Baseline 1.6 Simulation Framework, and Plans for Baseline 2.0

Dark SHINE Seasonal Workshop

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Outline

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3. From Baseline 1.0 to 1.6: Versions and Milstones
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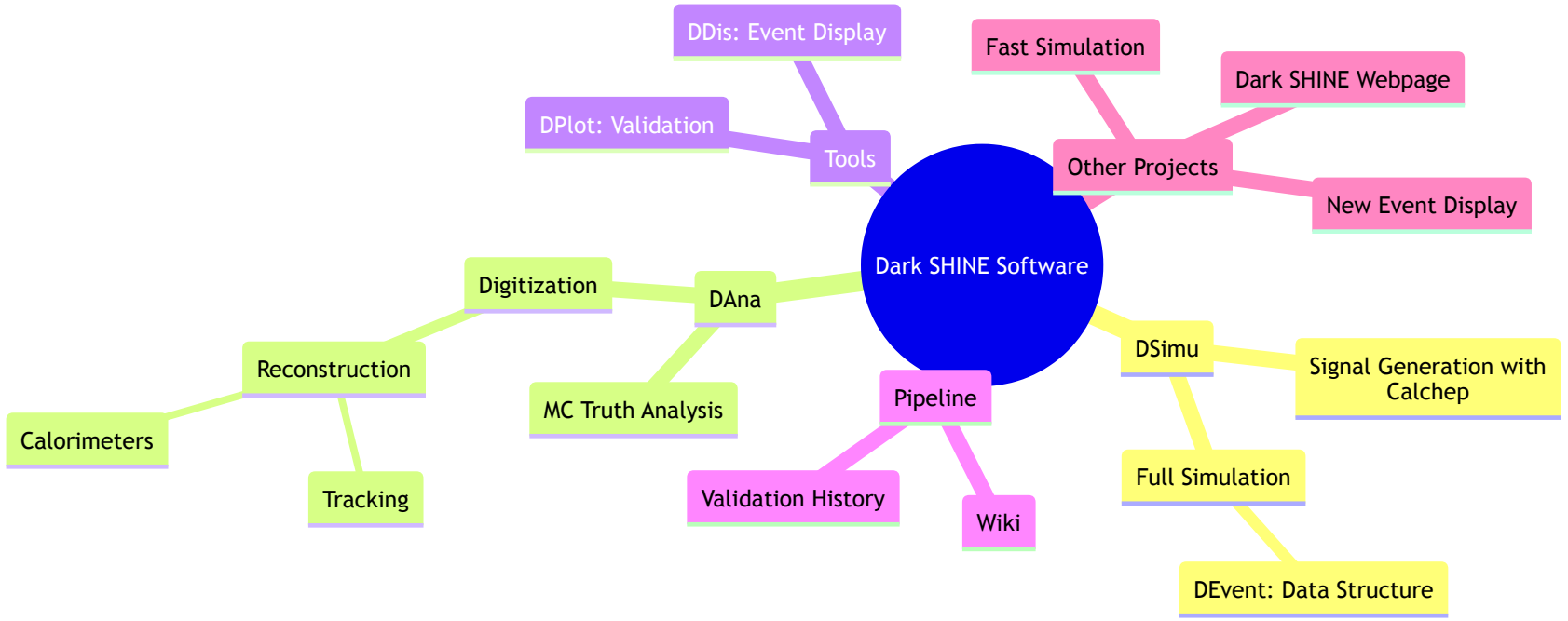
Overview

