. DarkLight Status
   - Analysis Framework: Cooker
   - digitization
   - Momentum Resolution
   - Signal

Dark Ages: Galactic Rotation Curves



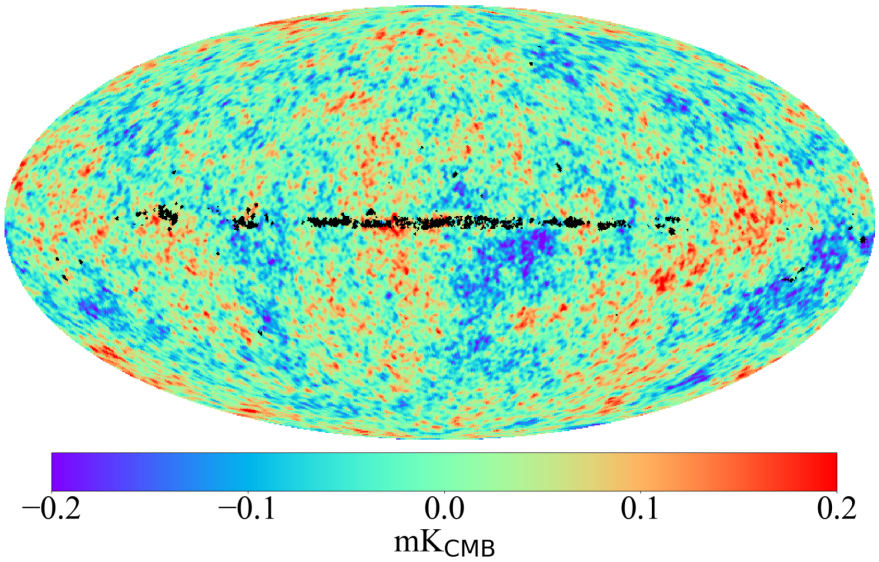
[https://doi.org/10.48550/arXiv.1701.01840]

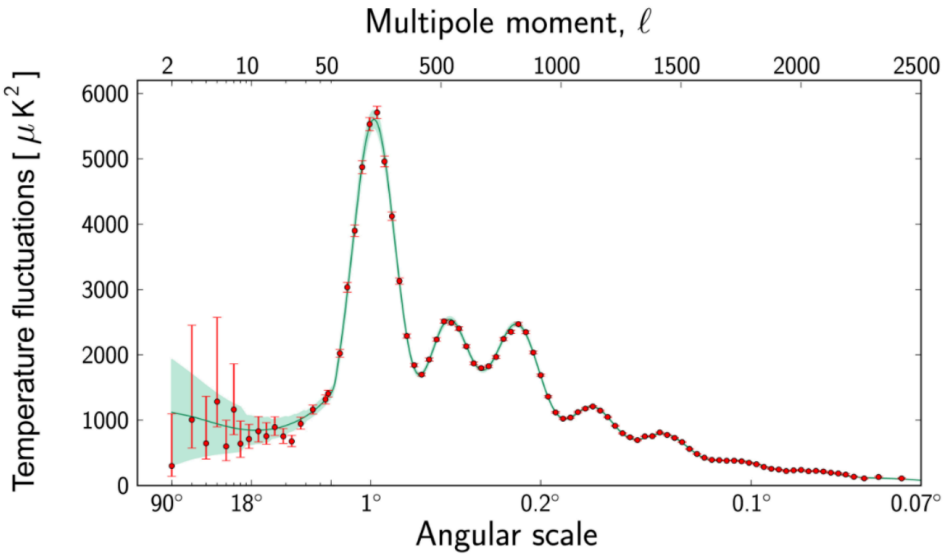
Dark Ages: Gravitational Lensing, Bullet Cluster



[https://doi.org/10.48550/arXiv.1701.01840]

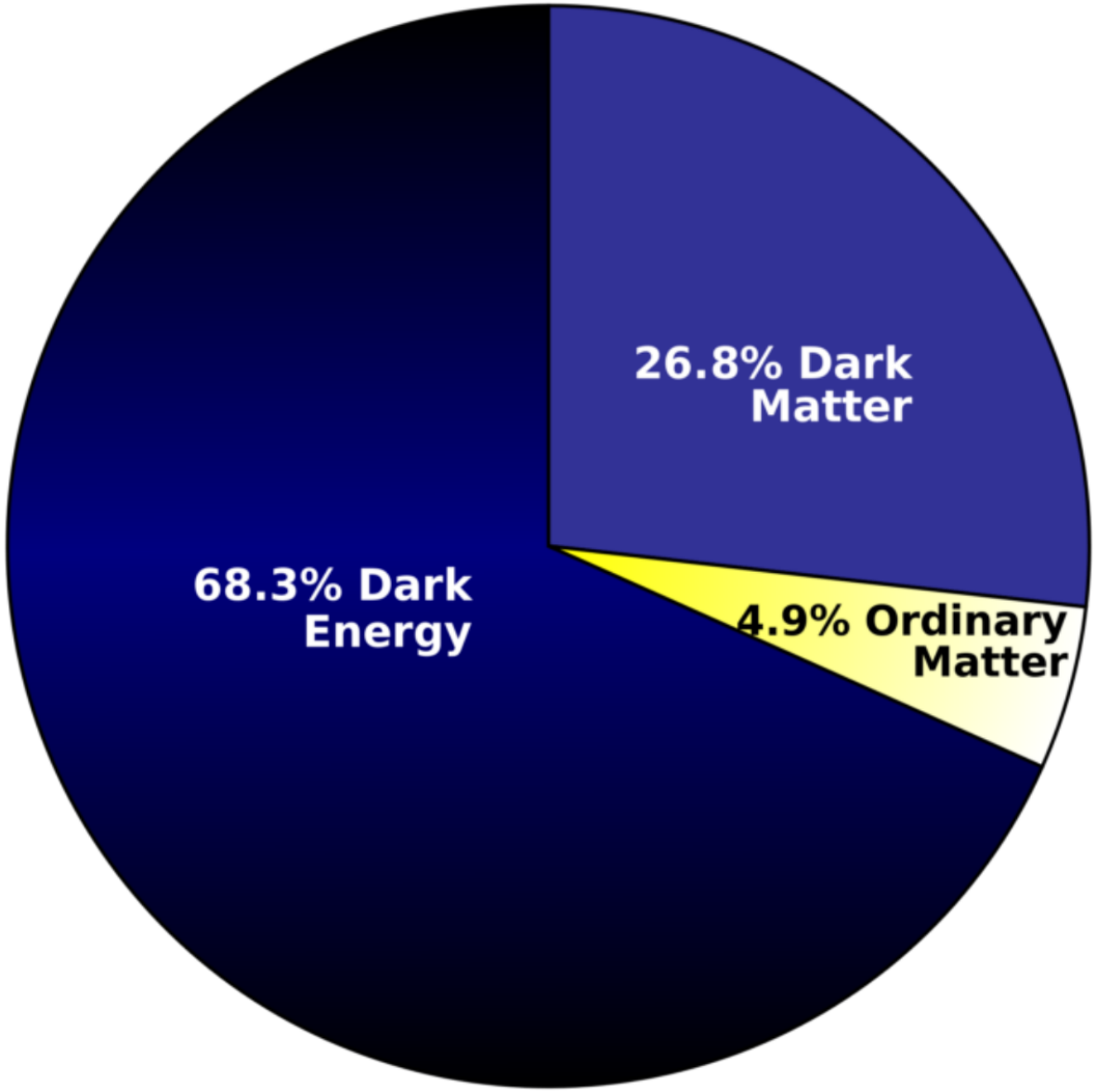
Dark Ages: Cosmic Microwave Background



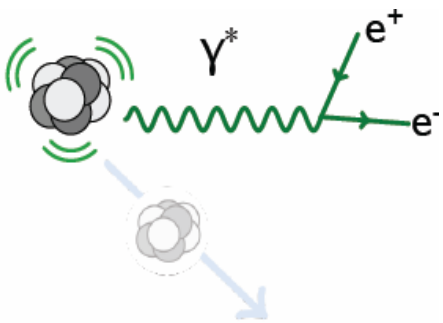


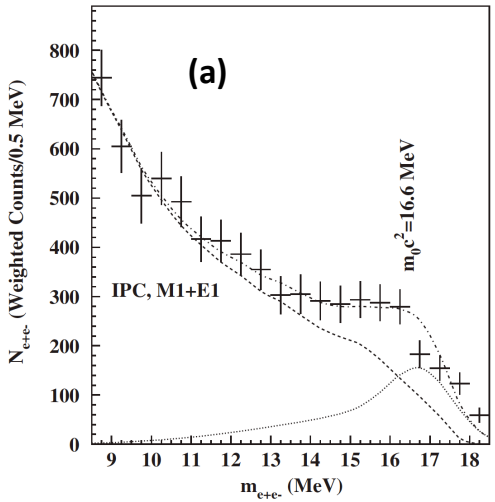
- Left over radiation from the hot early days of the universe
- Almost uniform background of radio waves that fill the universe
- Power spectrum of CMB measures the amount of fluctuation in the CMB temperature spectrum at different angular scales

