

Baseline 1.6 Simulation Framework, and Plans for Baseline 2.0

Dark SHINE Seasonal Workshop

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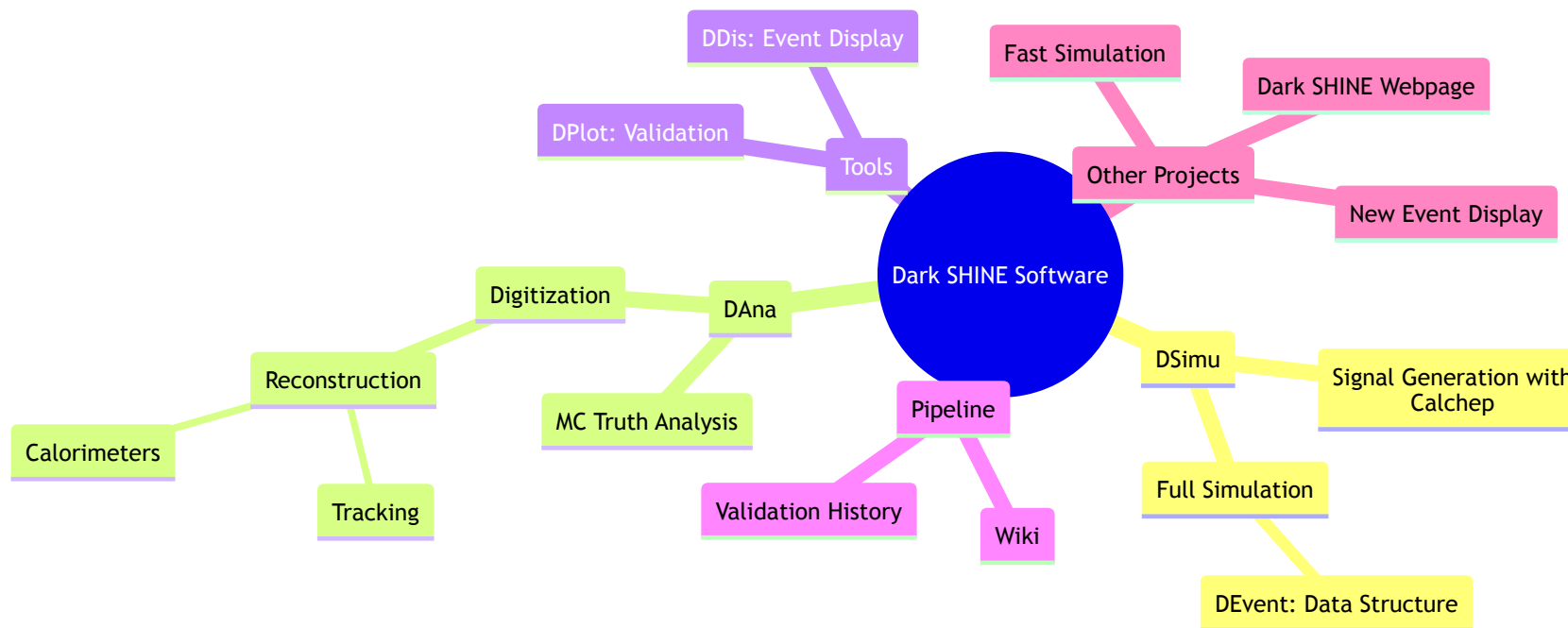
Outline

1. Overview
2. From Baseline 1.0 to 1.6: Detector Construction
3. From Baseline 1.0 to 1.6: Versions and Milstones
4. CI/CD Pipeline and Validation
5. CPU Performance and Event Storage
6. Sample Production
7. Tracking
8. Calorimetry
9. Future Plans and Timeline

