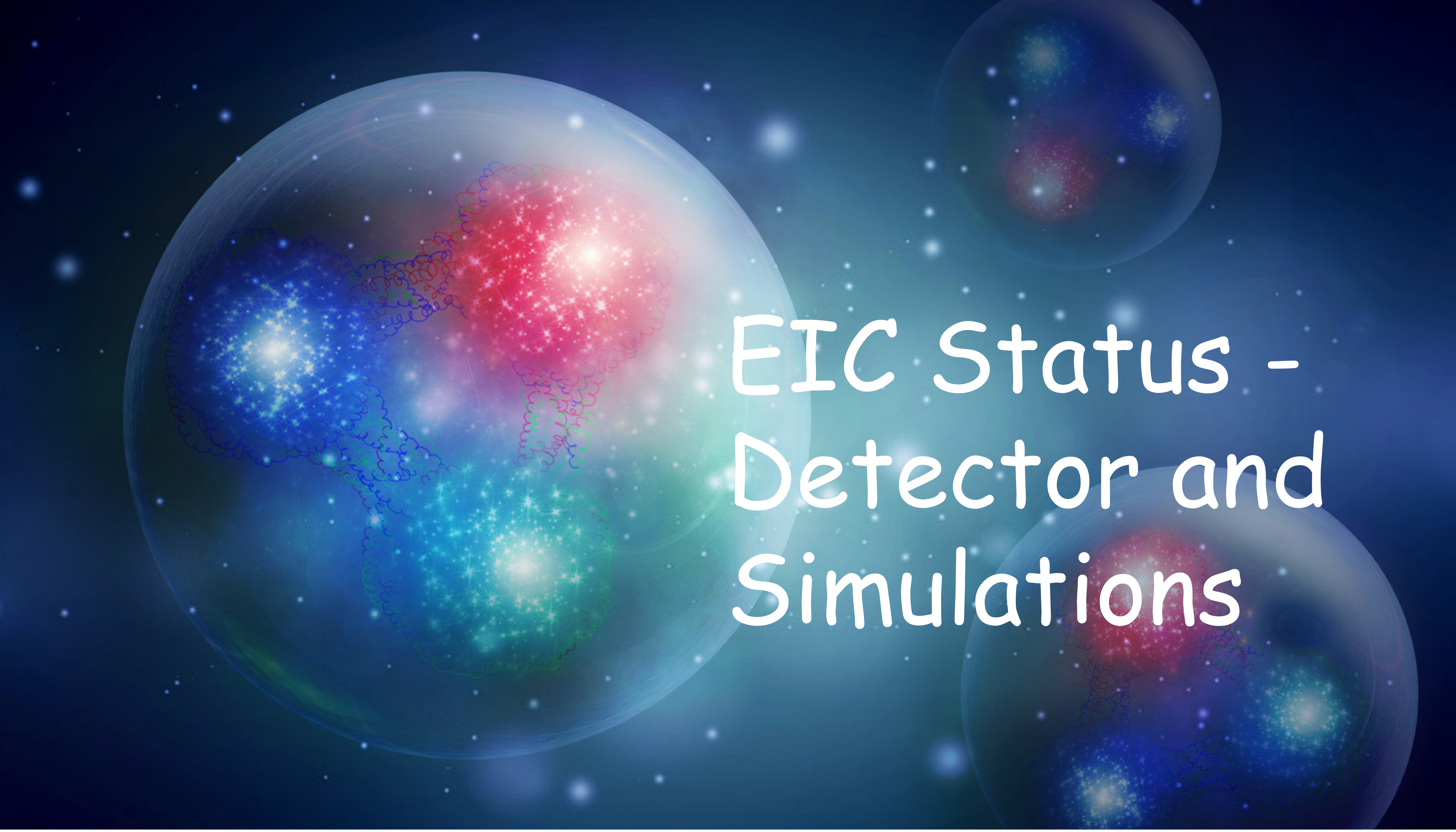


EIC Status - Detector and Simulations

Yulia Furletova (JLAB)

HUGS lectures

Outline

- Introduction to Electron Ion Collider
    - Highlights of EIC physics
    - US based EIC accelerators proposals
- Introduction to Deep Inelastic Scattering
    - DIS kinematic
- EIC detector design
    - Tracking
    - Vertex
    - Calorimeter
    - Muon detectors
    - Particle Identification detectors
        - dE/dx
        - Time of flight
        - Cherenkov
        - Transition radiation
- Detector simulation and reconstruction
- Conclusions

Lecture-1

Lecture-2

Lecture-3

Lecture-4

Lecture-5

Simulation and reconstruction

- Simulation chain
- Event Generators: PYTHIA, HERWIG,…
- Detector simulation
  - GEANT4, FLUKA
- Reconstruction
  - Tracking reconstruction: GENFIT
  - Vertex reconstruction: RAVE
  - Calorimeter energy reconstruction
  - …
- Event Analysis (PAW/Fortran or ROOT/C++ or etc)

Physics analysis

Examples:

- e +p/A -> e' + X
- e + p/A -> e' + π +X
- e+p/A -> e' + $c\bar{c}$ + X -> e' + D0 +X -> e'+(πK)+X
- e+p -> e' + J/ψ + p'
- e+p -> e' + γ + p'
- ....

Physics analysis

Physics analysis

Examples:

- e +p/A -> e' + X
- e + p/A -> e' + π +X
- e+p/A -> e' + $c\bar{c}$ + X -> e' + D0 +X -> e'+(πK)+X
- e+p -> e' + J/ψ + p'
- e+p -> e' + γ + p'
- ....

- Number of events:

$$\boxed{N = \frac{L \cdot \sigma}{a \cdot \varepsilon}}$$

where a is acceptance
ε is efficiency

-Estimate cross section (σ)
-Estimate background (σ)
-Estimate acceptance (detector coverage)
-Estimate efficiency (selection cuts)
-Get results

Physics analysis

N_{signal} , $N_{background}$

Event generators

Physics model

PYTHIA,
HERWIG, etc..

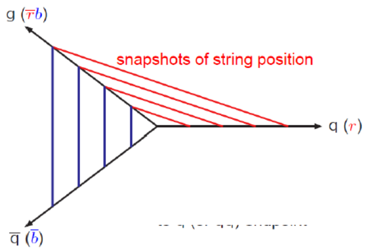
- Cross section
- Final state particles
- Kinematics
- Pure physics (at vertex), without detector effects

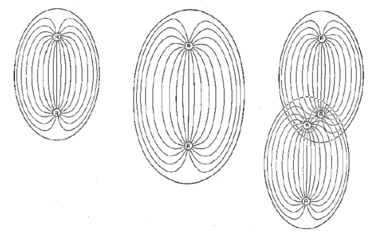
Physics analysis

Event generators and hadronization models

- String Model (Lund) : **JETSET, PYTHIA**

(the most used hadronization model, very successfully tested in e+e-)

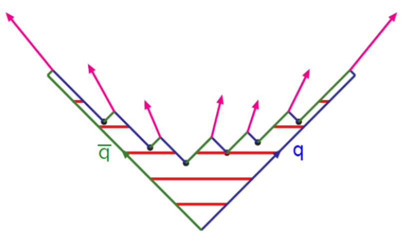


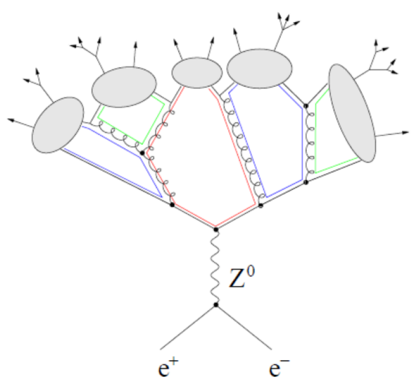


- Cluster Fragmentation Model: **HERWIG**

force gluon decays into quarks and antiquarks, q-qbar form colorneutral clusters , clusters decay isotropically into 2 hadrons , which can decay further into stable hadrons.

Rainer Fries





- Independent model) quarks and gluons fragment independently

Study hadronization on existing colliders (e+e-), so that it could be used by other communities(ep,pp)

Note, those models lead to different distributions for low momentum particles . For high momentum (β-> 1) particles the differences vanish.

Event Generators

Number of particles or intermediate states. They are all stable? NO

Stable with "1"

Particle Code:

$\pi+$ -> 211
K+ -> 321

e -> 11
p -> 2212

Mothers/other:
D0 -> 421
D+ -> 411
J/ψ -> 443
Gamma -> 22

@yuliapc:HepMC_analyze

File Edit View

64	0							0.508867	0.811740	0.497670	-0.001792	0.0007	
65	1							1.364146	1.450688	0.139570	-5.486144	1.7997	
66	-1							0.406603	0.438524	0.139570	-5.486144	1.7997	
	43	.22171E-01	.58784E+01	.26015E+03	.10000E+01	.26515E+00	.36025E+00	.80900E+01	.31573E-04	.22248E+00			
1	-1	0	11	3	4	-0.000000	0.000000	-5.000000	5.000000	0.000510	0.000000	0.0000	
2	1	0	2212	5	0	-2.498959	0.000000	49.937513	50.008803	0.938270	0.000000	0.0000	
3	-1	0	11	0	0	1.681881	-1.200578	-3.338090	3.925934	0.000510	0.000000	0.0000	
4	0	0	22	0	0	-1.681881	1.200578	-1.661909	1.074067	-2.424547	0.000000	0.0000	
5	1	0	2212	0	0	-2.498958	0.000000	49.937512	50.008802	0.938270	0.000000	0.0000	
6	0	1	22	0	0	-1.722391	1.190268	-0.549491	2.164557	-0.000000	0.000000	0.0000	
7	0	0	21	0	0	-0.208114	0.270092	8.638923	8.645649	-0.000000	0.000000	0.0000	
8	0	1	22	0	0	-1.722391	1.190268	-0.549491	2.164557	0.000000	0.000000	0.0000	
9	0	0	21	0	0	-0.208114	0.270092	8.638923	8.645649	0.000000	0.000000	0.0000	
10	0	0	4	0	0	-2.688509	0.410647	0.732542	3.191133	1.500000	0.000000	0.0000	
11	0	0	4	0	0	0.758004	1.049713	7.356889	7.619073	1.500000	0.000000	0.0000	
12	-1	1	11	0	0	1.681881	-1.200578	-3.338090	3.925934	0.000510	0.000000	0.0000	
13	0	0	4	21	24	-2.688509	0.410647	0.732542	3.191133	1.500000	0.000000	0.0000	
14	0	0	2101	21	24	-2.129878	-0.301336	36.978679	37.045722	0.579330	0.000000	0.0000	
15	0	0	4	18	19	0.758004	1.049713	7.356889	7.619073	1.500000	0.000000	0.0000	
16	0	0	2	18	19	-0.120457	0.041554	3.207493	3.226941	0.330000	0.000000	0.0000	
17	0	0	91	18	19	0.637548	1.091266	10.564382	10.846014	2.105359	0.000000	0.0000	
18	-1	0	411	25	27	0.602250	0.795048	8.829940	9.080579	1.869300	0.000000	0.0000	
19	1	1	211	0	0	0.035298	0.296218	1.734442	1.765435	0.139570	0.000000	0.0000	
20	0	0	92	21	24	-4.818387	0.109311	37.711222	40.236855	13.177232	0.000000	0.0000	
21	1	0	413	28	29	-2.722203	0.225083	1.781353	3.830714	2.010000	0.000000	0.0000	
22	-1	1	211	0	0	0.522840	0.038483	3.664699	3.704638	0.139570	0.000000	0.0000	
23	0	0	113	30	31	-1.024732	-0.060553	1.735096	2.115292	0.640436	0.000000	0.0000	
24	1	1	2212	0	0	-1.594292	-0.093702	30.530074	30.586211	0.938270	0.000000	0.0000	
25	1	1	321	0	0	0.888905	0.797953	7.920726	8.025486	0.493600	0.042504	0.0561	
26	-1	1	211	0	0	-0.194076	-0.161593	0.629665	0.692629	0.139570	0.042504	0.0561	
27	-1	1	211	0	0	-0.092579	0.158689	0.279549	0.362464	0.139570	0.042504	0.0561	
28	0	0	421	32	36	-2.477719	0.178936	1.627649	3.506667	1.864500	0.000000	0.00000	
29	1	1	211	0	0	-0.244484	0.046148	0.153704	0.324047	0.139570	0.000000	0.000000	
30	1	1	211	0	0	-0.036469	-0.036157	0.050464	0.157047	0.139570	0.000000	0.000000	
31	-1	1	211	0	0	-0.988263	-0.024396	1.684632	1.958245	0.139570	0.000000	0.000000	0.000000
32	0	0	311	37	37	-0.586858	0.093976	0.379234	0.862976	0.497670	-0.063812	0.004608	0.000000
33	1	1	211	0	0	-1.214314	0.205820	0.303164	1.276052	0.139570	-0.063812	0.004608	0.000000
34	-1	1	211	0	0	-0.163508	-0.163772	0.289862	0.396303	0.139570	-0.063812	0.004608	0.000000
35	0	0	111	38	39	-0.332109	0.159456	0.178605	0.431094	0.134980	-0.063812	0.004608	0.000000
36	0	0	111	40	41	-0.180930	-0.116545	0.476785	0.540242	0.134980	-0.063812	0.004608	0.000000
37	0	0	310	42	43	-0.586858	0.093976	0.379234	0.862976	0.497670	-0.063812	0.004608	0.000000
38	0	1	22	0	0	-0.048135	0.065634	-0.002556	0.081433	0.000000	-0.063823	0.004614	0.000000
39	0	1	22	0	0	-0.283974	0.093823	0.181160	0.349661	0.000000	-0.063823	0.004614	0.000000
40	0	1	22	0	0	-0.003209	-0.004136	0.159573	0.159659	0.000000	-0.063816	0.004606	0.000000
41	0	1	22	0	0	-0.177721	-0.112409	0.317212	0.380584	0.000000	-0.063816	0.004606	0.000000
42	-1	1	211	0	0	-0.353107	0.204204	0.070498	0.436845	0.139570	-1.920632	0.301948	0.000000
43	1	1	211	0	0	-0.233751	-0.110229	0.308736	0.426131	0.139570	-1.920632	0.301948	0.000000
	48	.17064E+00	.10932E+03	.53222E+03	.10000E+01	.64066E+00	.32241E+00	.94561E+00	.11144E-05	.13829E+00			
1	-1	0	11	3	4	-0.000000	0.000000	-5.000000	5.000000	0.000510	0.000000	0.000000	0.000000
2	1	0	2212	5	0	-2.498959	0.000000	49.937513	50.008803	0.938270	0.000000	0.000000	0.000000
3	-1	0	11	0	0	5.398927	-2.664379	3.808257	7.123914	0.000510	0.000000	0.000000	0.000000
4	0	0	22	0	0	-5.398928	2.664379	-8.808250	-2.123907	-10.455698	0.000000	0.000000	0.000000