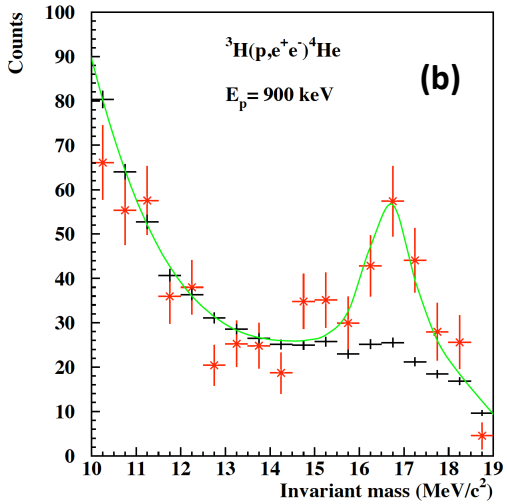
Dark Ages: Energy Density



Dark Ages: Puzzles



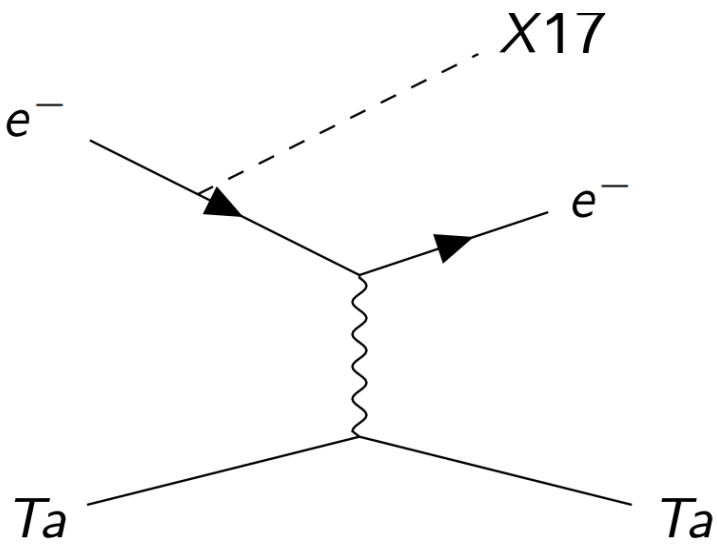


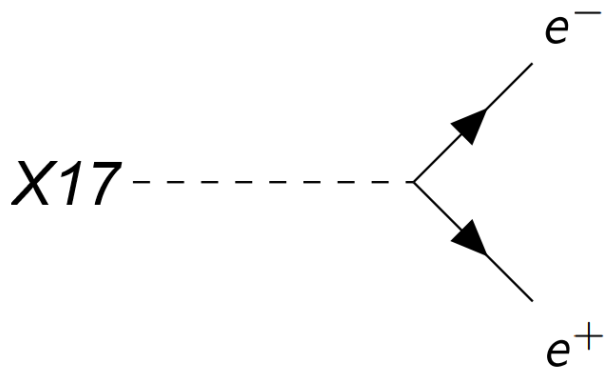


- Excess in e^+e^- invariant mass spectra in ^{*8}Be and ^{4}He
- corresponds to mass at 17 MeV/c^2
- Non-vanishing excess was observed at different angles and different experimental configurations
- Observed for ^{12}C PRC 106, L061601 (2022)

[https://arxiv.org/abs/1910.10459], [PRL 116, 042501 (2016)]