Overview

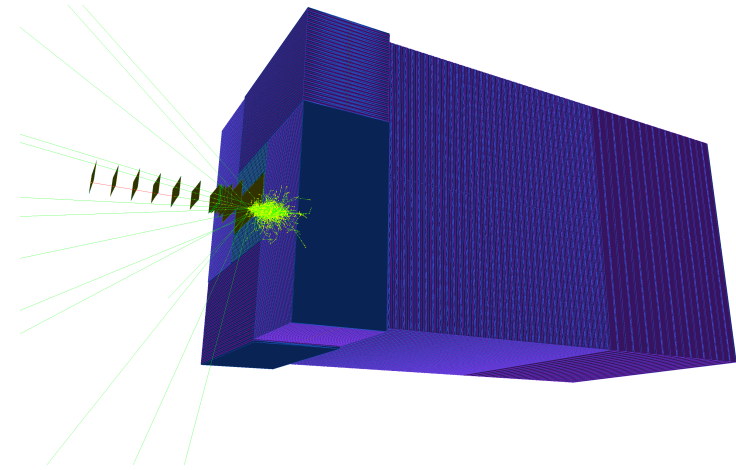
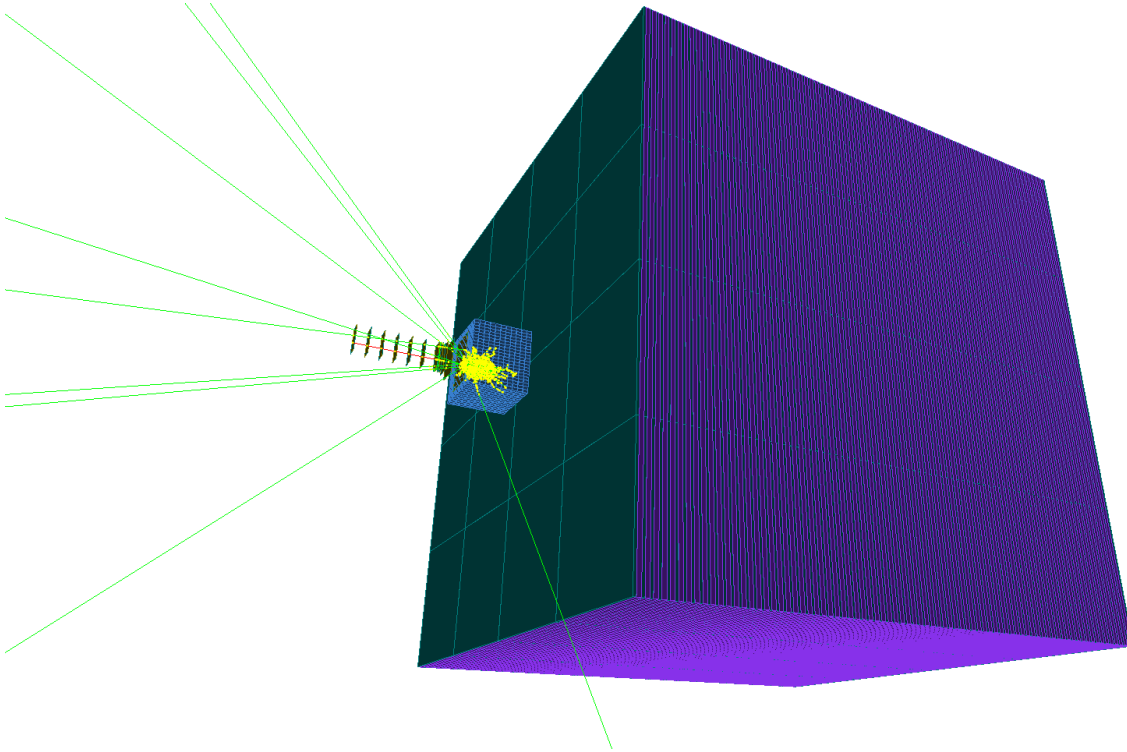
DarkSHINE Software is a software package, including five parts: **DSimu**, **DAna**, **DDis**, and **DPlot**.

- **DSimu** is the **simulation program** based on Geant4, characterized by Dark SHINE detector, controlled by **yaml configuration**.
- **DAna** is a **framework for the analysis and reconstruction tools**. It requires the output ROOT file (involving Geometry, DMagnet and DEvent) from DSimu.
- **DDis** is the **event display** for DSS. (requires Geometry and DEvent)
- **DPlot** is a quick plotting program for newbies and lazy man.
- **DEvent** is the **generic data structure** in DSS.