:

Yulia Furletova

Database of Event Generators for EIC (in progress)

Show all

$p \rightarrow\leftarrow p$

8 TeV
13 TeV
14 TeV
27 TeV
33 TeV
100 TeV

$e^+ \rightarrow\leftarrow e^-$

250 GeV
380 GeV
500 GeV
1 TeV
3 TeV

$\mu^+ \rightarrow\leftarrow \mu^-$

1 TeV
5 TeV
10 TeV
20 TeV
40 TeV

List of colliders and their center of mass energies

Get involved | Full Search | Experiments | Manual | Mirrors | Tools | About | Login

Full documentation

HepSim

Repository with Monte Carlo simulations for particle physics

Summary of "*gev35ep_lepto6ard_dislowq2*"

Information about event generator and sample size

Name:	*gev35ep_lepto6ard_dislowq2*
Collisions:	e-p
CM Energy:	0.035 TeV
Entry ID:	276
Topic:	SM
Generator:	LEPTO/ARIADNE
Calculation level:	LO+PS+hadronisation
Process:	DIS events at Q2>1 GeV2 and W2>4 GeV2
Total events:	25000000
Number of files:	500
Cross section (σ):	4.376E+05 ± 1957.1871 pb
Luminosity (L):	57.1245 pb^{-1} *(or)* 0.0571 fb^{-1} *(or)* 5.712E-05 ab^{-1}
Format:	ProMC
Download URL:	http://mc1.hep.anl.gov/web/hepsim/events/ep/35gev/lepto6ard_dislowq2/
Status:	Available
Mirrors:	http://eicsim01.jlab.org/hepsim/events/ep/35gev/lepto6ard_dislowq2/ http://mc.hep.anl.gov/asc/hepsim/events/ep/35gev/lepto6ard_dislowq2/ http://portal.nersc.gov/project/m1758/data/events/ep/35gev/lepto6ard_dislowq2/
EVGEN size:	15.896 GB
	Tags:
Fast simulation:	
Full simulation:	rfull058 | Info 519 / 13.03 GB 06/28/2017; rfull057 | Info 484 / 15.50 GB 06/19/2017; rfull056 | Info 496 / 12.43 GB 05/17/2017
Fast/Full size:	40.96 GB
Record slimmed:	No
Events weighted:	No
Submission time:	Wed May 17 16:30:14 CDT 2017
Updated on:	Mon Jul 24 14:44:56 CDT 2017

Argonne

Event Generators, example

- e+p/A -> e' + $c\bar{c}$ + X -> e' + D0 +X -> e'+(πK)+X

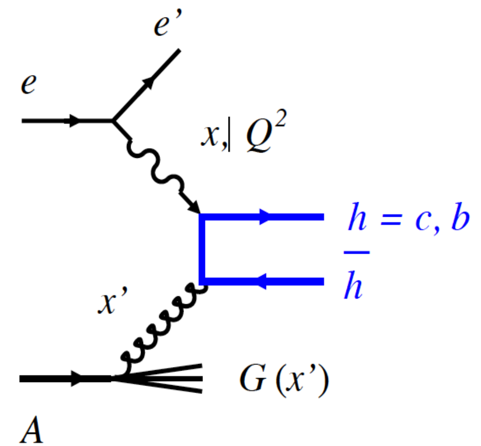
➢ Signal events: Charm BGF

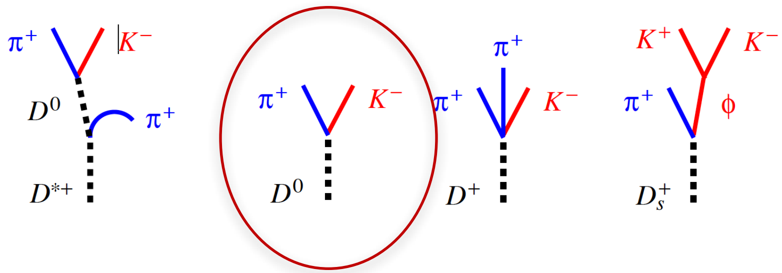
➢ Generate 100k events for Q^2> 10 GeV with Pythia or HERWIG

➢ Get cross section: σ~60 nb

➢ Run your Analysis program for selection (for example, D^0-> π K) :

✓ Select events with 2 particles? => need to run your selection





h_c	f	Decay	BR
D^0	59%	$K^-\pi^+$	3.9%
		$K^-\pi^+\pi^+\pi^-$	8.1%
D^+	23%	$K^-\pi^+\pi^+$	9.2%
D^{*+}	23%	$(K^-\pi^+)_{D0}\ \pi^+_{slow}$	2.6%
		$(K^-\pi^+\pi^+\pi^-)_{D0}\ \pi^+_{slow}$	5.5%
D_s^+	9%	$(K^+K^-)_\phi\ \pi^+$	2.3%
Λ_c^+	8%	$pK^-\pi^+$	5.0%

Event Generators

Number of particles or intermediate states. They are all stable? NO

Stable with "1"

Particle Code:

π+ -> 211
K+ -> 321

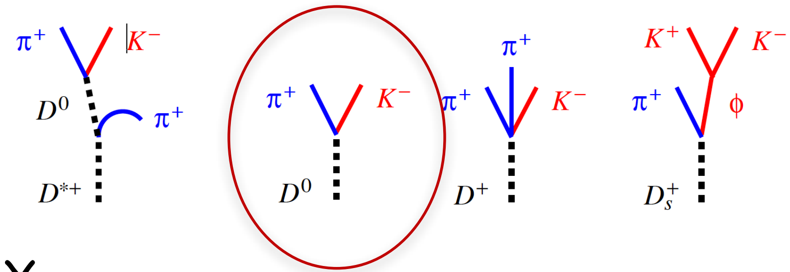
e -> 11
p -> 2212

Mothers/other:
D0 -> 421
D+ -> 411
J/ψ -> 443
Gamma -> 22

64	0							0.308867	0.811740	0.497670	-0.001792	0.0007	
65	1							1.364146	1.450688	0.139570	-5.486144	1.7997	
66	-1	1						0.406603	0.438524	0.139570	-5.486144	1.7997	
	43	.22171E-01	.58784E+01	.26015E+03	.10000E+01	.26515E+00	.36025E+00	.80900E+01	.31573E-04	.22248E+00			
1	-1	0	11	3	4	-0.000000	0.000000	-5.000000	5.000000	0.000510	0.000000	0.0000	
2	1	0	2212	5	0	-2.498959	0.000000	49.937513	50.008803	0.938270	0.000000	0.0000	
3	-1	0	11	0	0	1.681881	-1.200578	-3.338090	3.925934	0.000510	0.000000	0.0000	
4	0	0	22	0	0	-1.681881	1.200578	-1.661909	1.074067	-2.424547	0.000000	0.0000	
5	1	0	2212	0	0	-2.498958	0.000000	49.937512	50.008802	0.938270	0.000000	0.0000	
6	0	1	22	0	0	-1.722391	1.190268	-0.549491	2.164557	-0.000000	0.000000	0.0000	
7	0	0	21	0	0	-0.208114	0.270092	8.638923	8.645649	-0.000000	0.000000	0.0000	
8	0	1	22	0	0	-1.722391	1.190268	-0.549491	2.164557	0.000000	0.000000	0.0000	
9	0	0	21	0	0	-0.208114	0.270092	8.638923	8.645649	0.000000	0.000000	0.0000	
10	0	0	4	0	0	-2.688509	0.410647	0.732542	3.191133	1.500000	0.000000	0.0000	
11	0	0	4	0	0	0.758004	1.049713	7.356889	7.619073	1.500000	0.000000	0.0000	
12	-1	1	11	0	0	1.681881	-1.200578	-3.338090	3.925934	0.000510	0.000000	0.0000	
13	0	0	4	21	24	-2.688509	0.410647	0.732542	3.191133	1.500000	0.000000	0.0000	
14	0	0	2101	21	24	-2.129878	-0.301336	36.978679	37.045722	0.579330	0.000000	0.0000	
15	0	0	4	18	19	0.758004	1.049713	7.356889	7.619073	1.500000	0.000000	0.0000	
16	0	0	2	18	19	-0.120457	0.041554	3.207493	3.226941	0.330000	0.000000	0.0000	
17	0	0	91	18	19	0.637548	1.091266	10.564382	10.846014	2.105359	0.000000	0.0000	
18	-1	0	411	25	27	0.602250	0.795048	8.829940	9.080579	1.869300	0.000000	0.0000	
19	1	1	211	0	0	0.035298	0.296218	1.734442	1.765435	0.139570	0.000000	0.0000	
20	0	0	92	21	24	-4.818387	0.109311	37.711222	40.236855	13.177232	0.000000	0.0000	
21	1	0	413	28	29	-2.722203	0.225083	1.781353	3.830714	2.010000	0.000000	0.0000	
22	-1	1	211	0	0	0.522840	0.038483	3.664699	3.704638	0.139570	0.000000	0.0000	
23	0	0	113	30	31	-1.024732	-0.060553	1.735096	2.115292	0.640436	0.000000	0.0000	
24	1	1	2212	0	0	-1.594292	-0.093702	30.530074	30.586211	0.938270	0.000000	0.0000	
25	1	1	321	0	0	0.888905	0.797953	7.920726	8.025486	0.493600	0.042504	0.0561	
26	-1	1	211	0	0	-0.194076	-0.161593	0.629665	0.692629	0.139570	0.042504	0.0561	
27	-1	1	211	0	0	-0.092579	0.158689	0.279549	0.362464	0.139570	0.042504	0.0561	
28	0	0	421	32	36	-2.477719	0.178936	1.627649	3.506667	1.864500	0.000000	0.00000	
29	1	1	211	0	0	-0.244484	0.046148	0.153704	0.324047	0.139570	0.000000	0.000000	
30	1	1	211	0	0	-0.036469	-0.036157	0.050464	0.157047	0.139570	0.000000	0.000000	
31	-1	1	211	0	0	-0.988263	-0.024396	1.684632	1.958245	0.139570	0.000000	0.000000	0.000000
32	0	0	311	37	37	-0.586858	0.093976	0.379234	0.862976	0.497670	-0.063812	0.004608	0.000000
33	1	1	211	0	0	-1.214314	0.205820	0.303164	1.276052	0.139570	-0.063812	0.004608	0.000000
34	-1	1	211	0	0	-0.163508	-0.163772	0.289862	0.396303	0.139570	-0.063812	0.004608	0.000000
35	0	0	111	38	39	-0.332109	0.159456	0.178605	0.431094	0.134980	-0.063812	0.004608	0.000000
36	0	0	111	40	41	-0.180930	-0.116545	0.476785	0.540242	0.134980	-0.063812	0.004608	0.000000
37	0	0	310	42	43	-0.586858	0.093976	0.379234	0.862976	0.497670	-0.063812	0.004608	0.000000
38	0	1	22	0	0	-0.048135	0.065634	-0.002556	0.081433	0.000000	-0.063823	0.004614	0.000000
39	0	1	22	0	0	-0.283974	0.093823	0.181160	0.349661	0.000000	-0.063823	0.004614	0.000000
40	0	1	22	0	0	-0.003209	-0.004136	0.159573	0.159659	0.000000	-0.063816	0.004606	0.000000
41	0	1	22	0	0	-0.177721	-0.112409	0.317212	0.380584	0.000000	-0.063816	0.004606	0.000000
42	-1	1	211	0	0	-0.353107	0.204204	0.070498	0.436845	0.139570	-1.920632	0.301948	0.000000
43	1	1	211	0	0	-0.233751	-0.110229	0.308736	0.426131	0.139570	-1.920632	0.301948	0.000000
	48	.17064E+00	.10932E+03	.53222E+03	.10000E+01	.64066E+00	.32241E+00	.94561E+00	.11144E-05	.13829E+00			
1	-1	0	11	3	4	0.000000	0.000000	5.000000	5.000000	0.000510	0.000000	0.000000	0.000000
2													
3													
4													

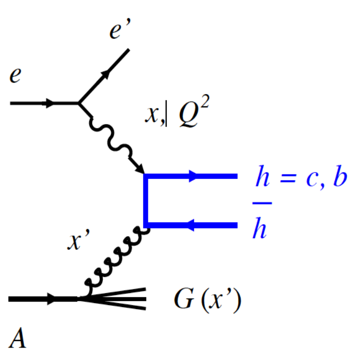
Select events with D^0? NO (lifetime of D0 $4.1 \cdot 10^{-13}$ sec)
Select only π + (211) and K- (321) emerging from D0 (421) ? NO

Event Generators



- e+p/A -> e' + $c\bar{c}$ + X -> e' + D0 +X -> e'+(πK)+X

Select **stable**, **charged** particles
Set a cut on minimum P_T (10-100MeV).
Set a cut on pseudo-rapidity ($|\eta| < 3.5$)
Select charged particles with displaced vertex.
Select pions and Kaons pair
Select π and K with opposite charge
Calculate and plot invariant mass of all combinations.