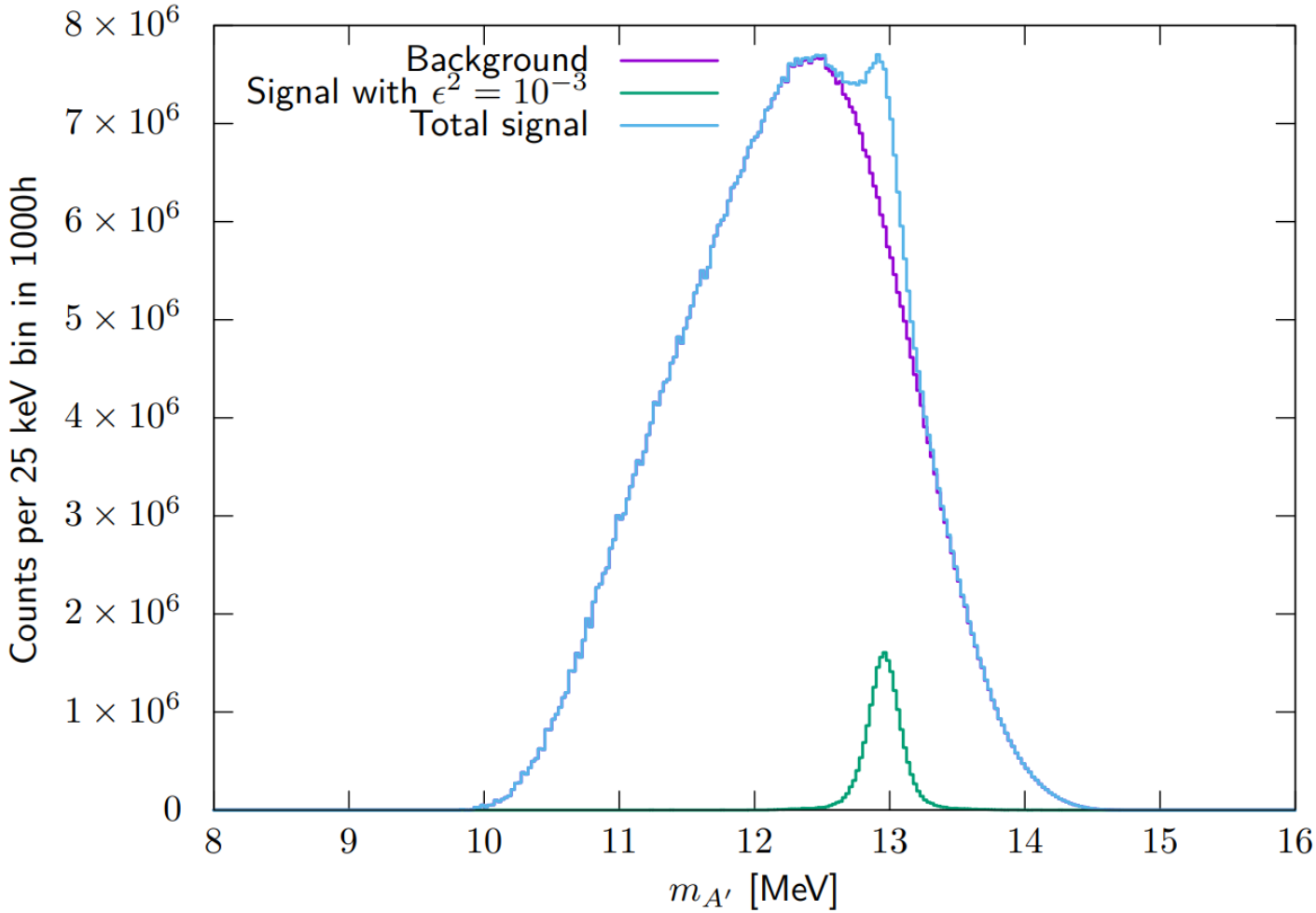
DarkLight Experiment





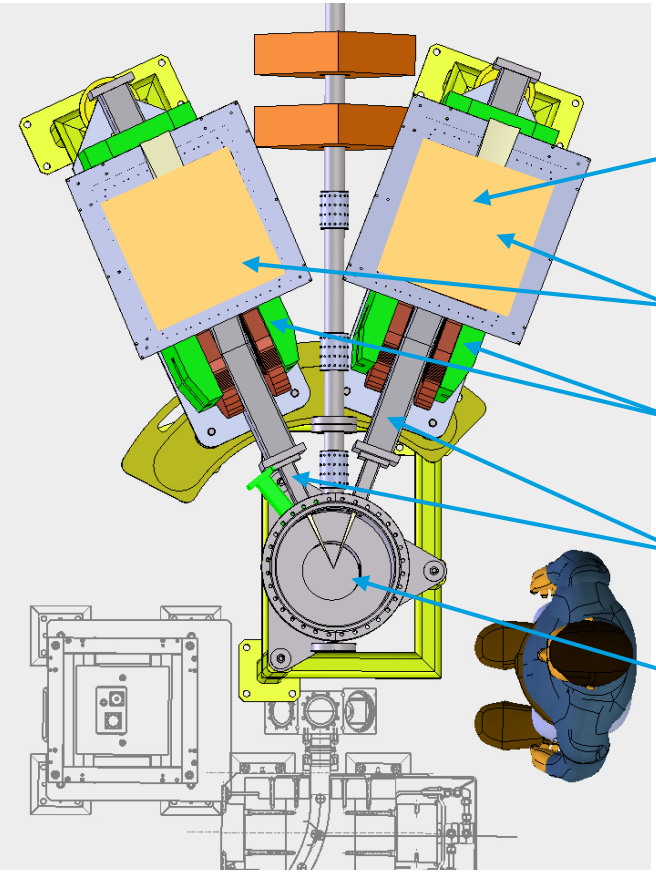
- Reaction: $e^- Ta \rightarrow e^T a + X$ and $X \rightarrow e^- e+$
- Detect $e^- e^+$ pair with two spectrometers and reconstruct invariant mass: $M_{ee} = M_{X17}$

DarkLight Experiment



- Search for bump in M_{ee} distribution

DarkLight Experiment



(Not in drawing)
Trigger detectors

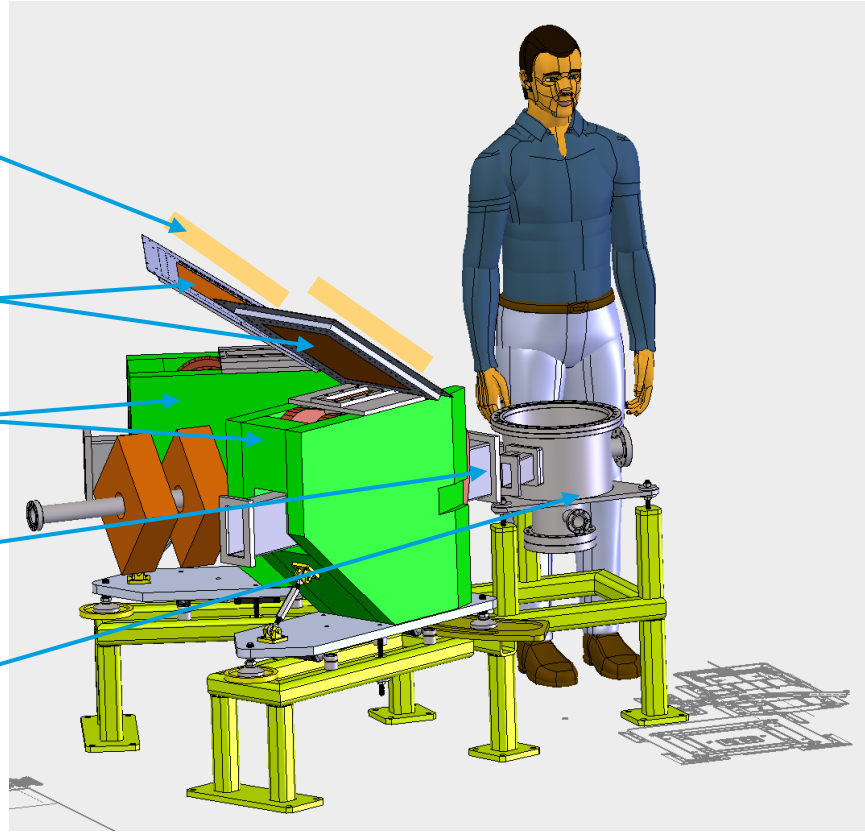
Tracking detectors

Dipole magnets

One fixed arm; one with two angles

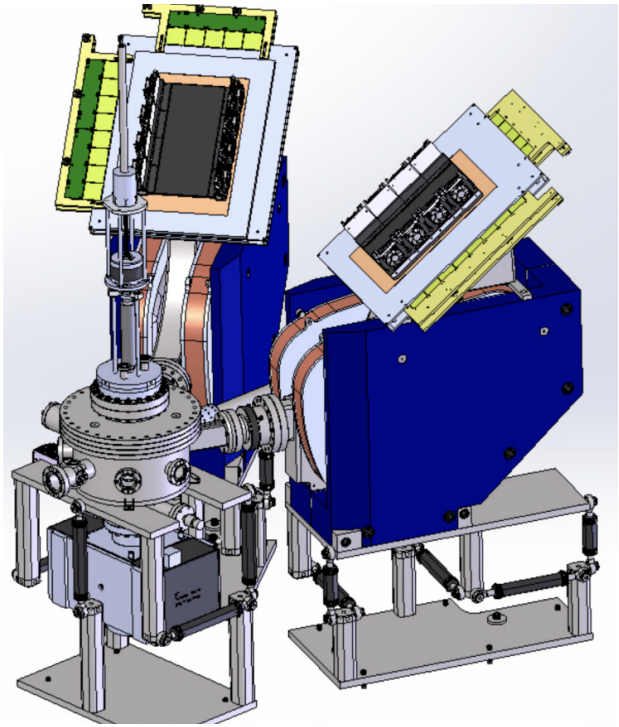
Target chamber

Part of vacuum system



DarkLight Experiment

- 1μm thick Ta foil target
- 1μm C foil for calibration and parasitic measurements
- 300 μA beam 30 MeV
- Target ladder allows for empty space configuration