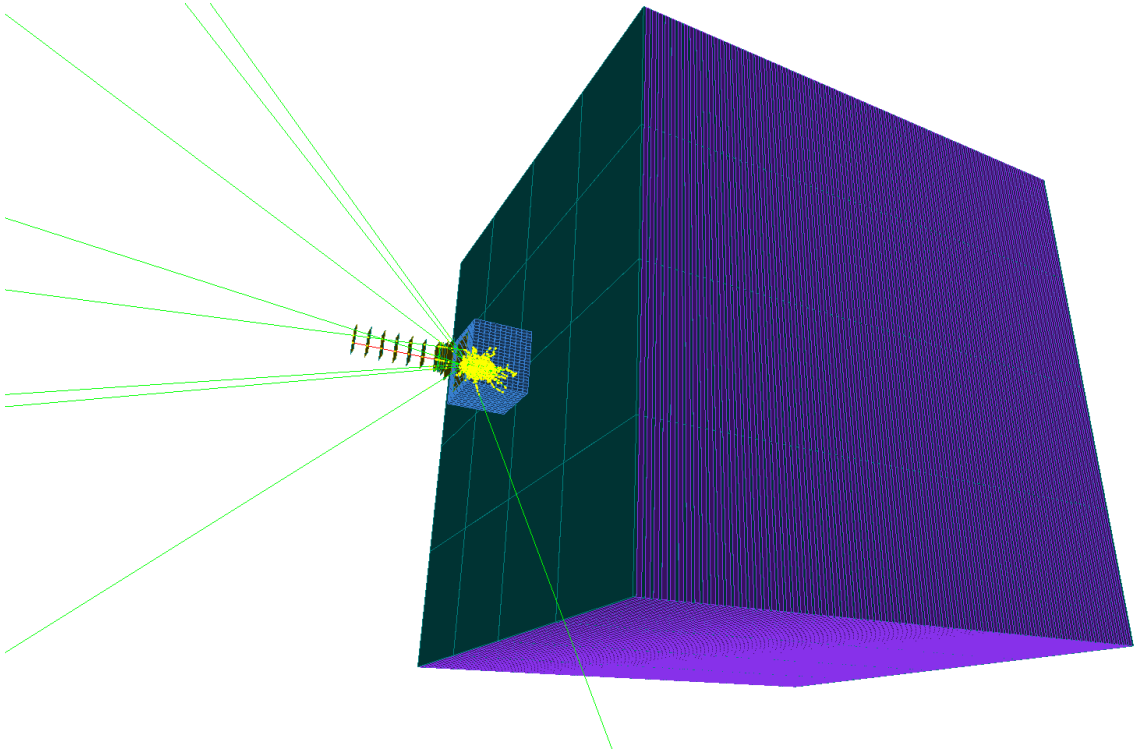
DarkSHINE Software is a software package, including five parts: DSimu, DAna, DDis, and DPlot.

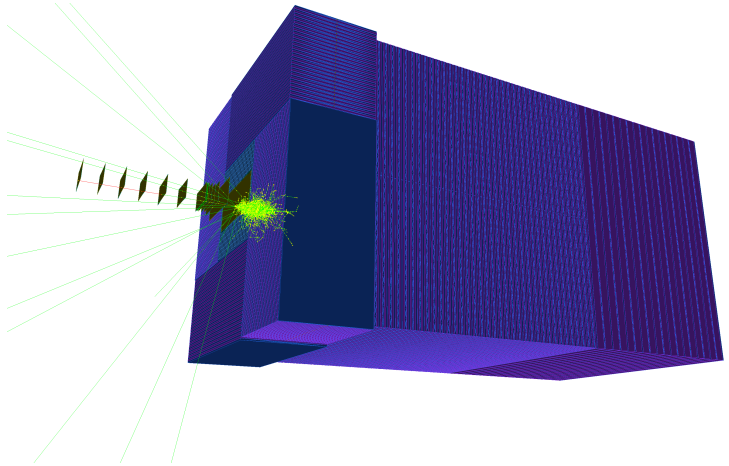
- DSimu is the simulation program based on Geant4, characterized by Dark SHINE detector, controlled by yaml configuration.
- DAna is a framework for the analysis and reconstruction tools. It requires the output ROOT file (involving Geometry, DMagnet and DEvent) from DSimu.
- DDis is the event display 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