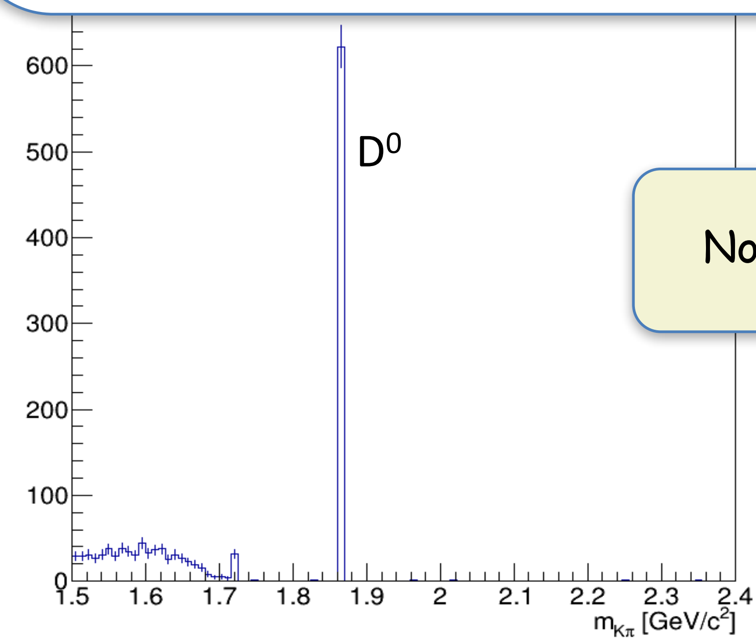


h_c	f	Decay	BR
D^0	59%	$K^-\pi^+$	3.9%
		$K^-\pi^+\pi^+\pi^-$	8.1%
D^+	23%	$K^-\pi^+\pi^+$	9.2%
D^{*+}	23%	$(K^-\pi^+)_{D0}\ \pi^+_{\text{slow}}$	2.6%
		$(K^-\pi^+\pi^+\pi^-)_{D0}\ \pi^+_{\text{slow}}$	5.5%
D_s^+	9%	$(K^+K^-)_\phi\ \pi^+$	2.3%
Λ_c^+	8%	$pK^-\pi^+$	5.0%

Event Generators

Select **stable**, **charged** particles

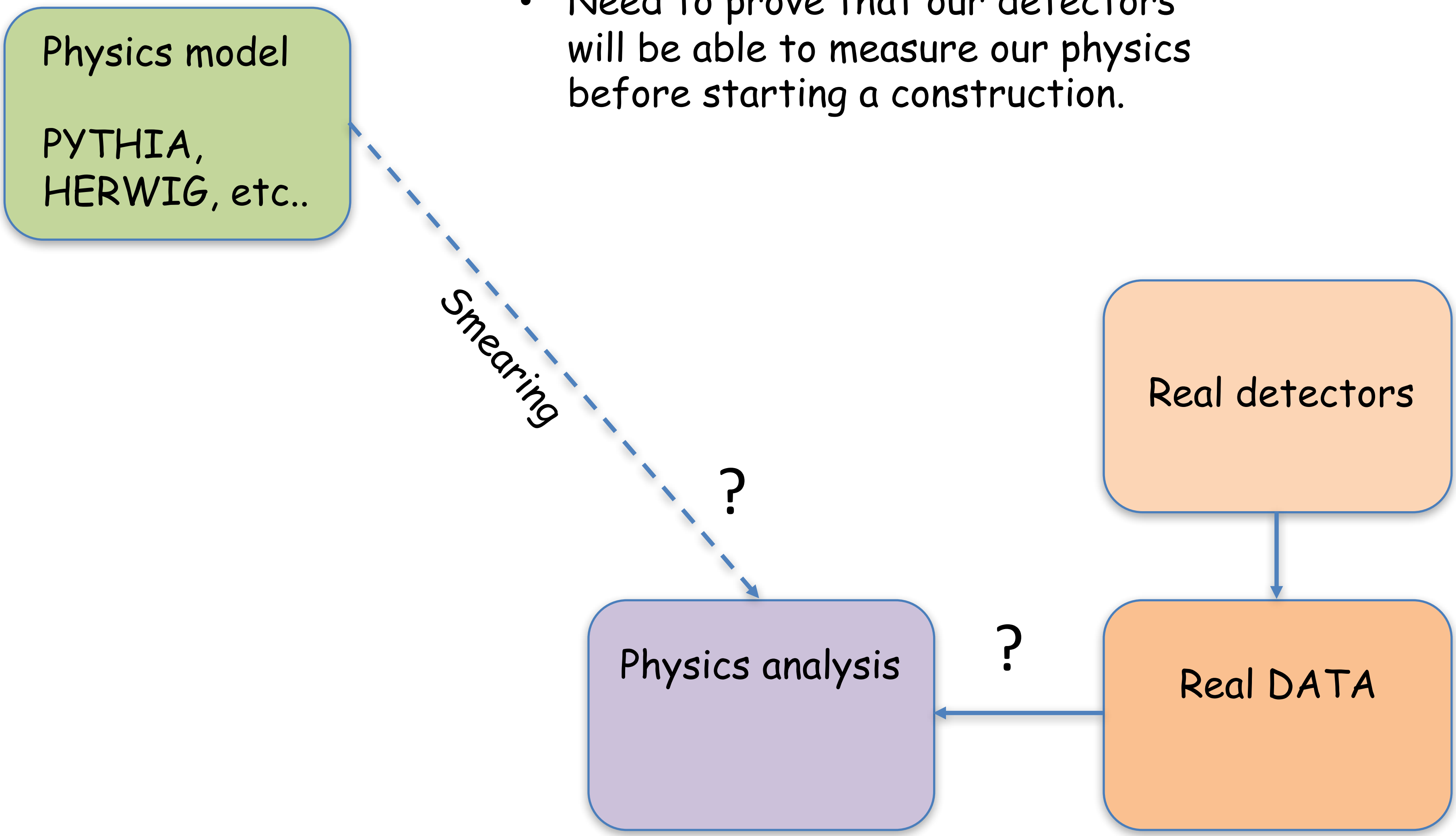
- Set a cut on minimum P_T (10-100MeV).
- Set a cut on pseudo-rapidity ($|\eta| < 3.5$)
- Select charged particles with displaced vertex.
- Select pions and Kaons pair
- Select π and K with opposite charge
- Calculate and plot invariant mass of all combinations.



Single mass bin.
No detector effects.
No background

Detector effect

- Need to prove that our detectors will be able to measure our physics before starting a construction.



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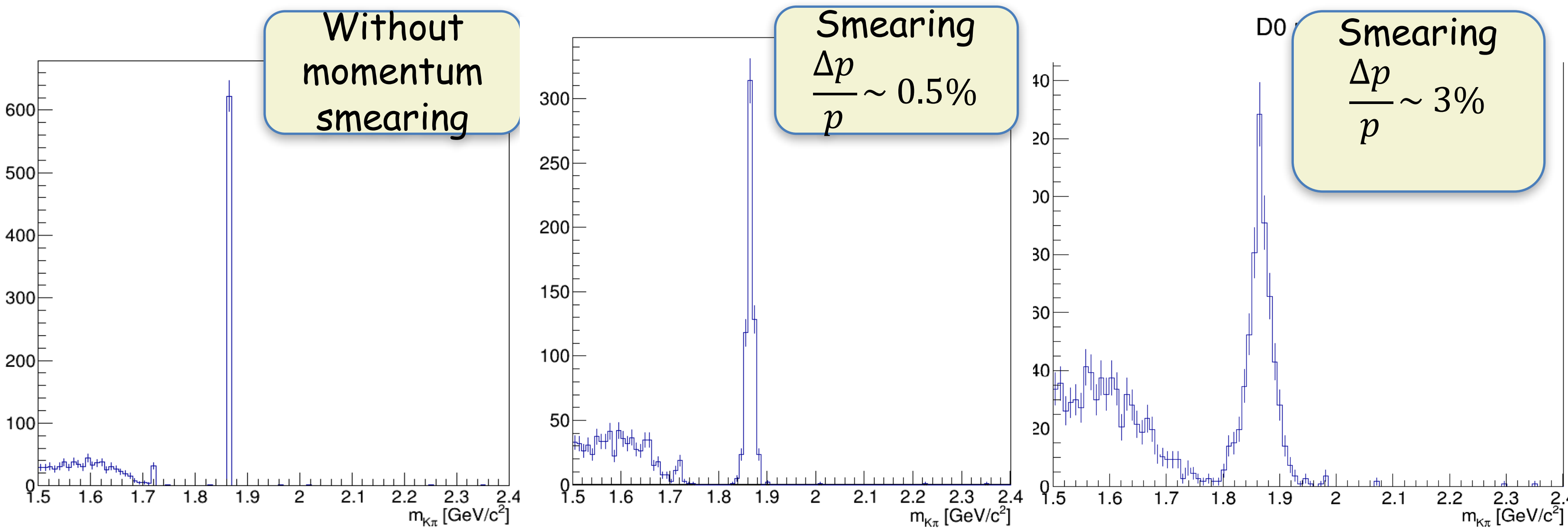
Event Generators

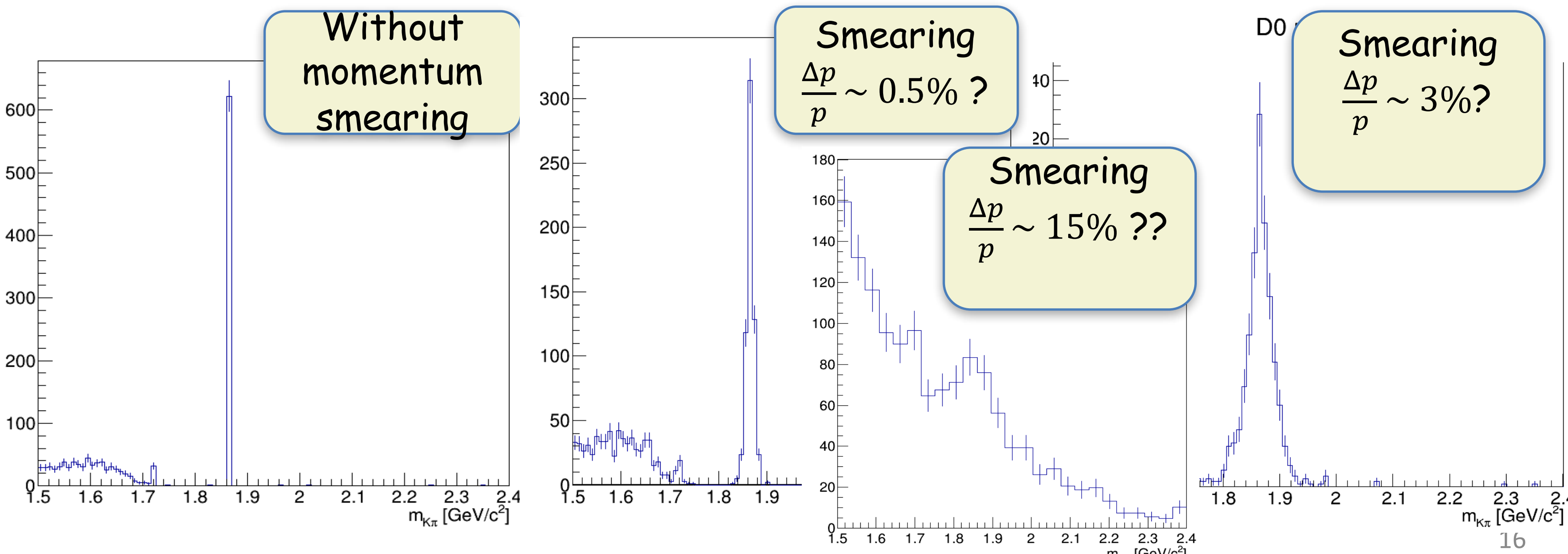
Select **stable**, **charged** particles
- Set a cut on minimum P_T (10-100MeV).
- Set a cut on pseudo-rapidity ($|\eta| < 3.5$)
- Select charged particles with displaced vertex.
- Select pions and Kaons pair
- Select π and K with opposite charge
- Calculate and plot invariant mass of all combinations.