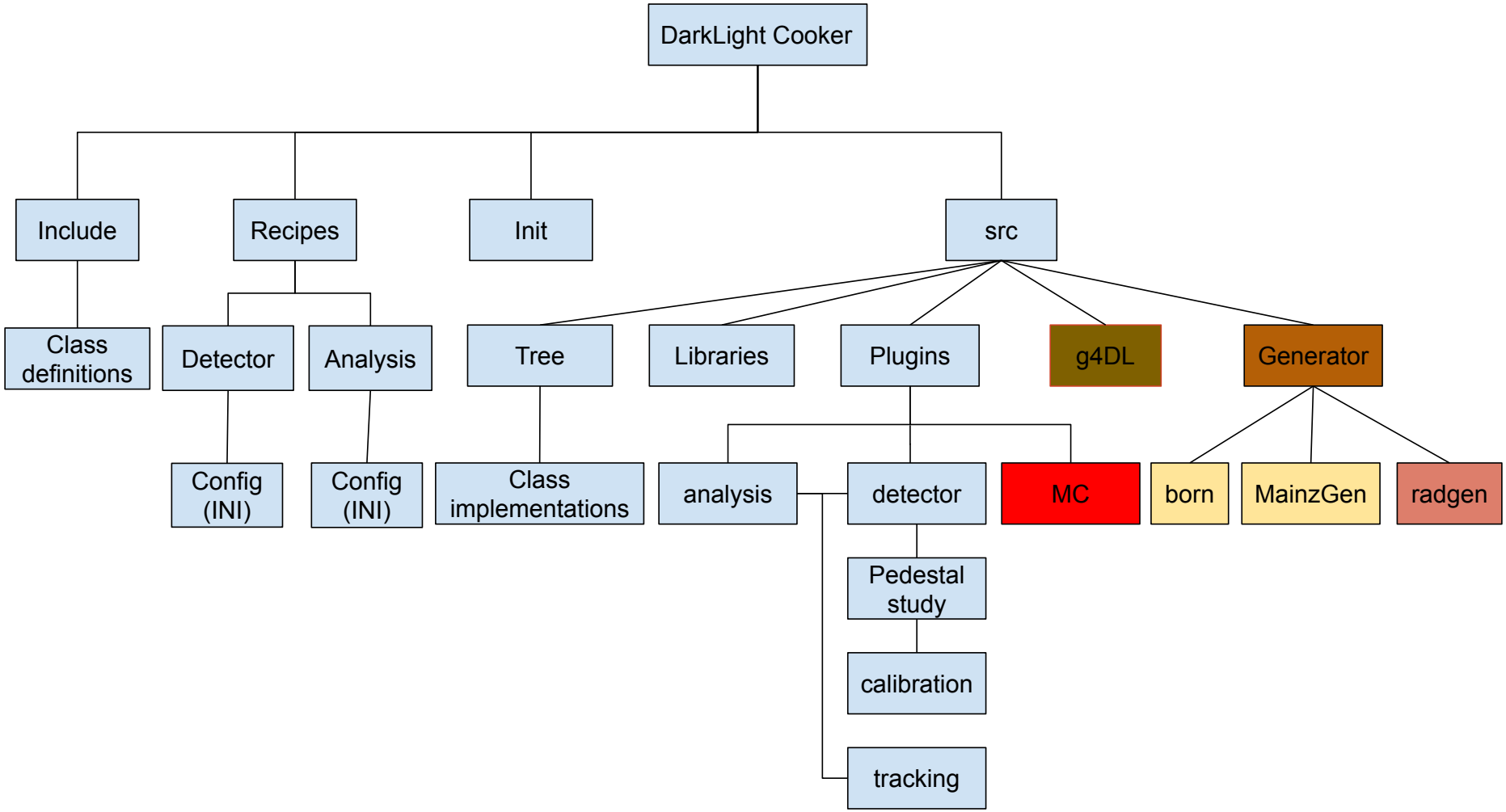


- **2011-2017: DarkLight at LERF: PAC37 (C2); approved (C1) by PAC39 (2013)**
  - **2012 Demonstrated to pass ERL mA beam through narrow aperture**
  - **2014 NSF/MRI funding, staging of DarkLight in Phase I (a,b,c), and II**
  - **2016 Last LERF operation, test beam time with DarkLight solenoid**
  - **2016 Atomki PRL claiming X17 (8-Be)** PRL 116, 042501 (2016)

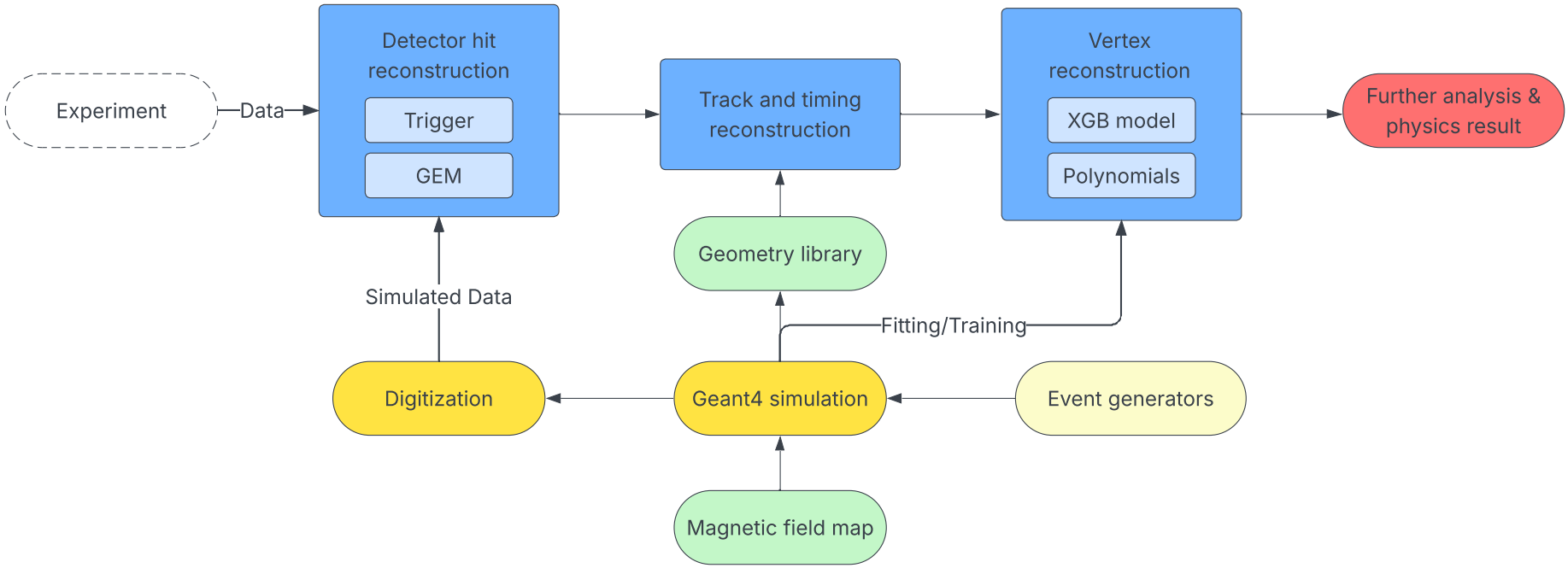
- **2018-2020: DarkLight at CEBAF: deferred by PAC46 (2018) and PAC48 (2020)**
  - **2019 Second Atomki claim (4-He)** arxiv:1910.10459

- **Since 2020: DarkLight at ARIEL (TRIUMF) initiated**
  - **DND2020: Developing New Directions in Fundamental Physics**
  - **2021: DarkLight proposal to TRIUMF, for 10-20 MeV search window Phase 1 approved by TRIUMF EEC with high priority for 1,300 beam hours**
  - **2022 Third Atomki claim (12-C)** arxiv:2209.10795

2025:Installation & Commissioning


DarkLight Cooker
Include
Recipes
Init
src
Class definitions
Detector
Analysis
Tree
Libraries
Plugins
g4DL
Generator
Config (INI)
Config (INI)
Class implementations
analysis
detector
MC
born
MainzGen
radgen
Pedestal study
calibration
tracking

Data Pipeline



GEM Digitization

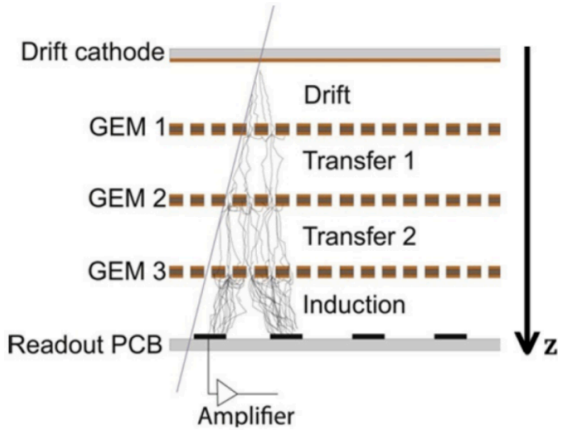
g4DL → **Reconstruct & Sample** → **Create Gaussians**

Passes locations of energy deposits in ROOT file. Unable to pass actual track information

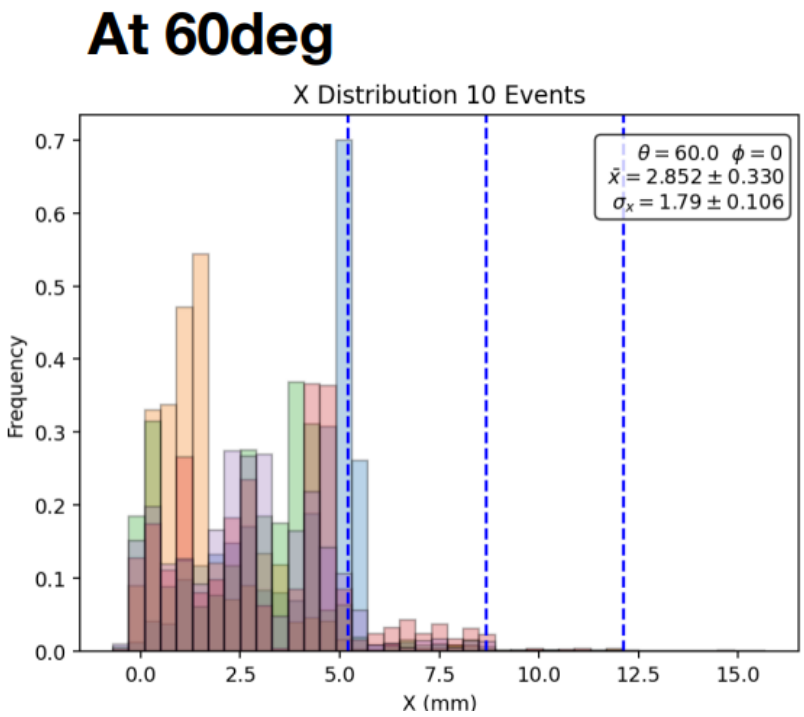
Reconstruct track information from energy deposits. Use track information to randomly sample points of ionization on path