From Baseline 1.0 to 1.6: Detector Construction

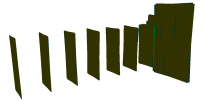
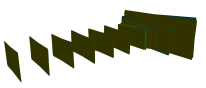
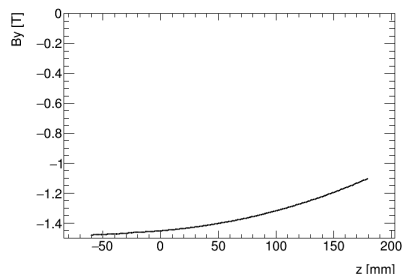
Detector Construction Overview



From Baseline 1.0 to 1.6: Detector Construction

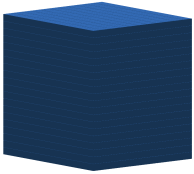
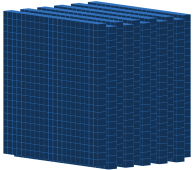
Tracking System

Baseline 1.6 Tracker uses **Si micro-strip** ($30\mu\text{m}$) and **non-uniform magnetic field**, while Baseline 1.0 uses non-strip (truth hit) and uniform magnetic field.

| Baseline | | Magnetic Field | Component | Material | Center Z (mm) | Size (mm) | Layer Number |
|----------|--|--|-----------------|----------|-----------------|---------------------------|--------------|
| 1.0 |  | $B_y = -1.5\text{T}$ | Tagging Tracker | Si | -607.83 ~ -7.83 | 100, 200, 0.1 | 7x2 |
| | | | Target | W | 0 | 100, 200, 0.35 | 1 |
| | | | Recoil Tracker | Si | 7.73 ~ 180.23 | 100~250, 200, 0.1 | 6x2 |
| 1.6 |  |  | Tagging Tracker | Si | -607.83 ~ -7.83 | 201, 100, 0.15 | 7x2 |
| | | | Target | W | 0 | 200, 100, 0.35 | 1 |
| | | | Recoil Tracker | Si | 7.73 ~ 180.23 | 201~501, 200, 0.15 | 6x2 |

From Baseline 1.0 to 1.6: Detector Construction

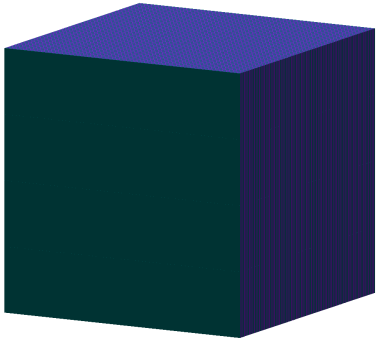
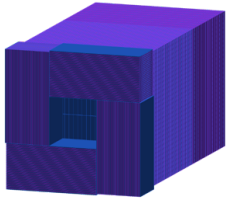
ECAL

| Baseline | | Configuration | Cell Number | Cell Gap | Gap Material | Cell Components | Material | Size (cm) |
|----------|---|---------------|-------------|----------|--------------|--------------------------------|------------------|--|
| 1.0 |  | Cubic | 20, 20, 11 | 0.1 mm | CarbonFiber | Wrapper APD Scintillator | Al Si LYSO | 2.53, 2.53, 4.13 1, 1, 0.1 2.5, 2.5, 4.0 |
| 1.6 |  | Staggered | 21, 21, 11 | 0.1 mm | CarbonFiber | Wrapper APD Scintillator | C Si LYSO | 2.53, 2.53, 4.13 1, 1, 0.1 2.5, 2.5, 4.0 |