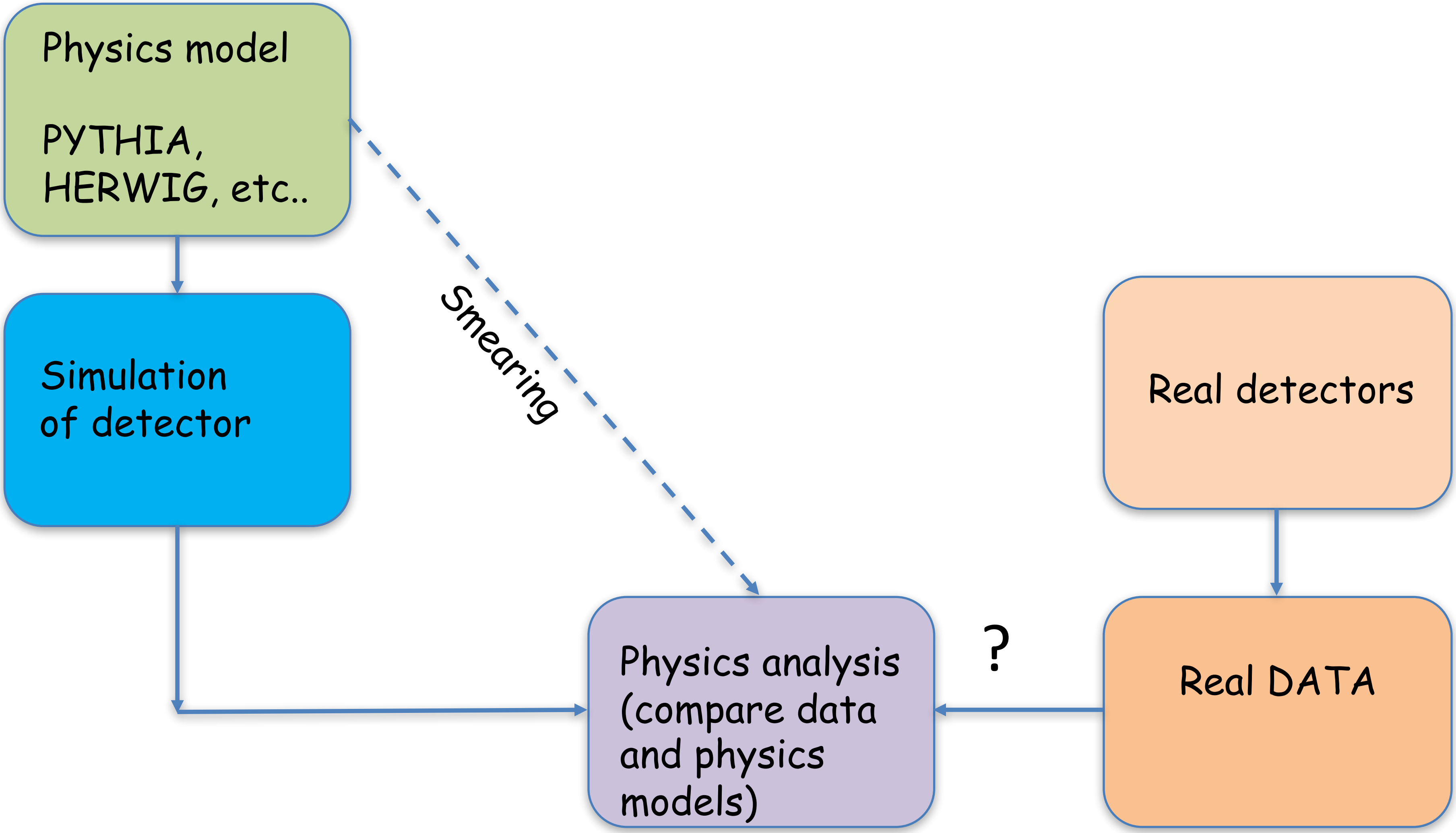
Event Generators: smearing

Select **stable**, **charged** particles

- Set a cut on minimum P_T (10-100MeV).
- Set a cut on pseudo-rapidity ($|\eta| < 3.5$)
- Select charged particles with displaced vertex.
- Select pions and Kaons pair
- Select π and K with opposite charge
- Calculate and plot invariant mass of all combinations.



Simulation chain

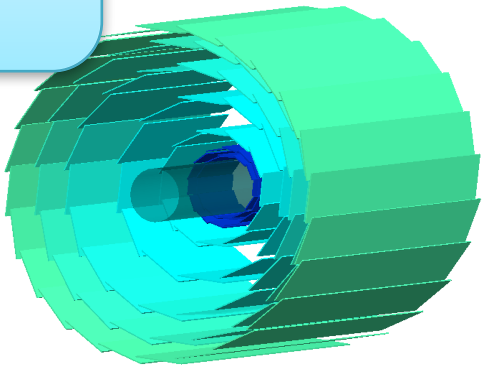


Simulation tools

GEANT4

Geometry description

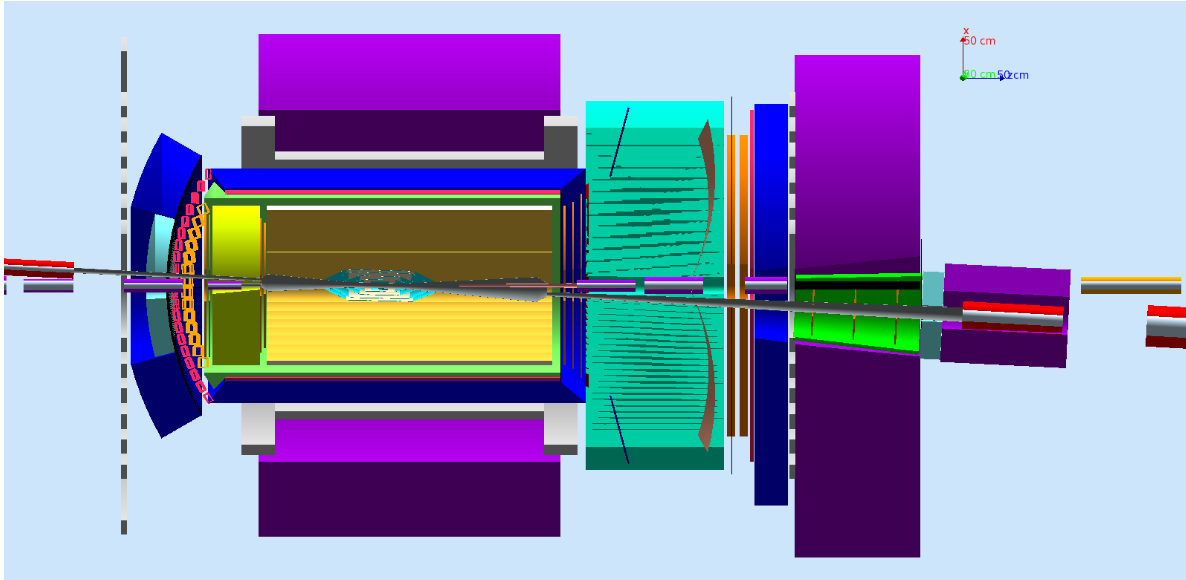
✓ GEOMETRY : GEANT4 simulation of detector



You have to provide:

- Geometry of the detector (including material)
- Physics processes
- Kinematics of particles going into the detector (angle, momenta, vertex)

- Magnetic field
- Actions during particle transportation
- Actions when particle goes through sensitive volume of the detector
- Etc.



GEANT4

geant4.cern.ch

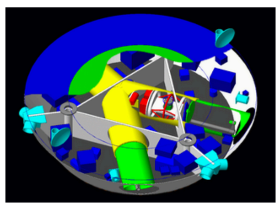
Geant 4

Geant4 is a toolkit for the simulation of the passage of particles through matter. Its areas of application include high energy, nuclear anc physics, as well as studies in medical and space science. The three main reference papers for Geant4 are: *Nuclear Instruments and M Physics Research* A **506** (2003) 250-303, *IEEE Transactions on Nuclear Science* **53** No. 1 (2006) 270-278, *Nuclear Instruments and M Physics Research* A **835** (2016) 186-225.

Applications

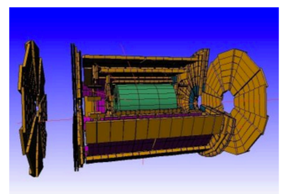
A sampling of applications, technology transfer and other uses of Geant4

User Support



Getting started, guides and information for users and developers

Publications



Validation of Geant4, results from experiments and publications

Collaboration

Who we are: collaborating members, organization ar information

Events

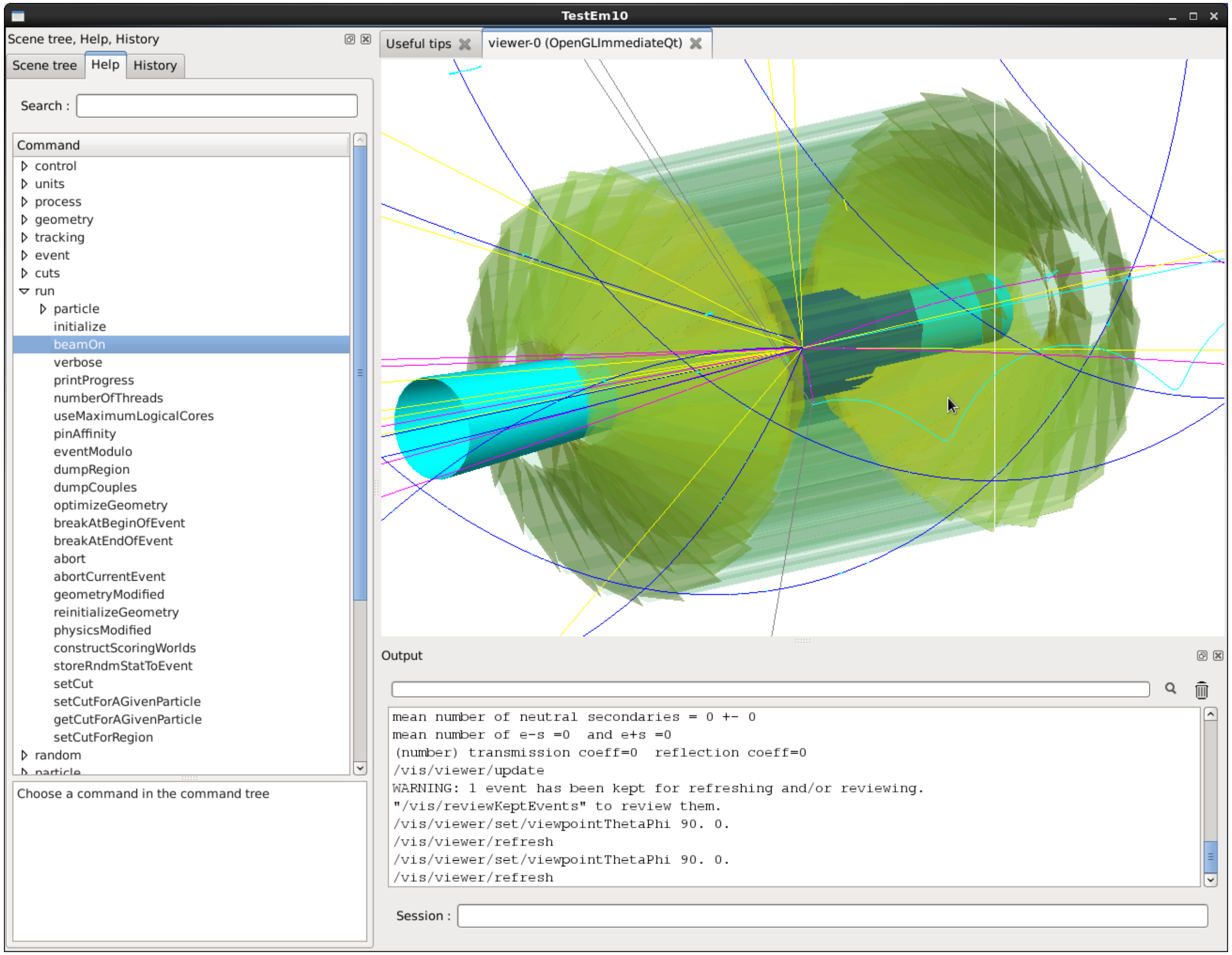
- 47th Geant4 Technical Forum, CERN, Geneva (Switzerland), **10 April 2018**.
- Geant4 Beginners Course, at TUM University, Munich (Germany), **16-20 April 2018**.
- Geant4 Tutorial, at Universite Paris-Saclay/LAL, Orsay (France), **14-18 May 2018**.
- Geant4 Course at the 15th Seminar on Software for Nuclear, Sub-nuclear and Applied Physics, Porto Conte, Alghero (Italy), **27 May - 1 June 2**
- Geant4 Tutorial, at the University of Texas MD Anderson Cancer Center, Houston (USA), **25-27 June 2018**.
- Geant4 Short Course at the African School of Physics 2018, University of Namibia, Windhoek (Namibia), **3 July 2018**.
- 7th International Geant4 Tutorial, at KIRAMS, Seoul (Korea), **9-13 July 2018**.
- 23rd Geant4 Collaboration Meeting, Lund University, Lund (Sweden), **27-31 August 2018**.
- 3rd Geant4 International User Conference at the Physics-Medicine-Biology Frontier, Bordeaux (France), **29-31 October 2018**.

- **Past events**

How to describe a geometry?