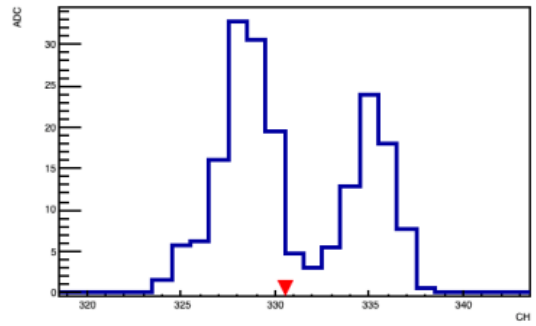
Ionization points are then turned into gaussians in GEM axis

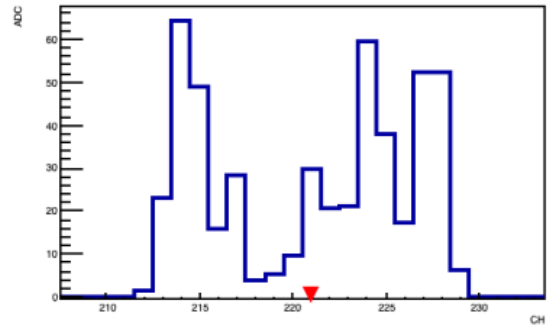
- Uses `Garfield++`

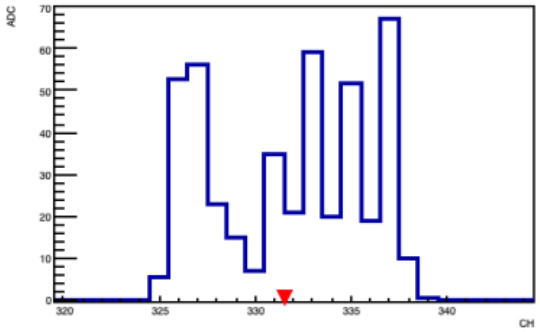


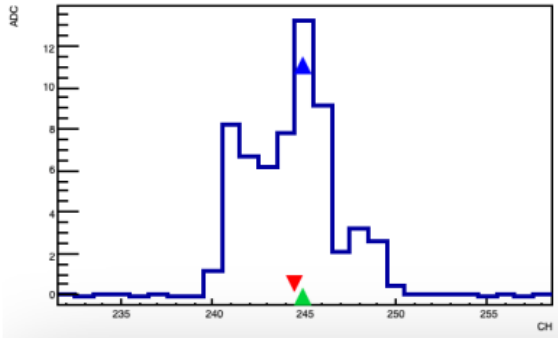
GEM Digitization