From Baseline 1.0 to 1.6: Detector Construction

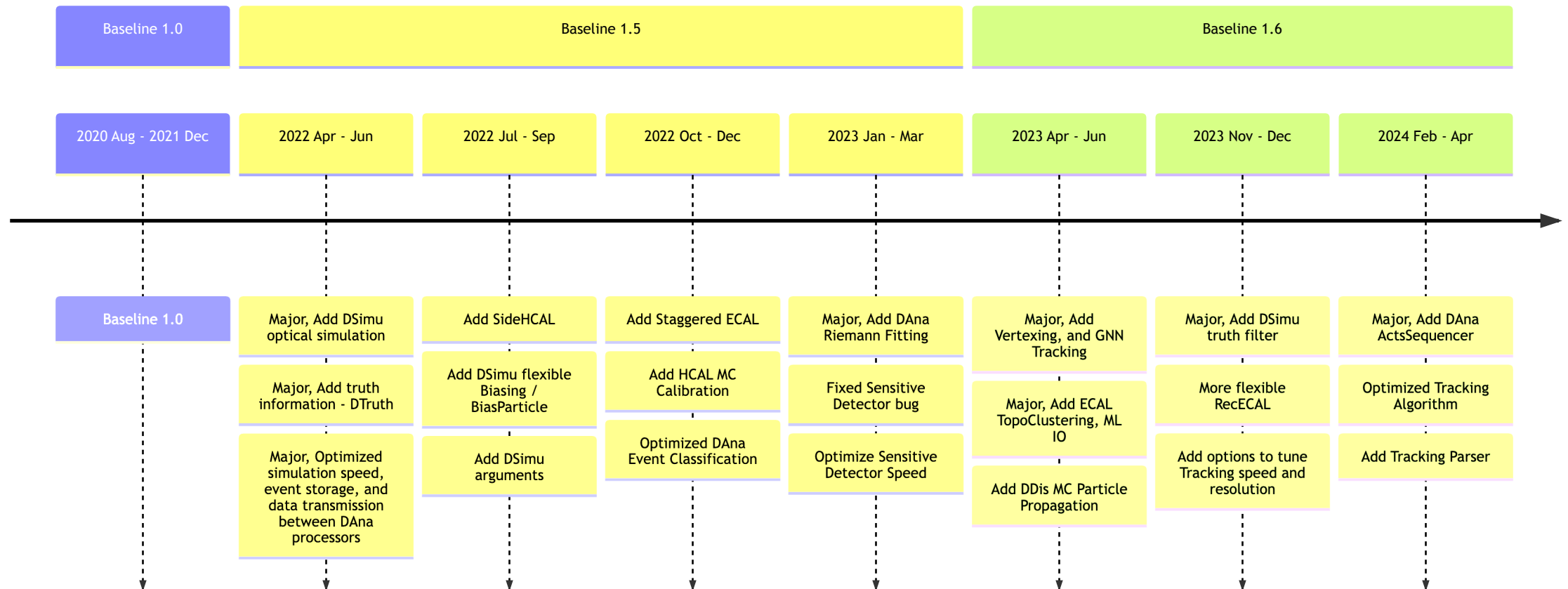
HCAL

In Baseline 1.6, The Design of HCAL is optimized. SideHCAL is added around the 4 sides of ECAL.

| Baseline | | Configuration | Cell Gap | Module Gap | Gap Material | Cell Components | Material | Size (cm) |
|----------|--|---------------|----------|------------|--------------|---|---|---|
| 1.0 |  | XY-Abs-XY | 0 | 0.5 mm | CarbonFiber | Wrapper APD Scintillator | Al Si Polystyrene | 1.03, 5.03, 100.7 0.3, 0.3, 0.1 1, 5, 100.57 |
| 1.6 |  | X-Abs-Y | 0.1 mm | 0.5 mm | CarbonFiber | Wrapper APD Scintillator Fiber Clad Fiber | C Si Polystyrene Polystyrene PMMA | 1.03, 5.03, 75.55 0.3, 0.3, 0.1 1, 5, 75.42 r=1.2 mm r=1.176 mm |

From Baseline 1.0 to 1.6: Versions and Milestones

Many functions and optimizations have been added to the software since 2020.



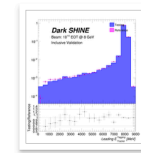
CI/CD Pipeline and Validation

Pipeline to build and draw **validation plots** will be triggered in each commit to **master** branch.

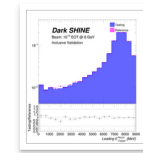
- Or with keyword **[CI]** or **[VIP]** in the commit message

- Validation plots in the pipeline artifacts, and can be posted on wiki.