- Inside GEANT4 (c++):

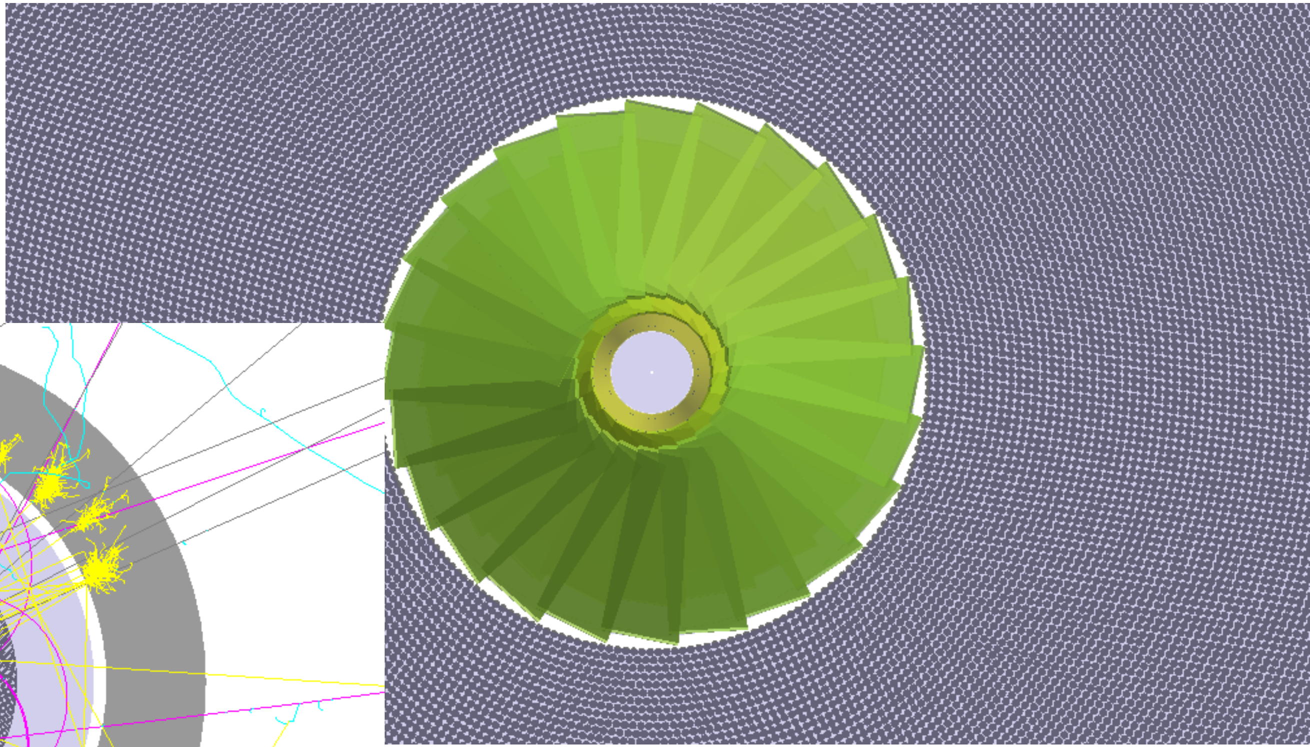
✓ Beampipe
✓ Silicon Vertex tracker

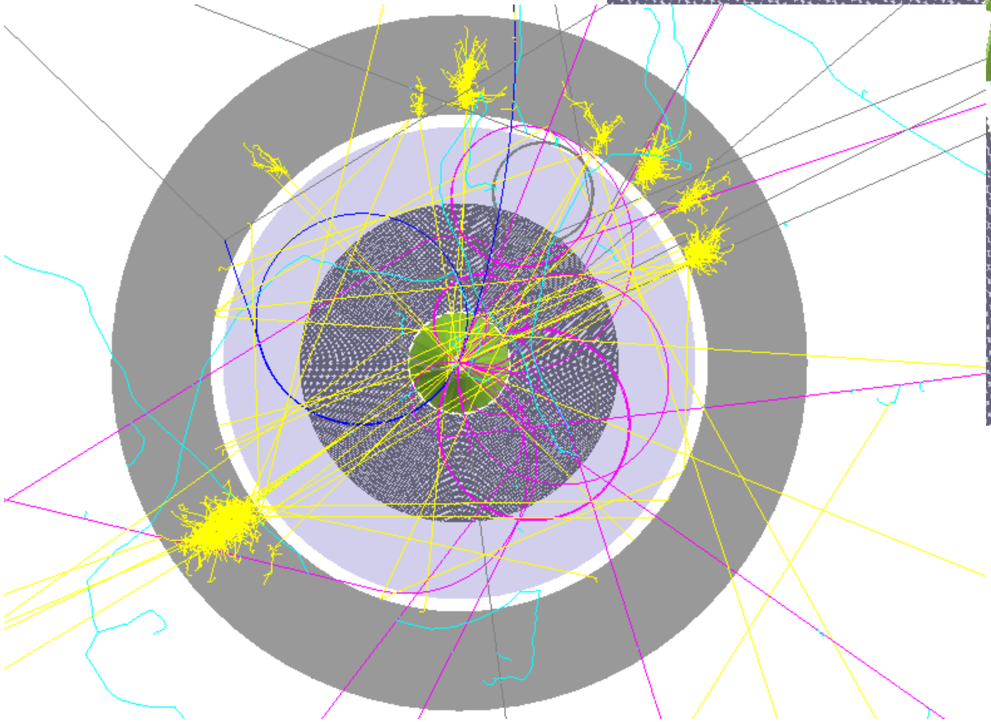


How to describe a geometry?

- Inside GEANT4 (c++)

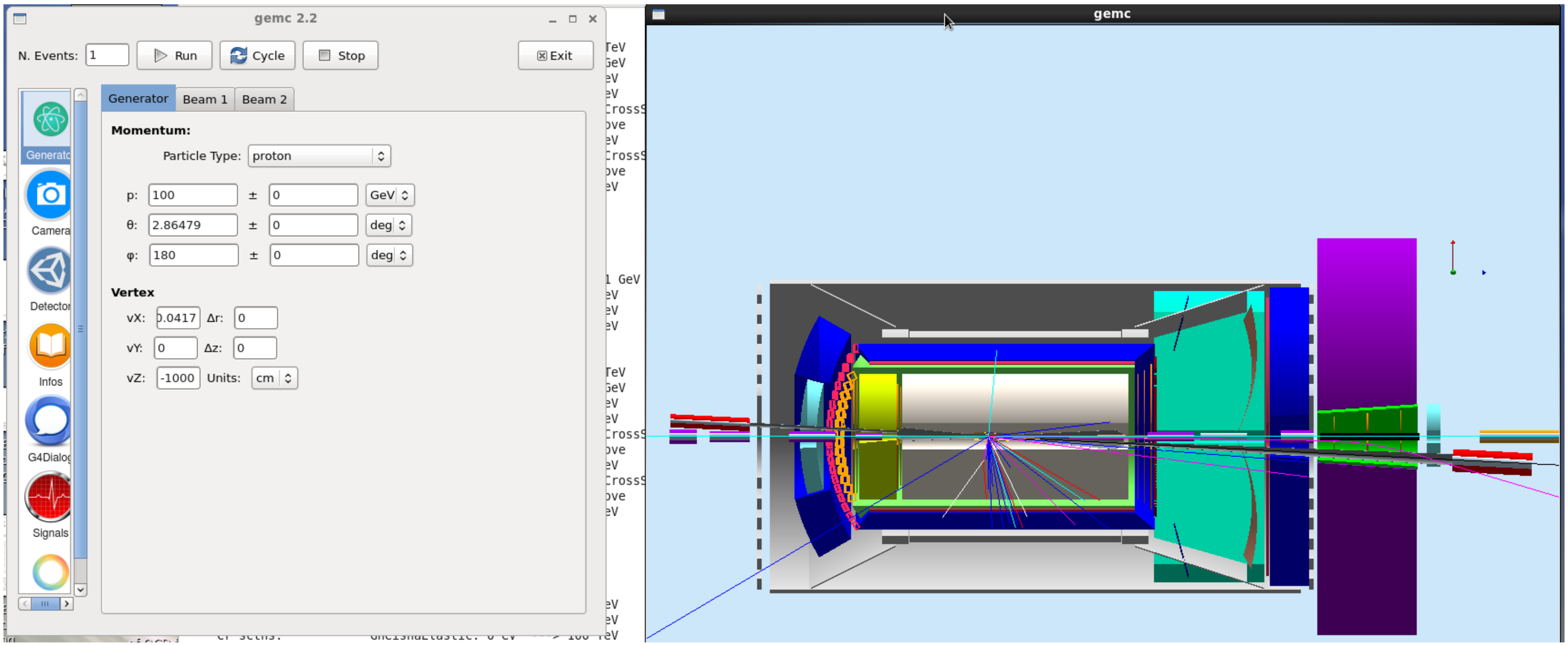
  ✓ Straw tracker
  ✓ EM calorimeter





How to describe a geometry?
GEMC

- Use a wrapper around GEANT4 => GEMC (perl)
- https://gemc.jlab.org/gemc/html/index.html



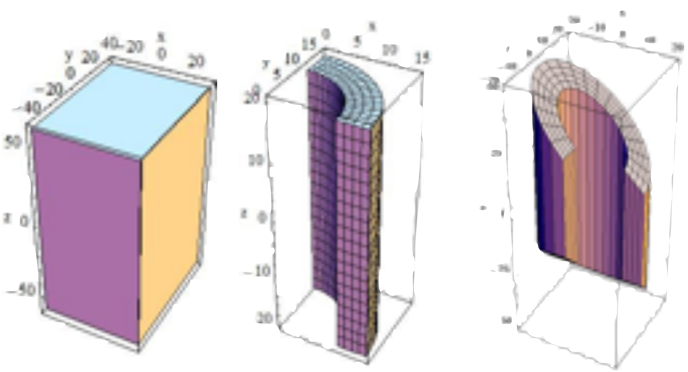
Yulia Furletova

How to describe a geometry? GEMC (JLAB)

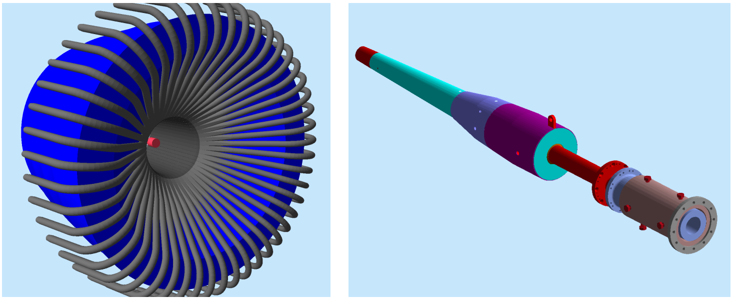
- https://gemc.jlab.org/gemc/html/index.html

Input: Native, CAD, GDML. Arbitrary hierarchy, can be mixed and matched. Materials, sensitivity assigned at run-time.

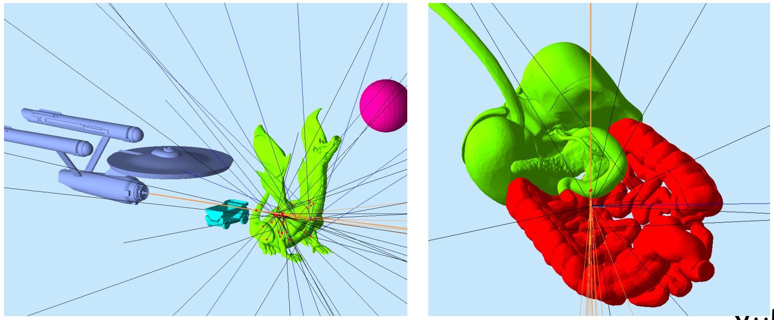
Native

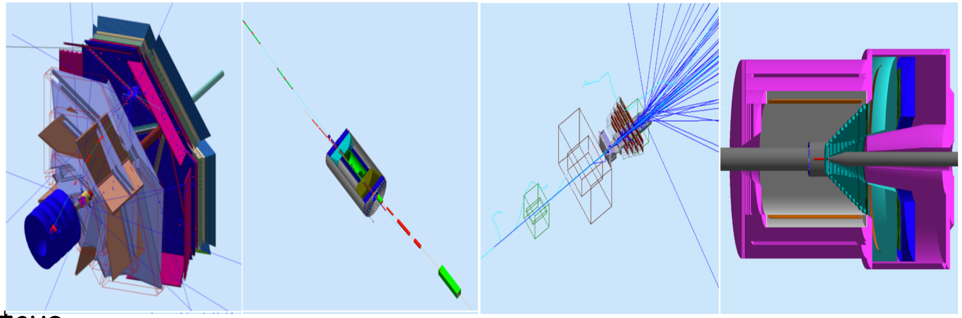


CAD



GDML





GEMC with docker

Getting started

1. Install Docker

2. Run container

   docker run -p 6080:6080 -v /my/data/dir:/data -it --rm electronioncollider/jleic:1.0.2