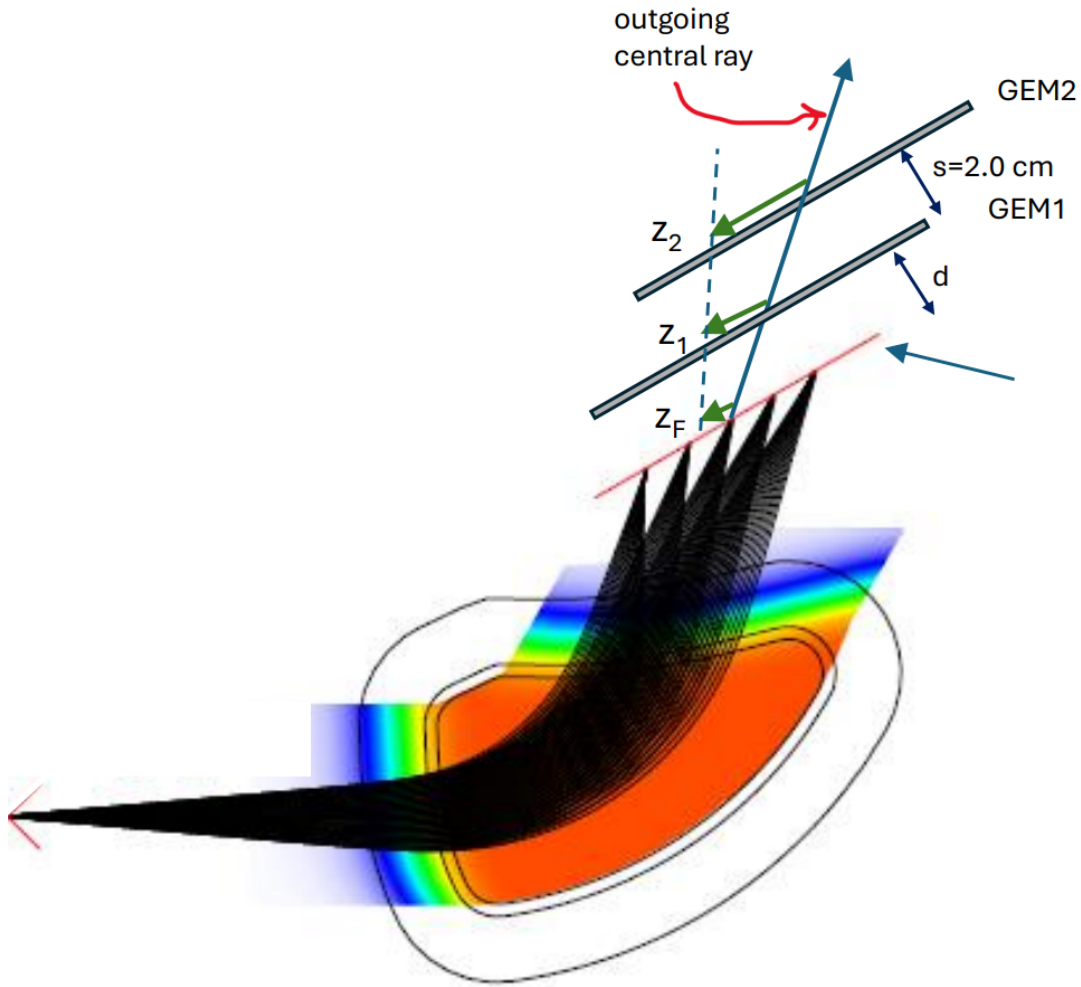






- Go from `G4` hits to `ADC`
- This has been implemented into `Cooker`

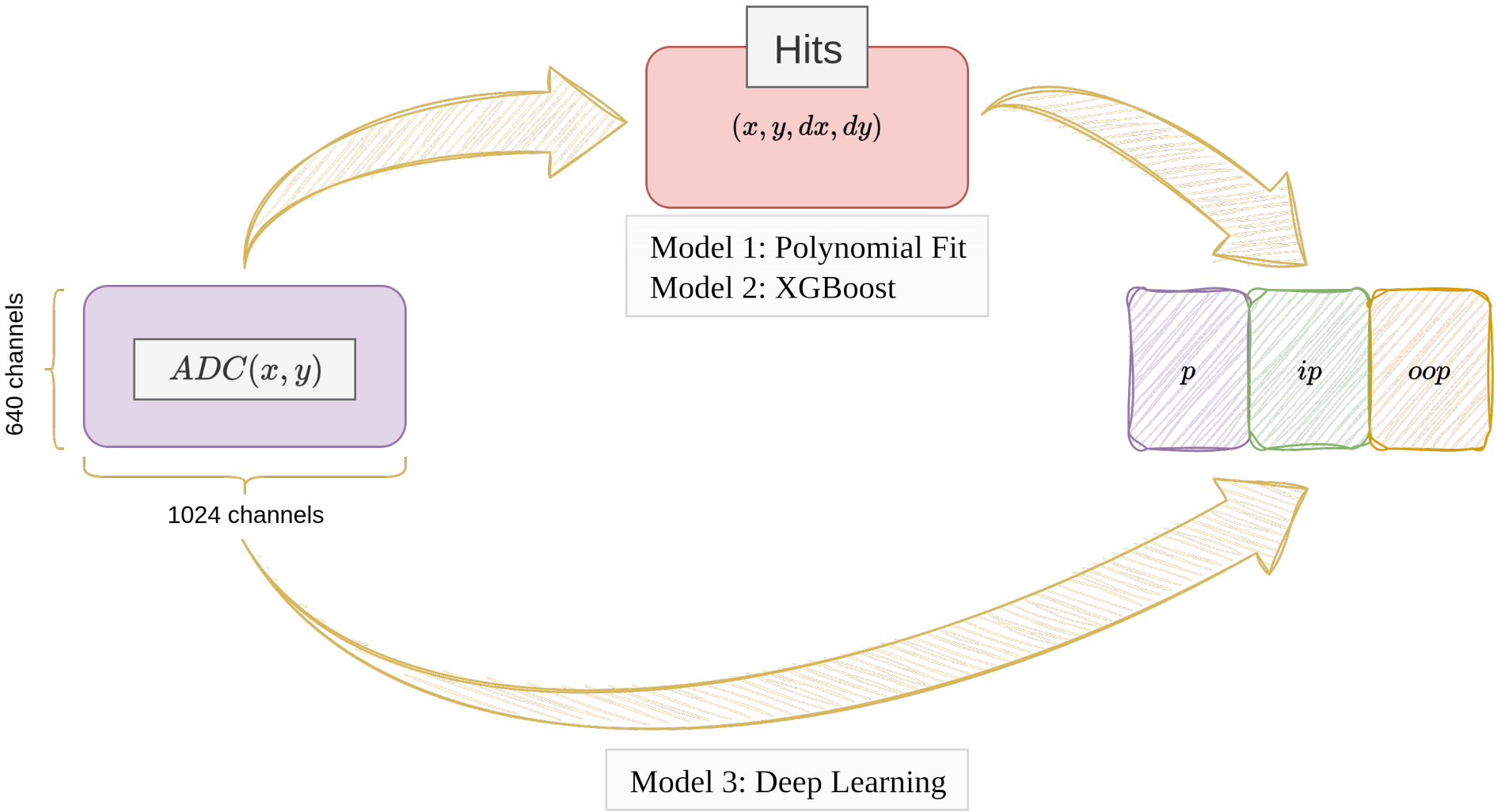
Central Momentum Resolution



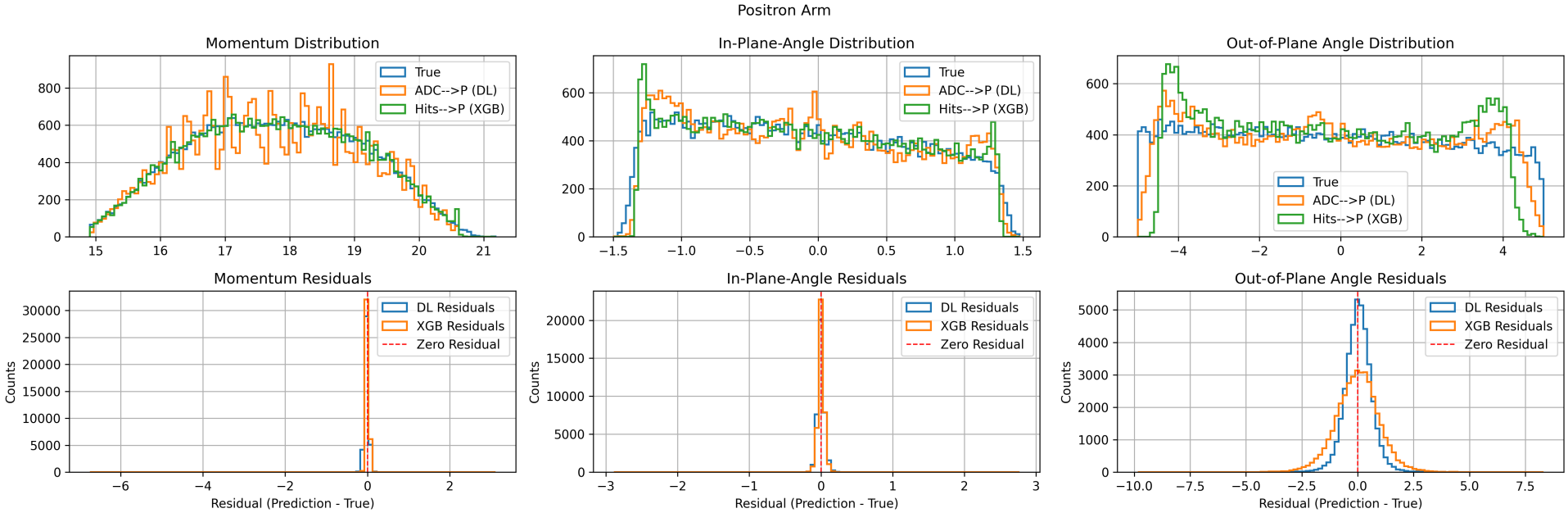
- Resolution of central momentum given digitization

[Daniel & Myself]