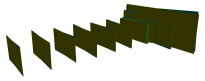
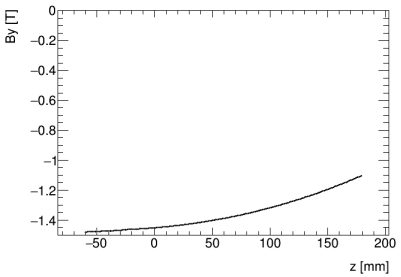




From Baseline 1.0 to 1.6: Detector Construction

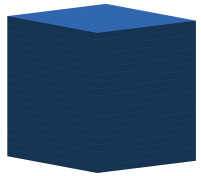
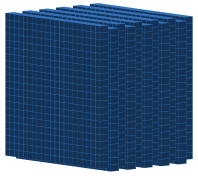
Tracking System

Baseline 1.6 Tracker uses **Si micro-strip** ($30\mu\mathrm{m}$) 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		$B_y = -1.5\mathrm{T}$	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

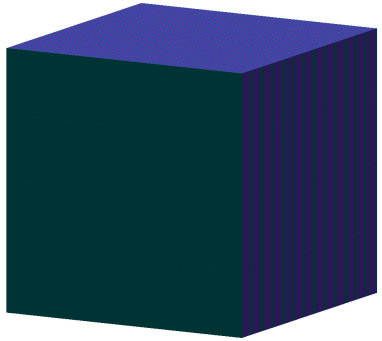
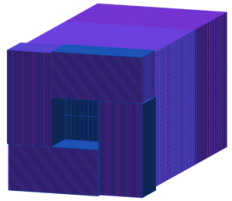
ECAL