3. Point browser to:

   http://localhost:6080

GEMC with docker

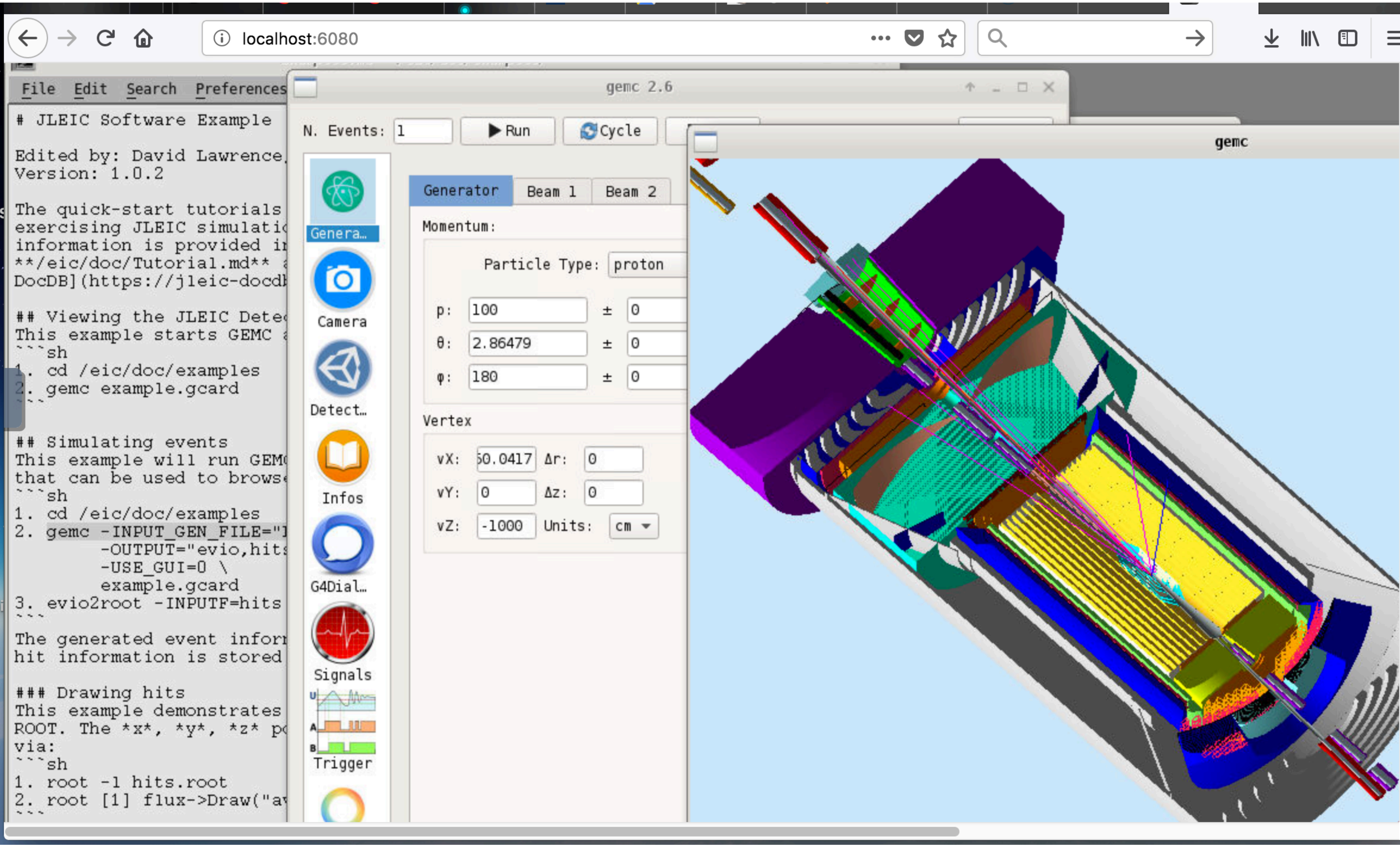
```
JLEIC container example README

Jan. 31, 2018  David Lawrence


# INTRODUCTION

This provides an example for exercising JLEIC simulation
software in this container.

# Quick Start

## View Geometry

1.)  cd /eic/doc/examples

2.)  gemc example.gcard


## Simulate events

1.)  cd /eic/doc/examples

2.)  gemc -INPUT_GEN_FILE="LUND,pythia-sample.lund" \
          -OUTPUT="evio,sample_out.evio" \
                  -USE_GUI=0 \
                  example.gcard

3.)  evio2root -INPUTF=sample_out.evio

This should produce a file sample_out.root that can be
used to browse and plot data.
```

Event generator (LUND file)

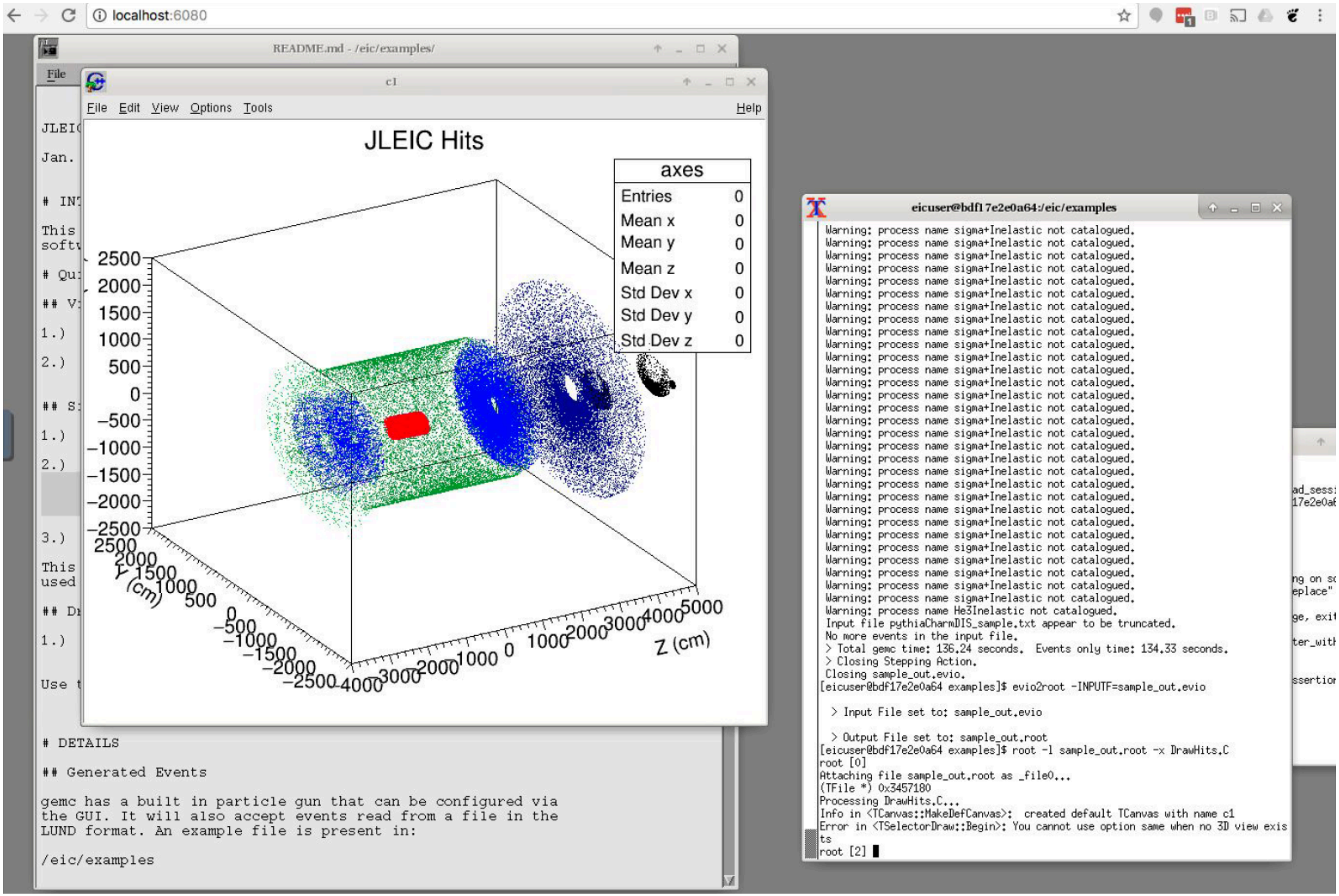
Geometry card

Output file with hits

GEMC with docker

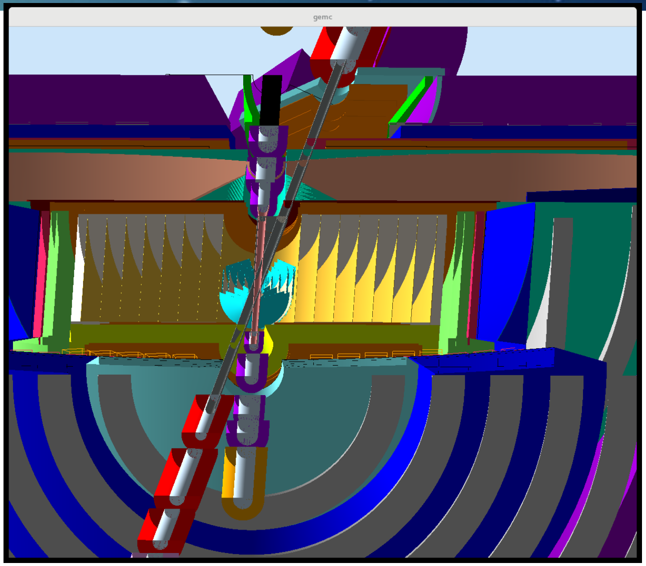


Hits (docker)



localhost:6080
README.md - /eic/examples/
c1
JLEIC Hits
axes
Entries 0
Mean x 0
Mean y 0
Mean z 0
Std Dev x 0
Std Dev y 0
Std Dev z 0
Y (cm)
Z (cm)
eicuser@bdf17e2e0a64:/eic/examples
Warning: process name sigma+Inelastic not catalogued.
Warning: process name He3Inelastic not catalogued.
Input file pythiaCharmDIS_sample.txt appear to be truncated.
No more events in the input file.
> Total gemc time: 136.24 seconds. Events only time: 134.33 seconds.
> Closing Stepping Action.
Closing sample_out.evio.
[eicuser@bdf17e2e0a64 examples]$ evio2root -INPUTF=sample_out.evio
> Input File set to: sample_out.evio
> Output File set to: sample_out.root
[eicuser@bdf17e2e0a64 examples]$ root -l sample_out.root -x DrawHits.C
root [0]
Attaching file sample_out.root as _file0...
(TFile *) 0x3457180
Processing DrawHits.C...
Info in <TCanvas::MakeDefCanvas>: created default TCanvas with name c1
Error in <TSelectorDraw::Begin>: You cannot use option same when no 3D view exists
root [2]
DETAILS
Generated Events
gemc has a built in particle gun that can be configured via the GUI. It will also accept events read from a file in the LUND format. An example file is present in:
/eic/examples

Simulation chain



Physics model

PYTHIA, HERWIG, etc..

Simulation of detector

Smearing

Real detectors

Physics analysis (compare data and physics models)

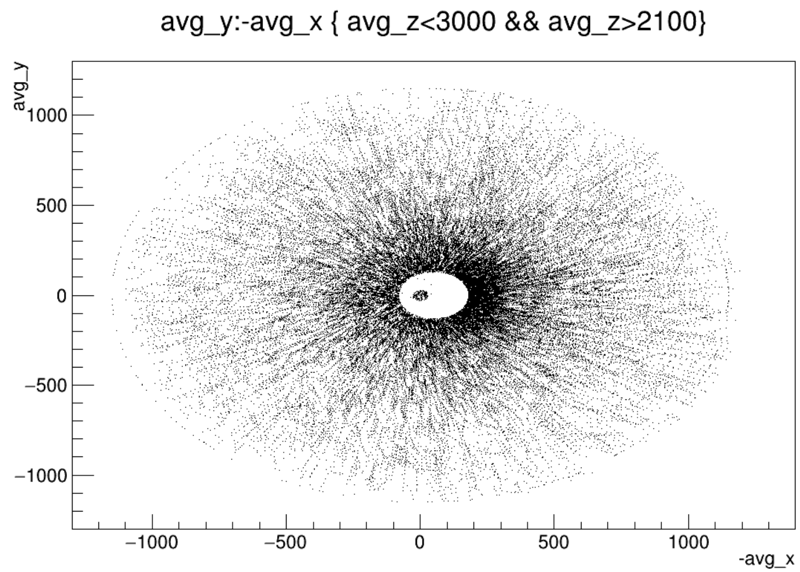
?

Real DATA

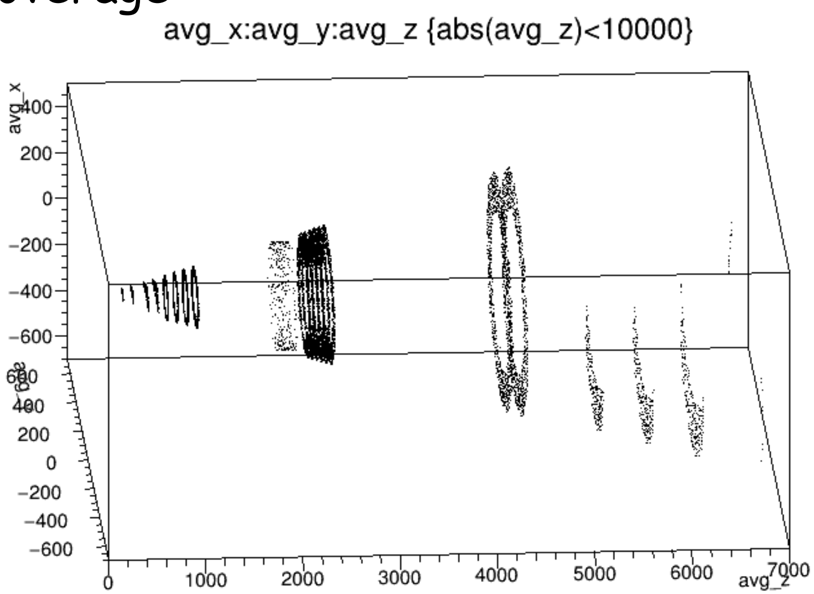
Acceptance coverage

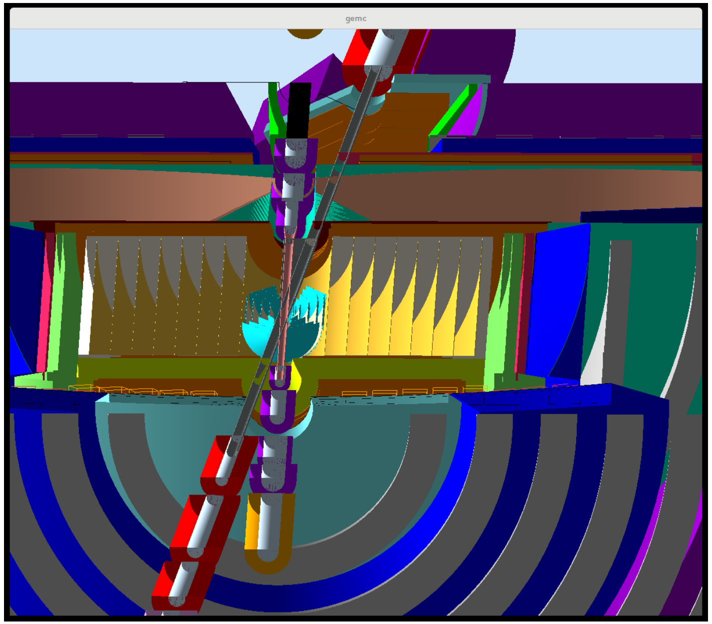
Occupancy in the detector..