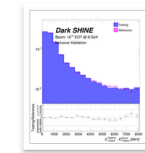
| Status | Pipeline | Created by | Stages |
|------------------------------------|--|------------|--------|
| Passed 00:40:18 3 weeks ago | Merge branch 'hotfix_add_parser' into 'master' #9924 72 → 0a1190a7 merge request | | ✓ ✓ |
| Passed 00:39:31 3 weeks ago | Merge branch 'hotfix_add_parser' into 'master' #9923 71 → 0a1190a7 merge request | | ✓ ✓ |
| Passed 00:39:17 1 month ago | [CI] purify macro #9772 hotfix_ddump_parser → c060b61b 🙄 | | ✓ ✓ |
| Passed 00:44:28 2 months ago | [CI] purify macro #9544 josef_for_master → c060b61b 🙄 | | ✓ ✓ |
| Passed 00:43:21 3 months ago | [CI] purify macro #9533 master → c060b61b 🙄 | | ✓ ✓ |
| Passed 00:38:53 3 months ago | [CI] pre step cleanup for acts #9398 acts-xuliang → 71460a47 🙄 | | ✓ ✓ |
| Passed 00:43:32 3 months ago | [CI] purify macro #9397 acts-xuliang → 688ab909 🙄 | | ✓ ✓ |
| Passed 00:45:36 | fix cmake warnings #9393 63 → 879e4404 | | ✓ ✓ |