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

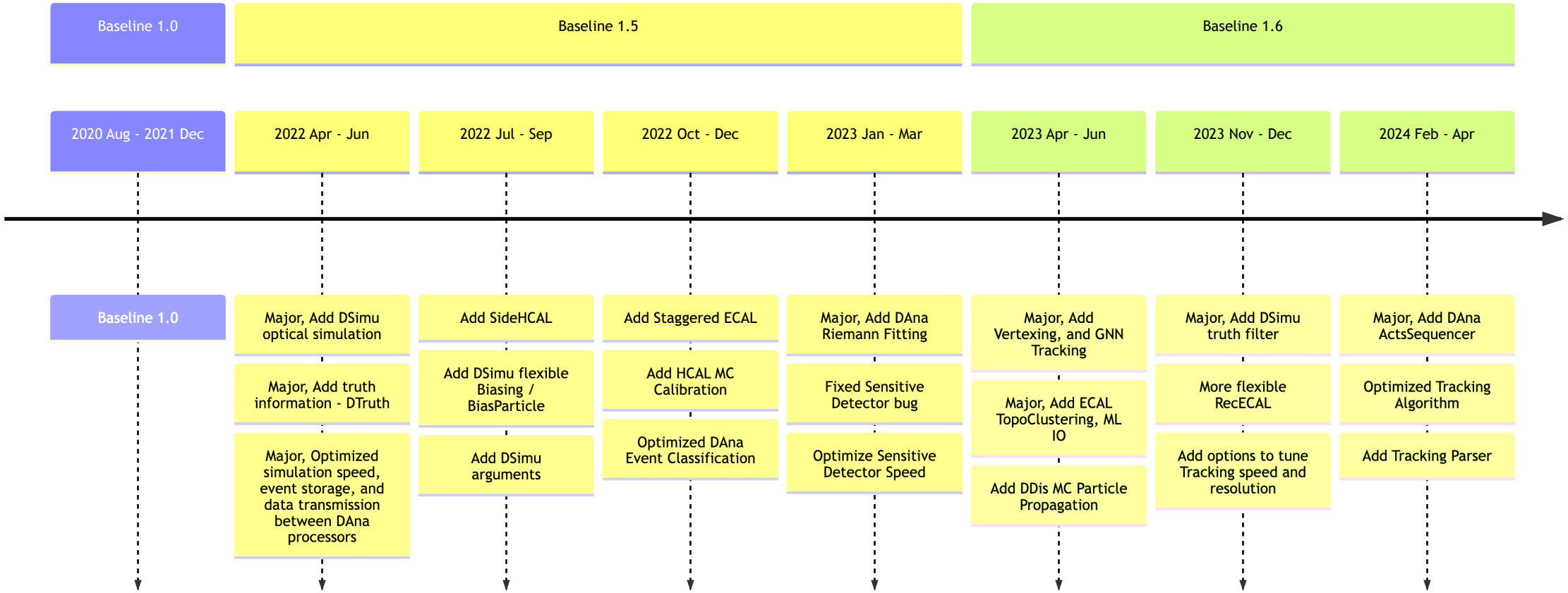
HCAL

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 Milstones

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

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		

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

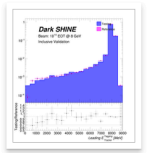
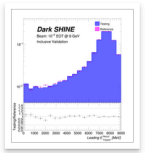


fig_0.png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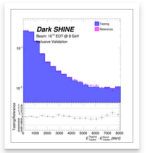


fig_2.png

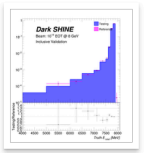


fig_3.png

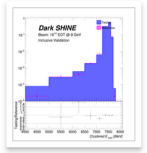


fig_4.png

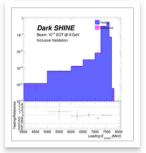


fig_5.png

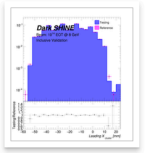


fig_6.png

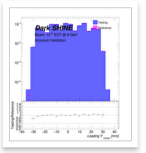
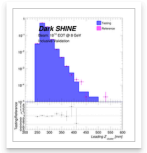


fig_7.png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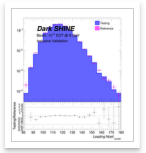


fig_9.png

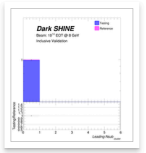


fig_10.png

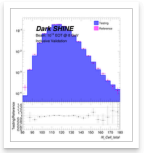


fig_11.png

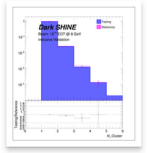


fig_12.png

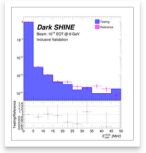


fig_13.png

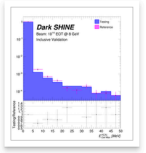
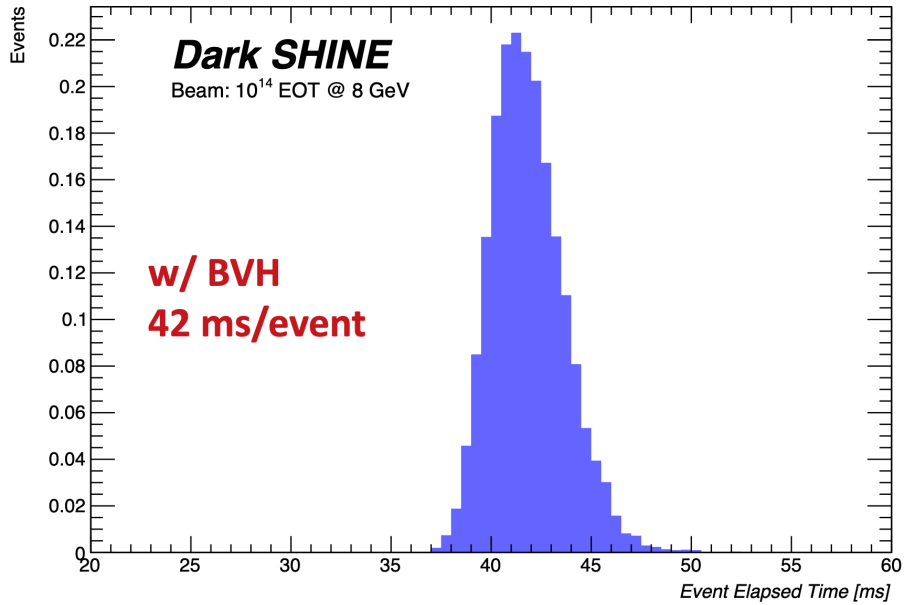