Beamline elements limit our acceptance



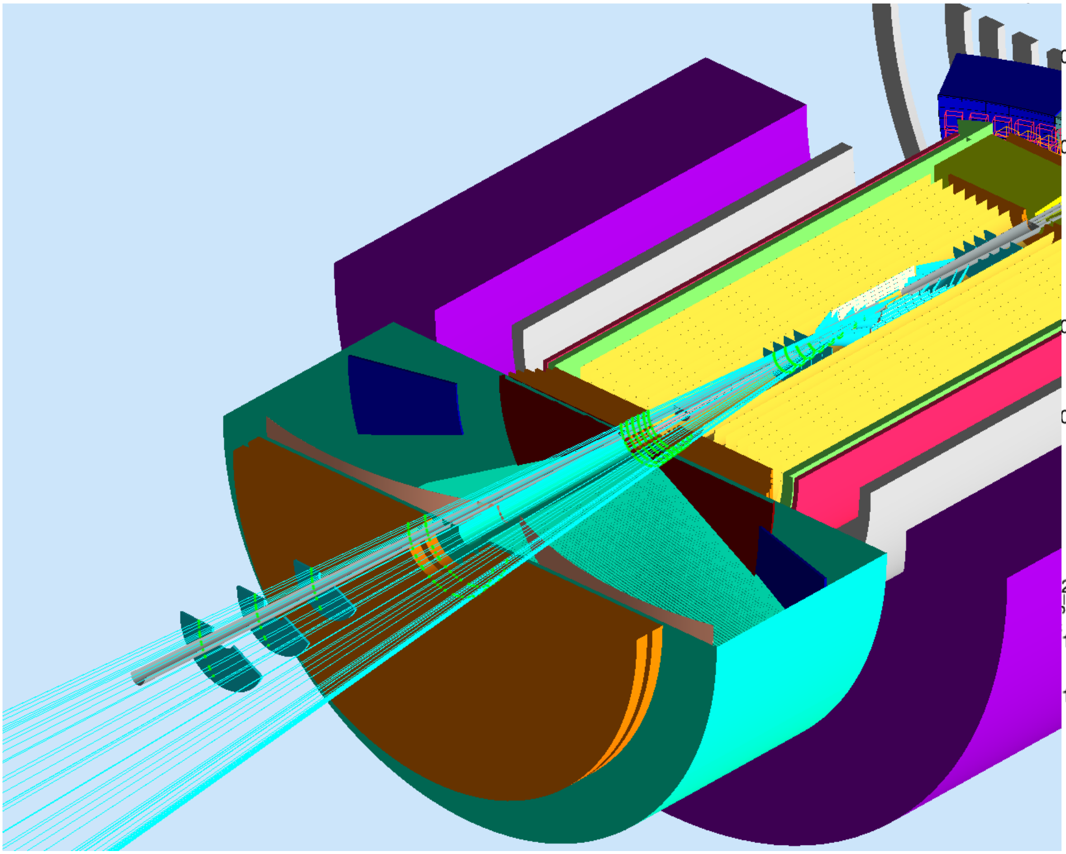
Acceptance coverage

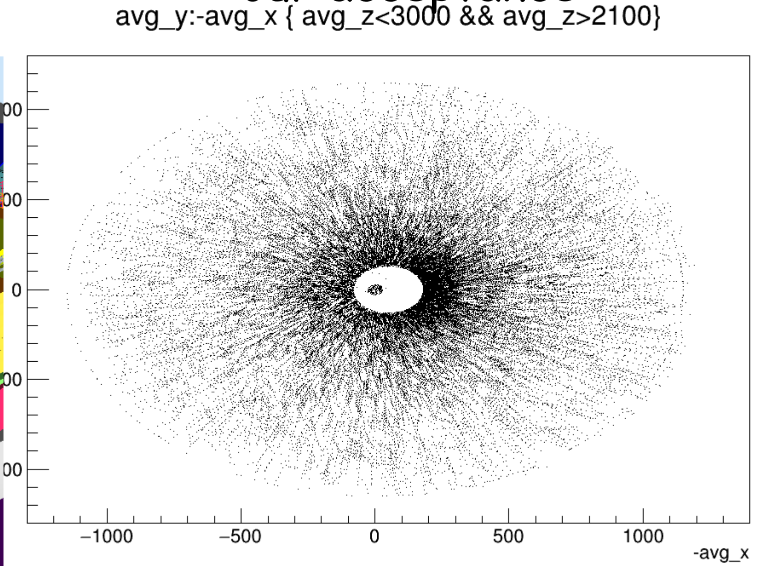


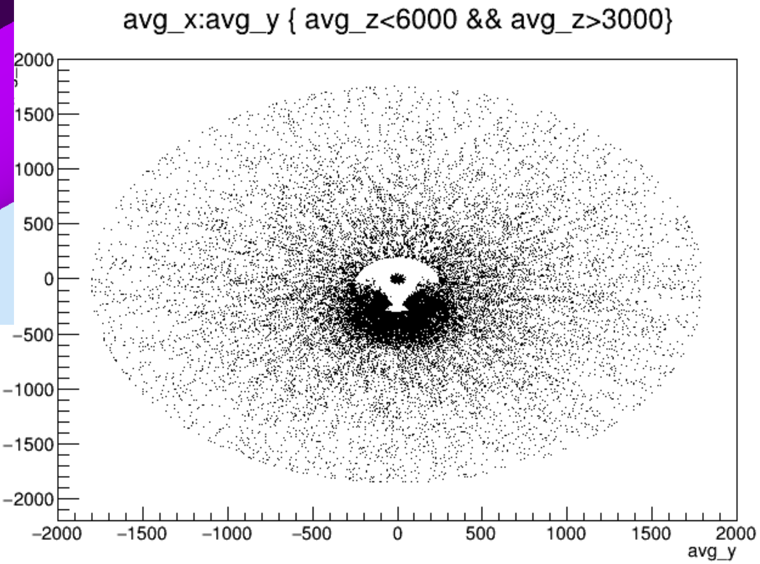


Acceptance coverage

Beamline elements limit our acceptance



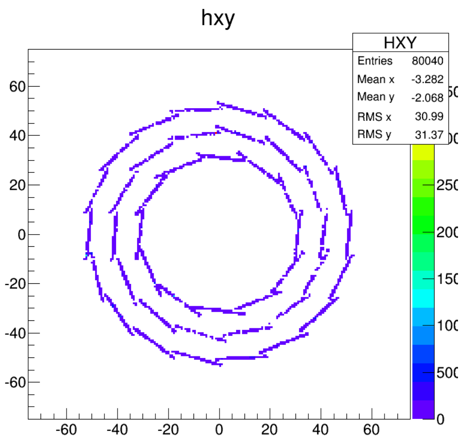


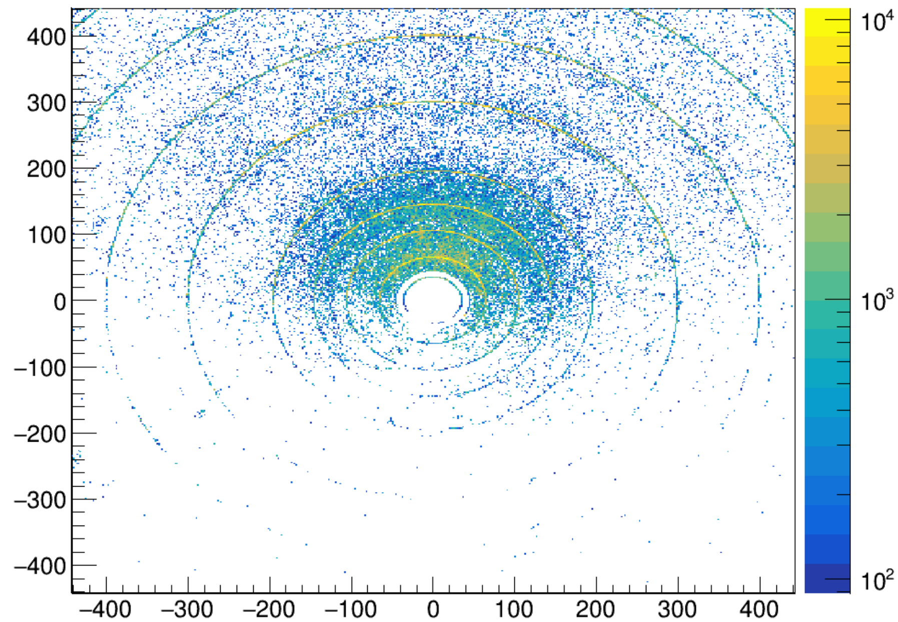


Occupancy

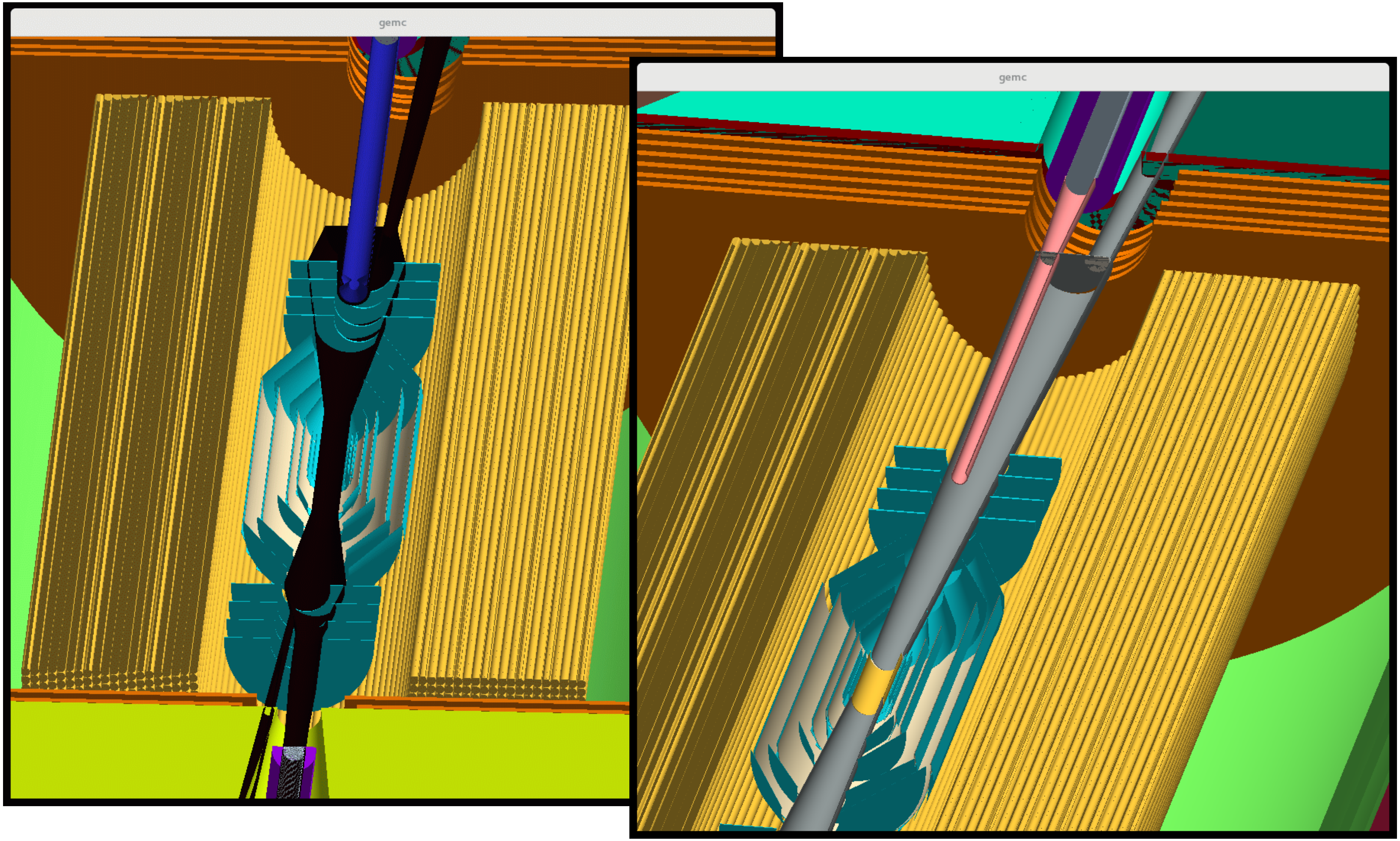
..With beam related background (here synchrotron radiation)