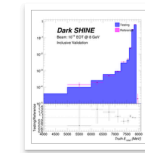
fig_0.png



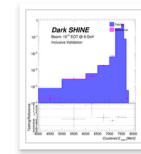
fig_1.png



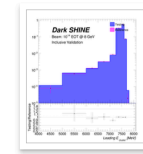
fig_2.png



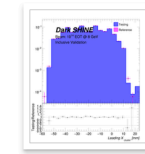
fig_3.png



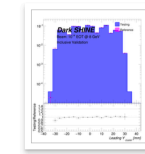
fig_4.png



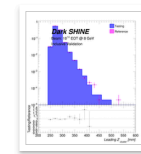
fig_5.png



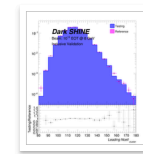
fig_6.png



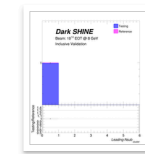
fig_7.png



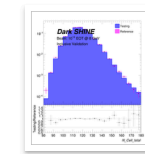
fig_8.png



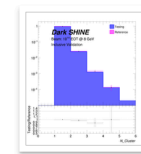
fig_9.png



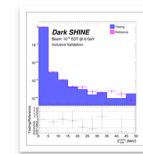
fig_10.png



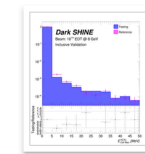
fig_11.png



fig_12.png



fig_13.png

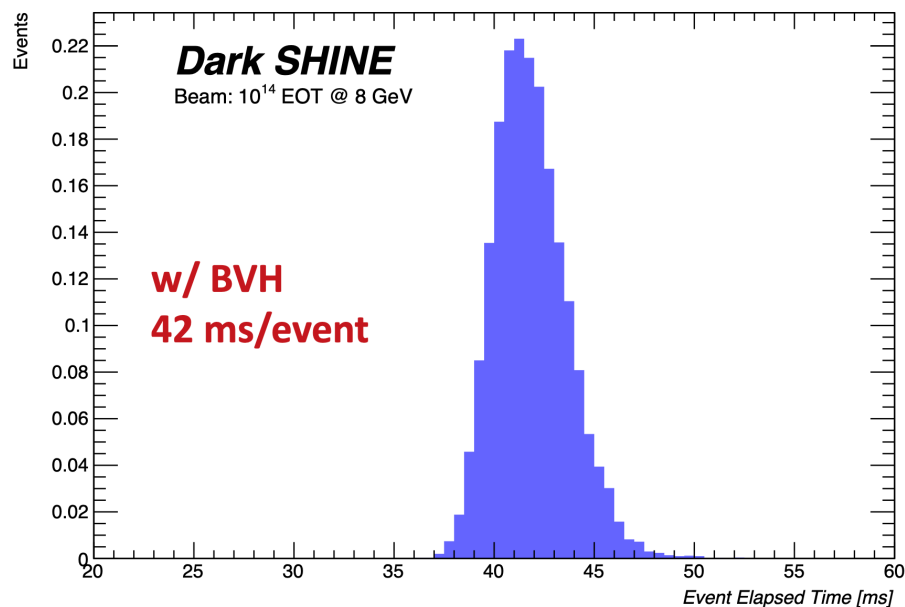


fig_14.png

CPU Performance and Event Storage

DSimu (Simulation)

Current Simulation Speed is **x21** faster than Baseline 1.0 (900ms)



Storage: 60KB / event → 14 KB / event







DAna (Reconstruction)

~9ms per event

```
=====
-----> Run Summary <-----
Processor Name      Execution Time / Event [sec]
Digitizer           0.00011327
MCTruthAnalysis     0.00000786
Tracking            0.00073550
ActsSequencer       0.00468526
RecECAL             0.00206078
RecHCAL             0.00000159
CutFlowAnalysis     0.00000048
-----
Total Processed Event(s): 100000
Total Processing Time:  902.03383600 [sec]
=====
```

Sample Production

 **Target EOT: 10^{14}**

| Name | Process Branching Ratio | Biasing Factor | Filter Efficiency | Equivalent Event Number | Beam On Number | Estimate Time [16000 core hour] | Time per Event [ms] |
|---|-------------------------|----------------|-------------------|--|-----------------|---------------------------------|---------------------|
| Inclusive | 1.00E+00 | 1E+00 | 100% | - | - | - | 79.19 |
| Inclusive w/ ECAL trigger | 1.00E+00 | 1E+00 | 100% | 1E+11 | 1.00E+11 | 66.620 | 38.37 |
| Inclusive w/ ECAL+missP trigger | 1.00E+00 | 1E+00 | 100% | 1E+12 | 1.00E+12 | 90.592 | 5.22 |
| GMM Target (with hardbrem) w/ ECAL+missP trigger | 1.50E-08 | 1E+08 | 6.557% |  1E+14 | 1.53E+07 | 0.001 | 3.17 |
| GMM ECAL (with hardbrem) w/ ECAL+missP trigger | 1.63E-06 | 1E+07 | 16.333% |  1E+14 | 6.12E+07 | 0.005 | 4.47 |
| PN Target (with hardbrem) w/ ECAL+missP trigger | 1.37E-06 | 1E+06 | 6.466% |  1E+14 | 1.55E+09 | 0.128 | 4.75 |
| PN ECAL (with hardbrem) w/ ECAL+missP trigger | 2.31E-04 | 1E+05 | 16.446% |  1E+14 | 6.08E+09 | 0.737 | 6.98 |
| EN Target (E > 4GeV) w/ ECAL+missP trigger | 5.10E-07 | 1E+05 | 1.47% |  1E+14 | 6.08E+10 | 1.646 | 1.39 |
| EN ECAL (E > 4GeV) w/ ECAL+missP trigger | 3.25E-06 | 1E+05 | 0.56% |  1E+14 | 1.79E+11 | 1.025 | 0.33 |

Tracking

Dark SHINE Tracking Package:

- Track Finding
 - **Greedy algorithm**
 - Future ML method
- Fitting
 - Kalman filter
 - **Riemann filter**
- Output
 - Seed for Tracker-ECAL PFA
 - Vertex for visible decay
 - ...