fig_14.png

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
  - …

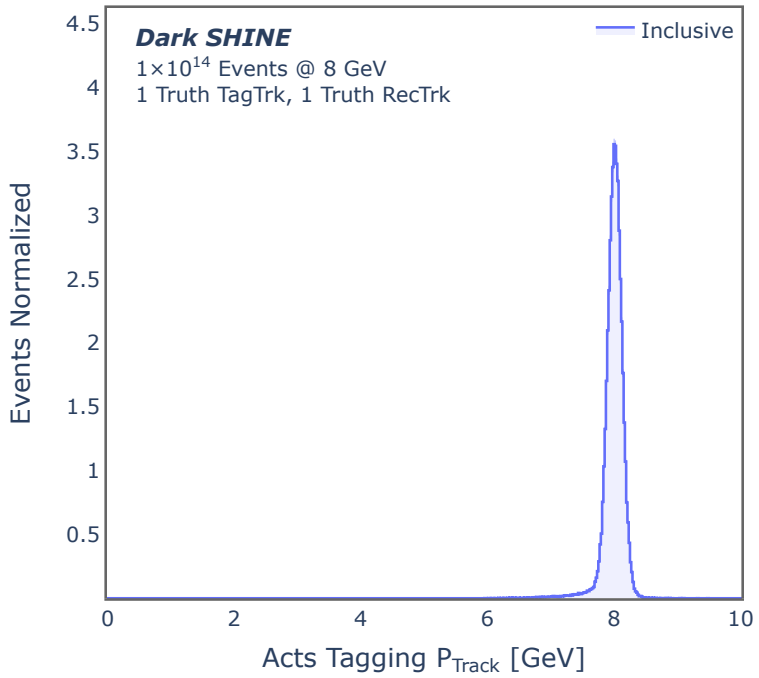
Acts Sequencer:

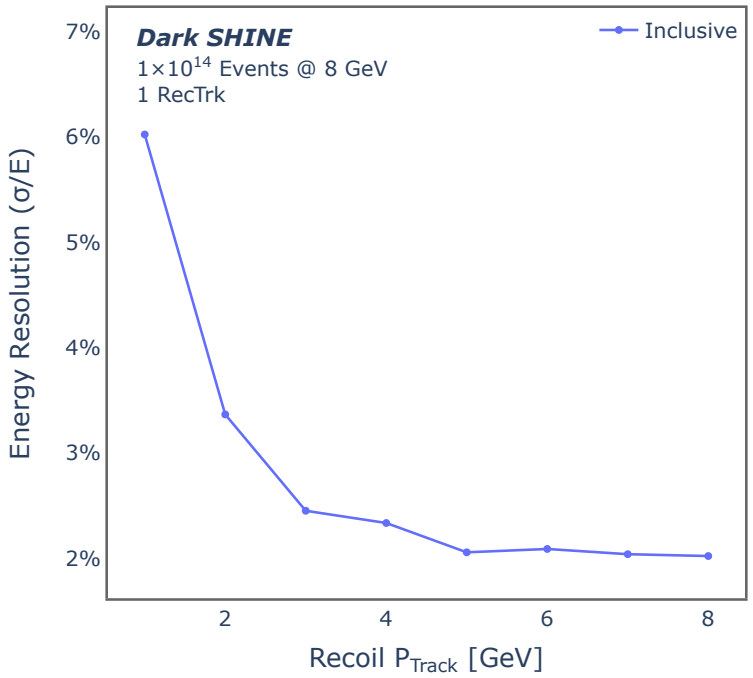
- SeedingAlgorithm
  - Default Seeding
  - Truth Seeding
- Track Finding & Fitting
  - **CombinatorialKalmanFilter**
- Output
  - Vertex for visible decay
  - Seed for Tracker-ECAL PFA [WIP]