Vertex Reconstruction

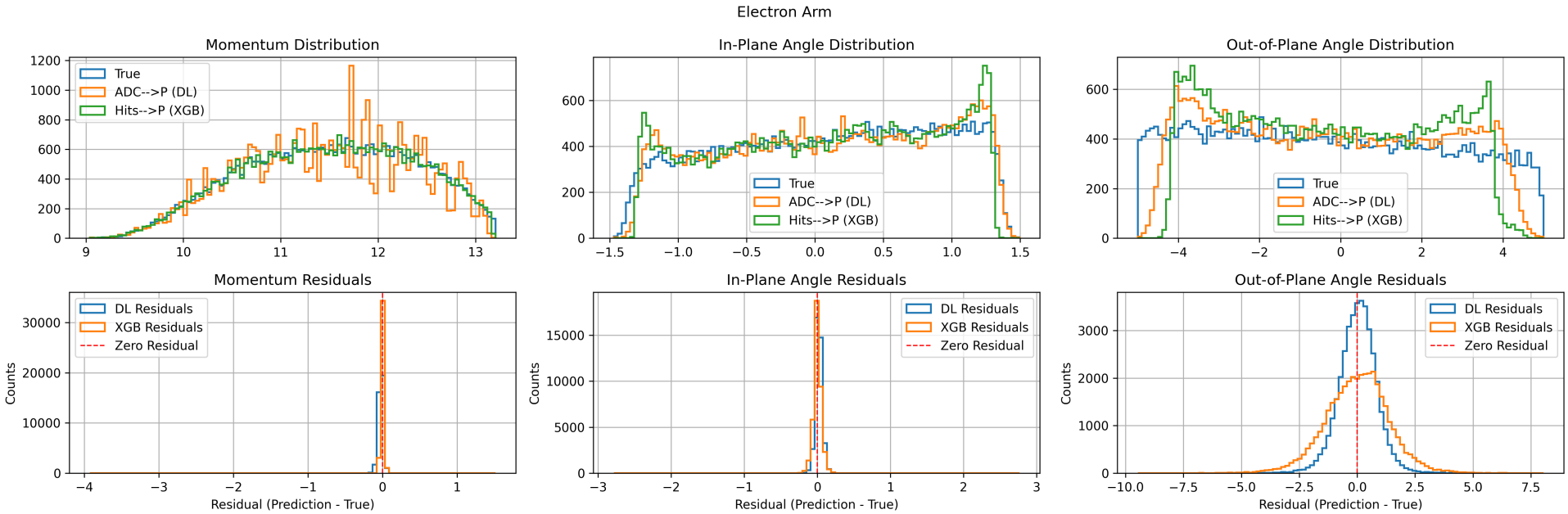


Vertex Reconstruction



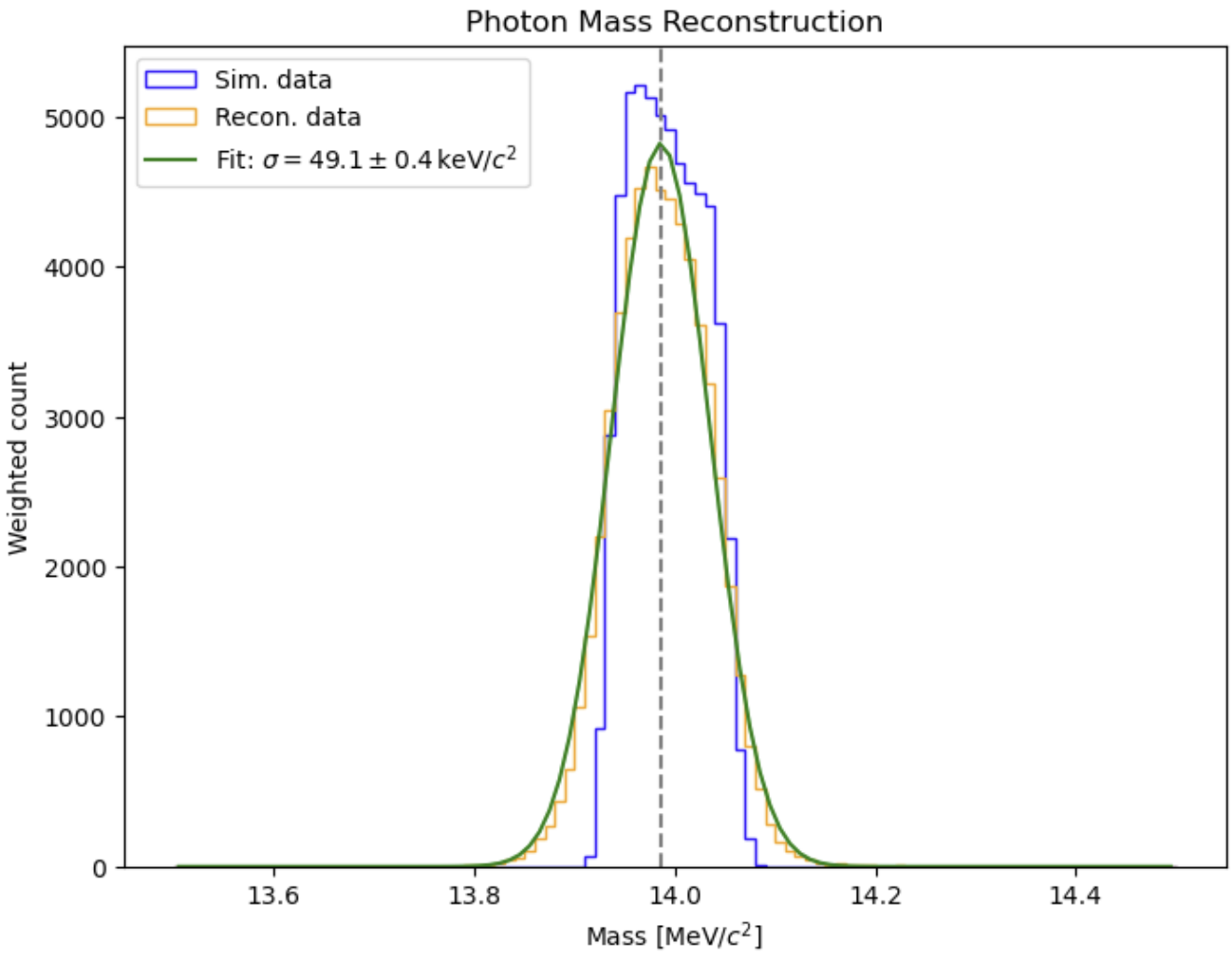
[Sid & Xavier]

Vertex Reconstruction



[Sid & Xavier]

Vertex Reconstruction



- Signal reconstruction: $\mathrm{M} = 14.5\ \mathrm{MeV}/c^2$

[Sid & Xavier]

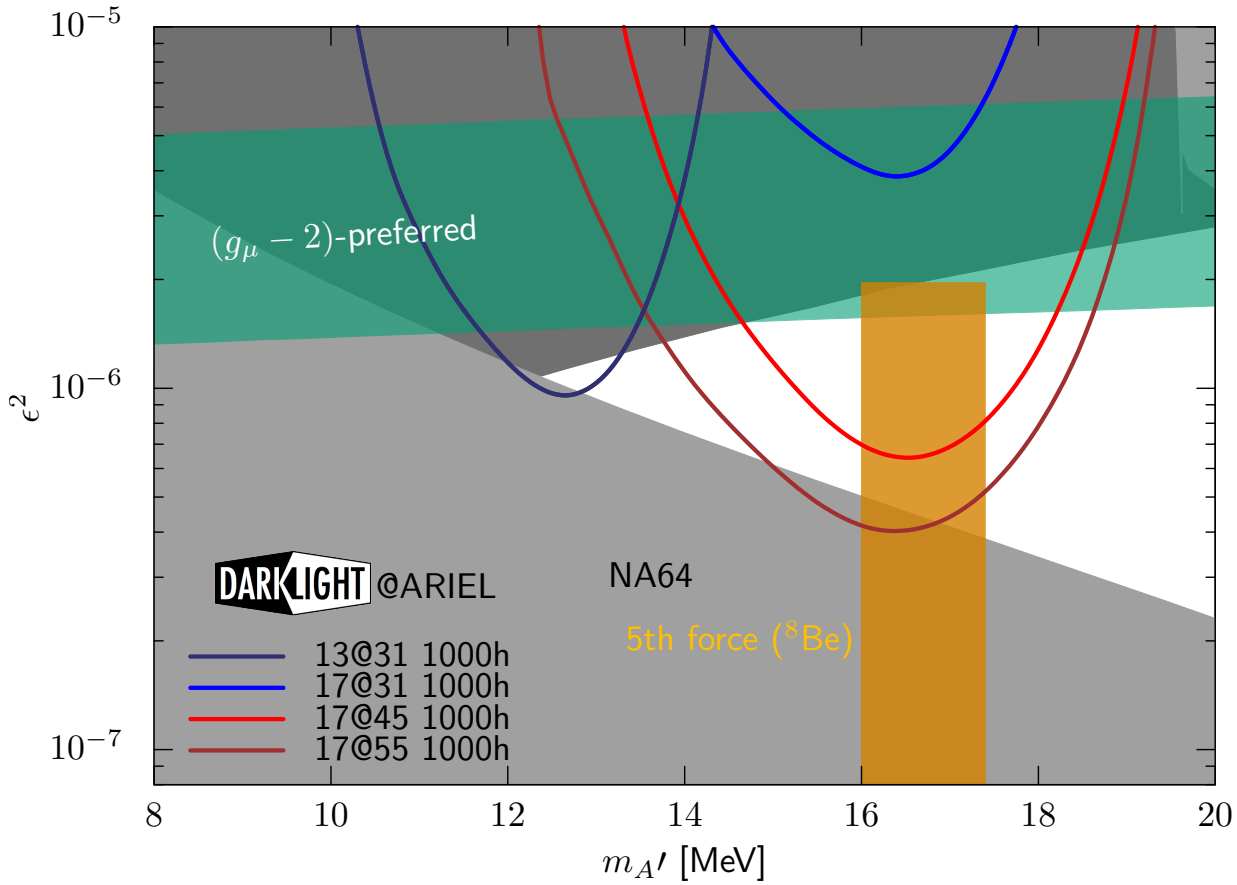
Summary & Future Work

- The work goes on!!!