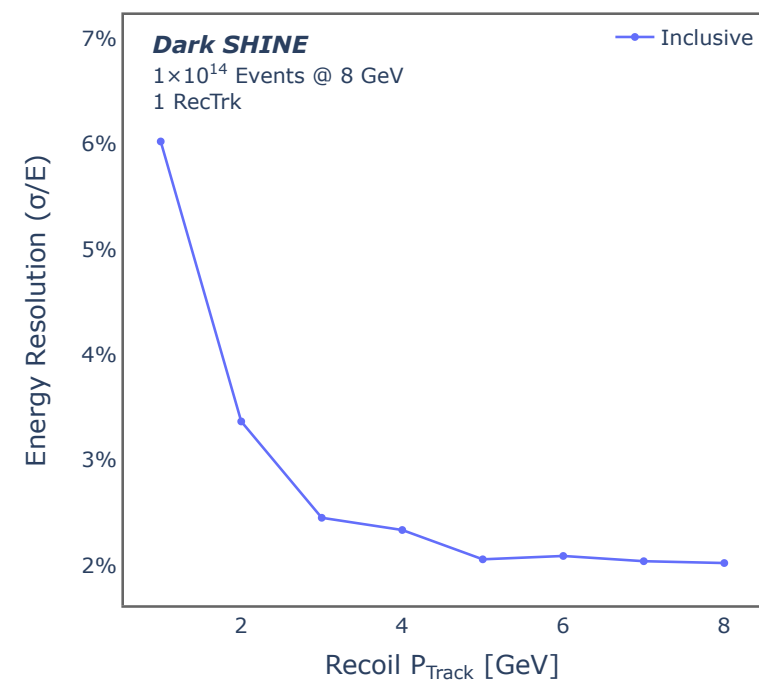
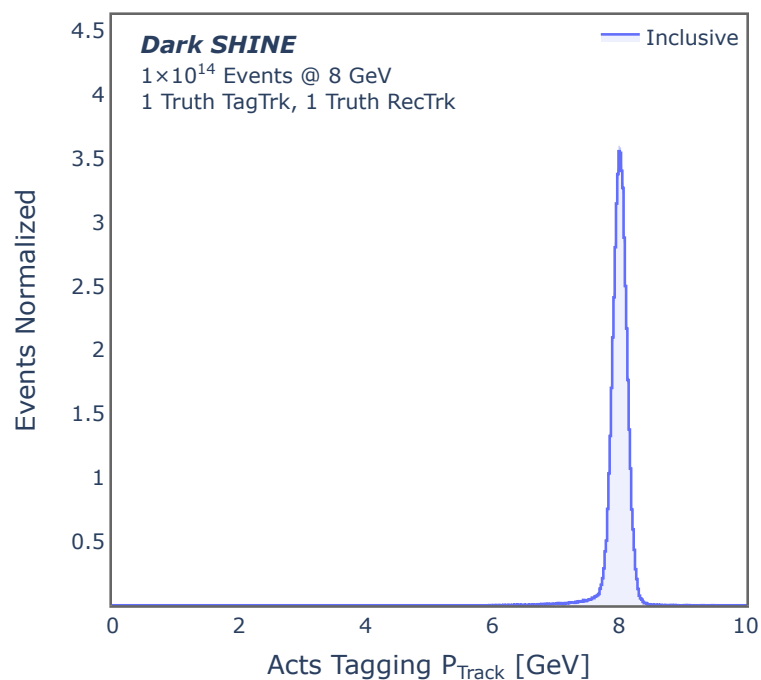
Acts Sequencer:

- SeedingAlgorithm
 - Default Seeding
 - Truth Seeding
- Track Finding & Fitting
 - **CombinatorialKalmanFilter**
- Output
 - Vertex for visible decay
 - Seed for Tracker-ECAL PFA [WIP]

Tracking

Tracking Efficiency and Resolution (Truth Seeding)

| Efficiency | Inclusive | Signal 5 MeV |
|------------|-----------|--------------|
| Tagging | 99.94% | 99.94% |
| Recoil | 99.76% | 80.49 % |



Calorimetry

(For ECAL Clustering etc., see Qibin & Zhiyu's Talk)