Tracking

Filter 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)

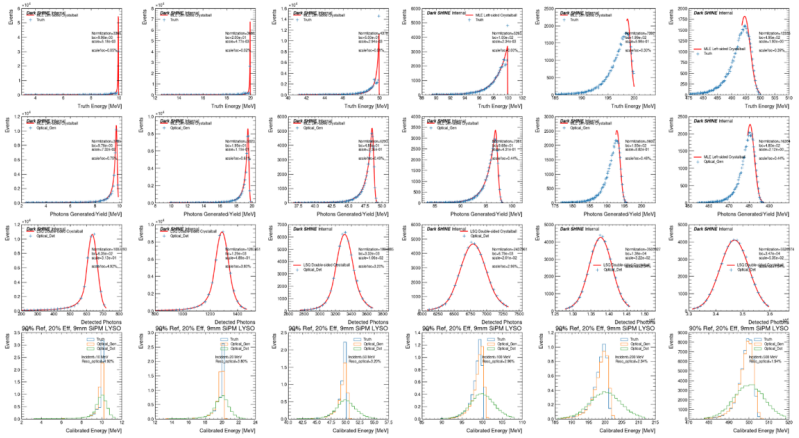
ECAL Smearing method

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.

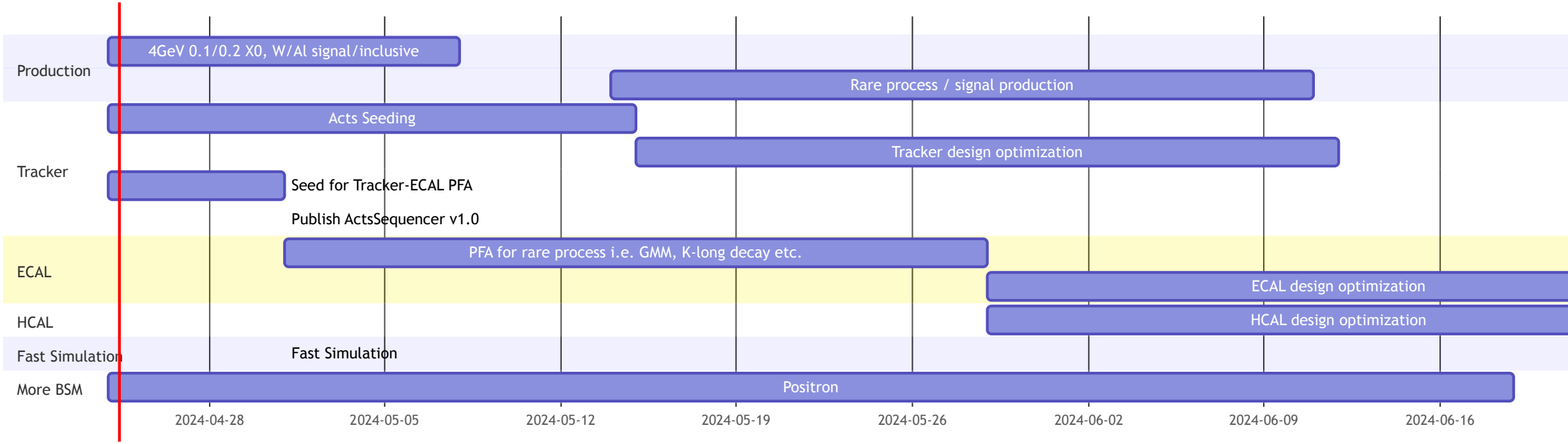
Smearing parameter used in analysis

	$A\sqrt{MeV}$	$A\sqrt{GeV}$	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