Now onto the Installation Presentation

Back Up

Exclusion

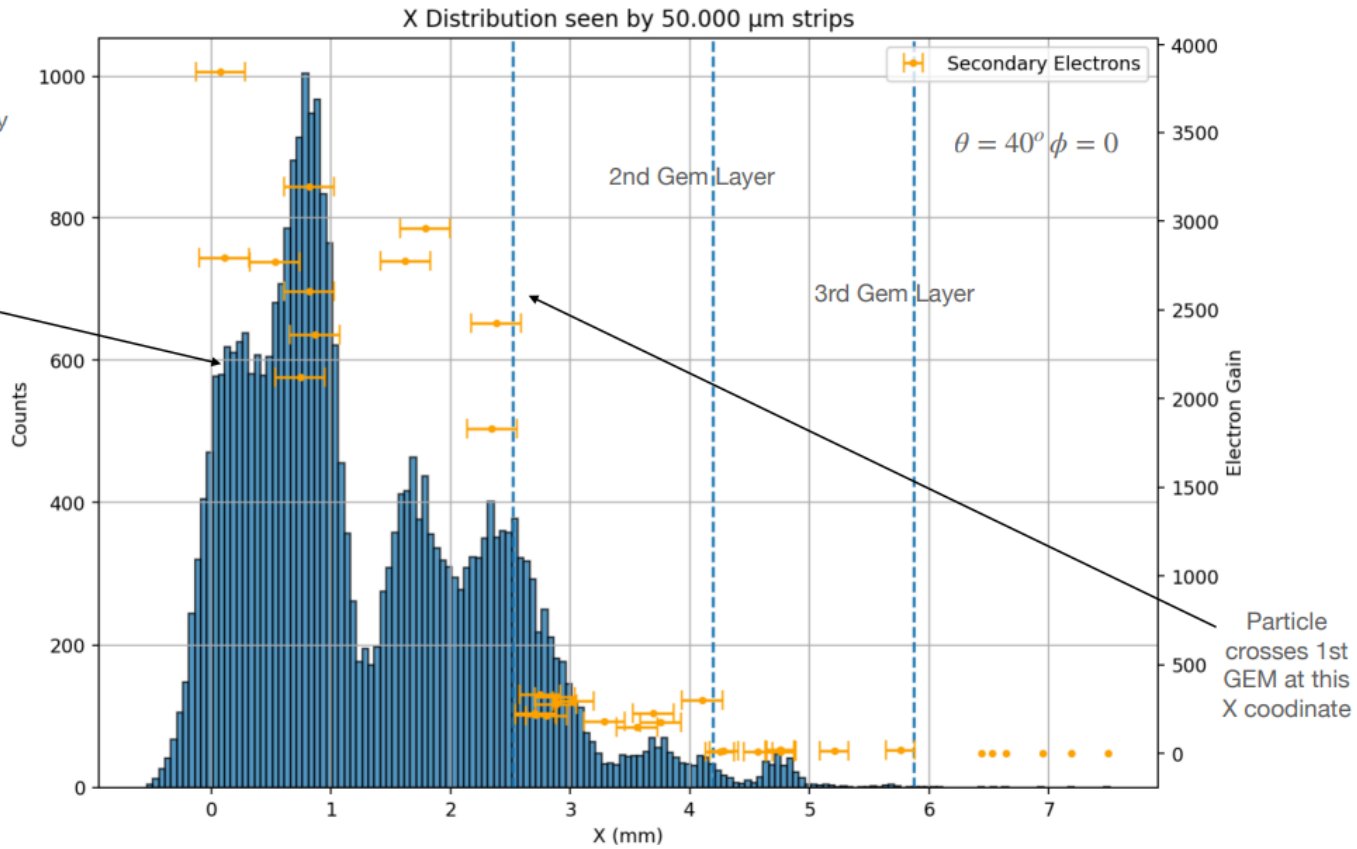

10^{-5}
10^{-6}
10^{-7}
ϵ^2
$(g_\mu - 2)$-preferred
DARKLIGHT @ARIEL
NA64
5th force (^{8}Be)
13@31 1000h
17@31 1000h
17@45 1000h
17@55 1000h
8
10
12
14
16
18
20
$m_{A'}$ [MeV]

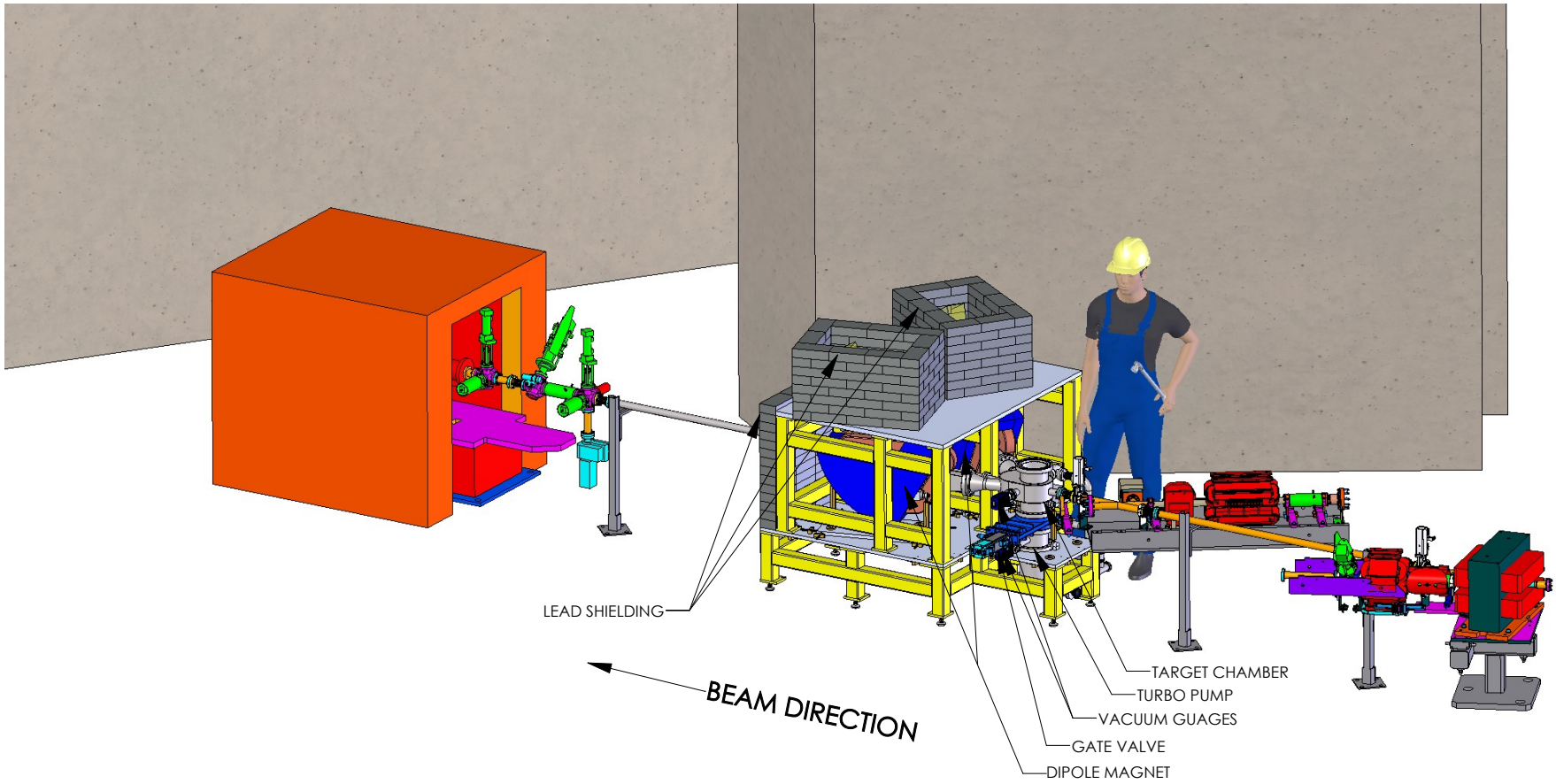
Correlating Gain and X Distribution

X error bars is the expected std of gaussian caused by shower of secondary electrons on their respective layers

With high enough resolution, we see the corresponding gaussian to each secondary electron

NOTE: different event from previous slides




LEAD SHIELDING
BEAM DIRECTION
TARGET CHAMBER
TURBO PUMP
VACUUM GUAGES
GATE VALVE
DIPOLE MAGNET

Key Points of New Config

- `Branch` of new config: default is to use `INI`
- `cmake ../ -DUSE_XML=ON` to turn on `XML parsing`
- **Not tested if `XML` parsing if fully working. `Cedar keeps hanging`**
- Use `std::map` as look-up table
- `key: runnumber, id (channel no.), detector element`
- Not all detector elements and/or channels are changed for all run numbers
- Changed elements get overwritten
- `eetsumMorConfig` creates a `map` of `runnumber` and `sequence of config items`
- Might be buggy, and some functionality still to be added

Keeping Things the same

GEMini functions

```
Long_t GEMini::setAPV(int id,int off,int ch,int ch_off,const char *name){ ...  }
Long_t GEMini::setPedestals(int id, char *param){ ....  }
Long_t GEMini::setAxis(int id, int apvid1,int offset1, int apvid2,int
offset2,const char* name){ ...  }
```

XML <run nr="10137">

```
<apv id="0">0,128,0,"APV0"</apv>
<apvped id="0">"229.61 852.181 872.292 855.482 872.207 848.577..."
<axis id="0">0,0,7,128,"x"</axis>
```

INI: [run:10137]

```
apv=0,0,128,0,"APV0"
apvped=0,"229.61 852.181 872.292 855.482 872.207 848.577..."
axis=0,0,0,7,128,"x"
```

Eet-Sum-Mor Init File

```
[config]
 apvped=setPedestals
 apvgain=setGains
 apv=setAPV
 axis=setAxis
 format=setDataFormat

[run:10137]
 apv=13,0,128,0,"APV0"
 apv=14,128,128,0,"APV1"
 apv=15,256,128,0,"APV2"
 apv=16,384,128,0,"APV3"

 axis=0,0,0,7,128,"x"
 axis=1,8,0,12,128,"y"
```