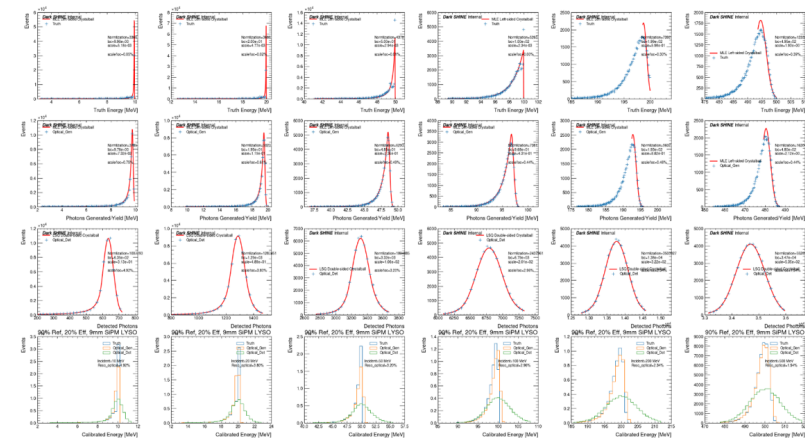
ECAL Smearing method

The smearing of ECAL is done in reconstruction/analysis level. For each ECAL cell, the energy of hits are summed, then Gaussian function is used to do the smearing, with the mean value set to truth energy and sigma from the formula $\frac{\sigma}{E} = \frac{A}{\sqrt{E}} + B + \frac{C}{E}$. The A B C parameters are extracted from standalone simulation with optical process enabled.

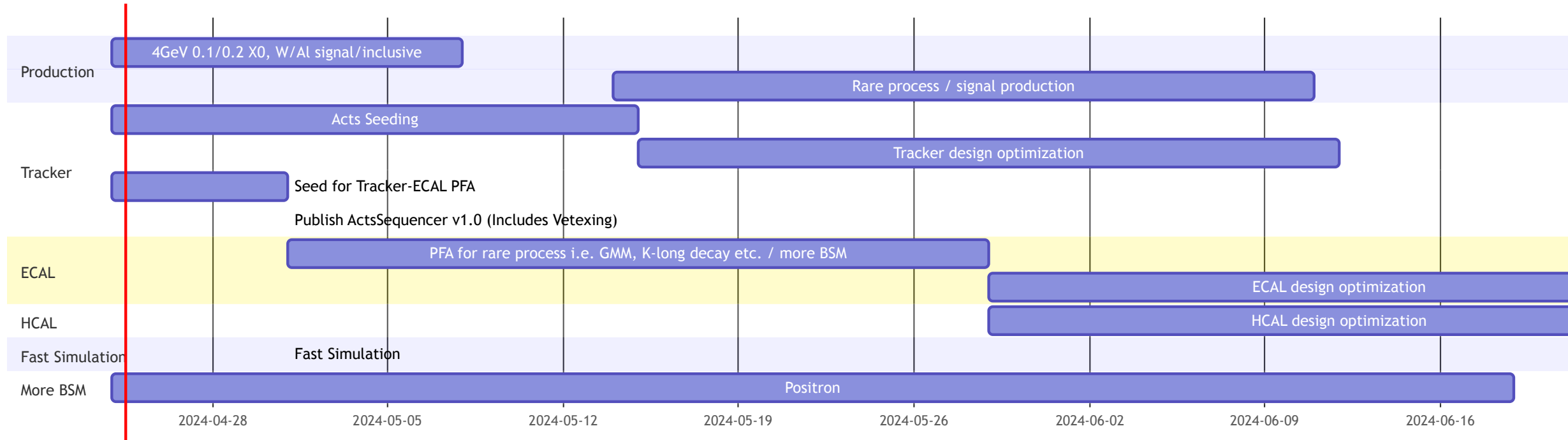
Smearing parameter used in analysis

| | $A\sqrt{MeV}$ | $A\sqrt{GeV}$ | B | C/MeV |
|--------------|---------------|---------------|-------|---------|
| R90_LYSO | 31.62% | 1.00% | 0.00% | 0.0000 |
| R10_LYSO | 211.69% | 6.69% | 0.00% | 0.0851 |
| R90_S9_PWO4 | 134.56% | 4.26% | 0.70% | 0.0001 |
| R90_S36_PWO4 | 73.32% | 2.32% | 0.17% | 0.7051 |

Detailed plots: set1



Future Plans and Timeline



Thanks

Documentations / Git Repo