Occupancy



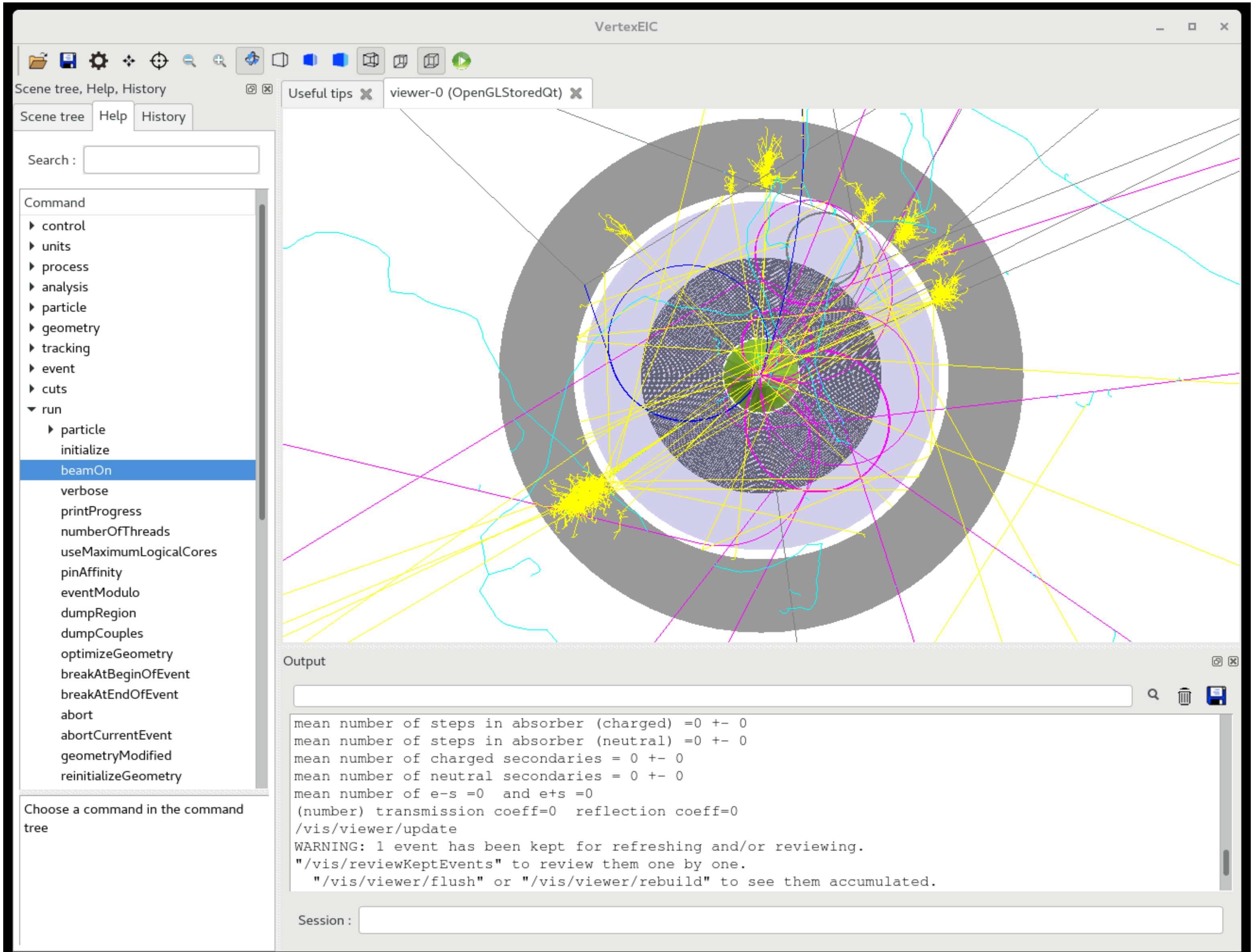


Overlapping volumes



Yulia Furletova

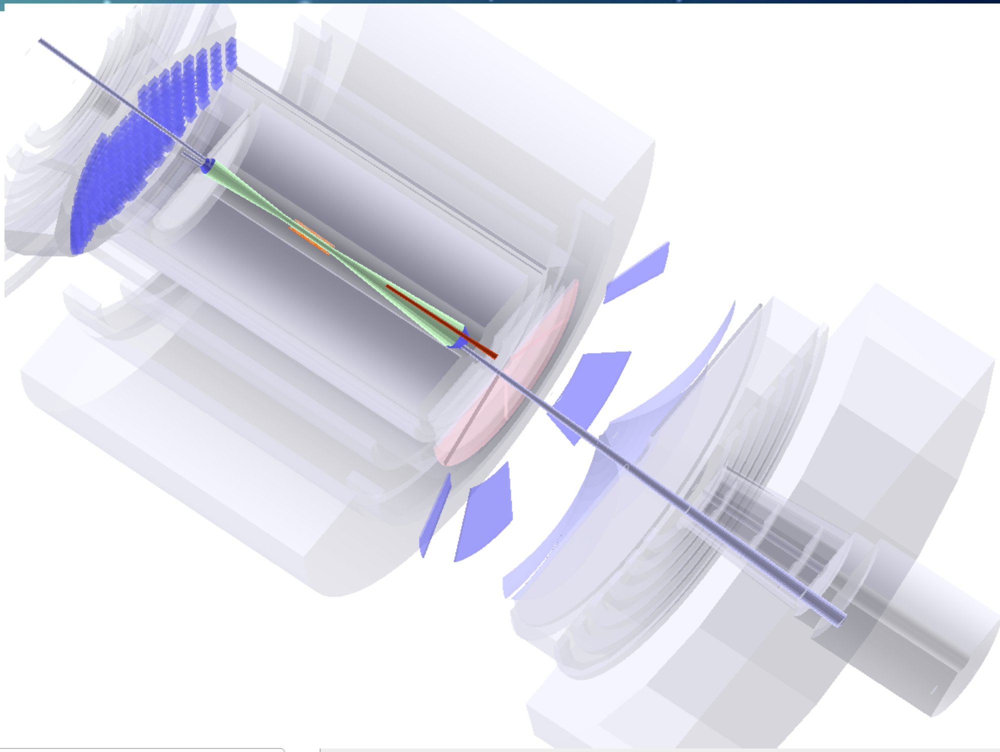
Calorimeter depth

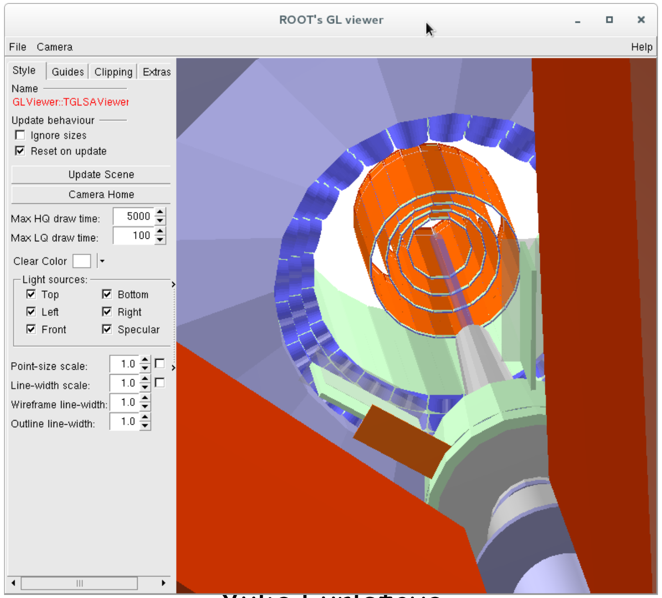


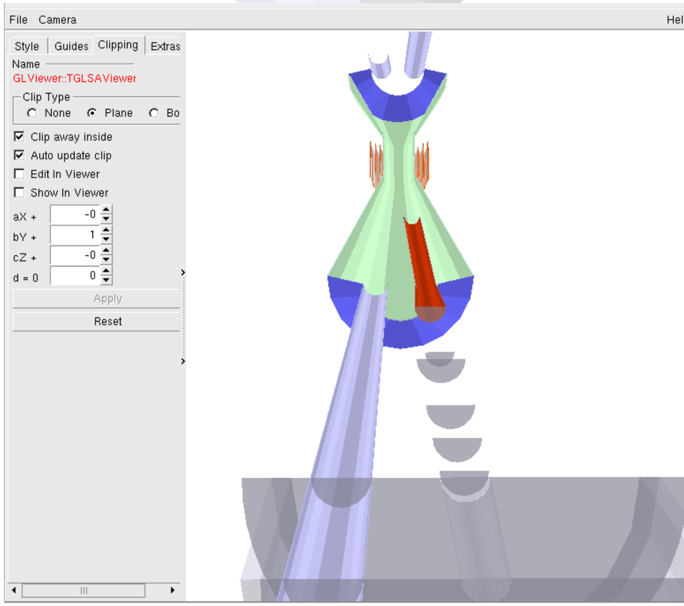
Geometry

- ✓ Convert geometry into other format
- ✓ Use different viewer

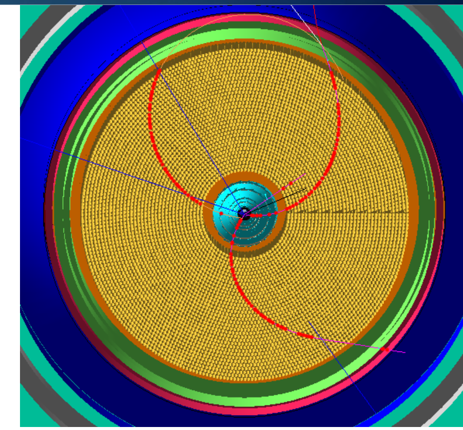
- ✓ GDML to Root







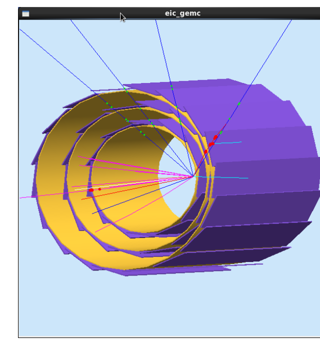
Simulation tools

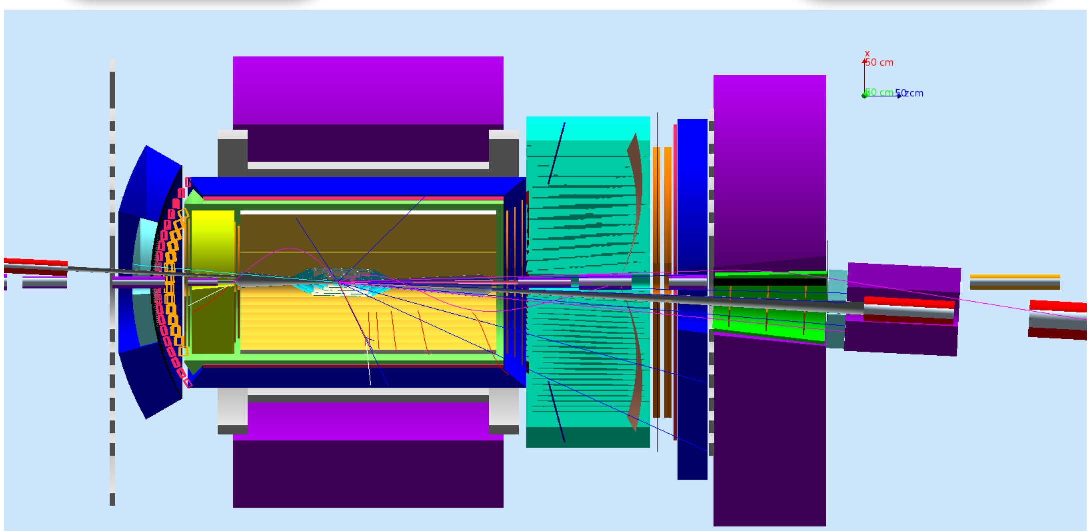


- ✓ Final state particles (from event generator)
- ✓ GEOMETRY : GEANT4 simulation of detector
- ✓ Output file with geometry and hits…

Event generator → File with particles → GEANT4 → Geometry description

GEANT4 → File with hits (x,y,z)





?

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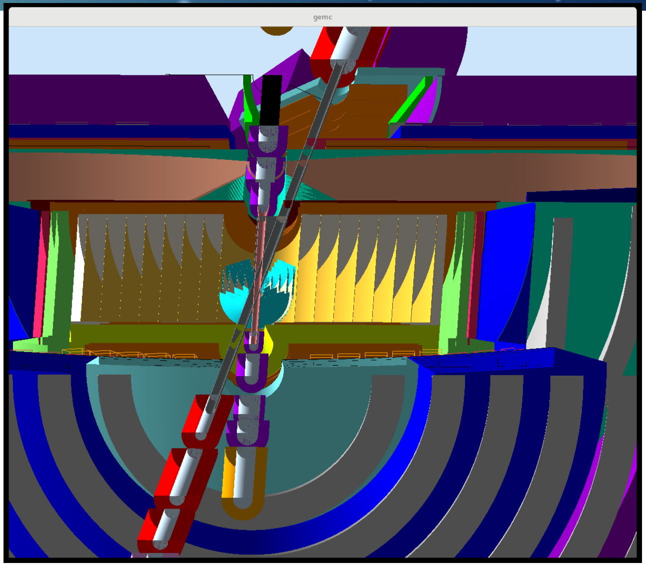
Simulation chain



Physics model

PYTHIA, HERWIG, etc..

Simulation of detector

Reconstruction: Convert hits and deposited Energy into p, Vtx, E, charge and PID

Smearing

Physics analysis (compare data and physics models)

?

Real detectors

Real DATA

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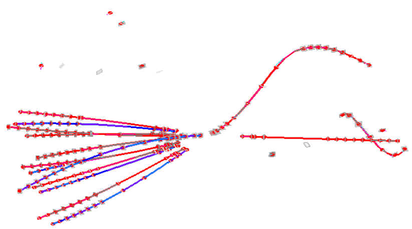
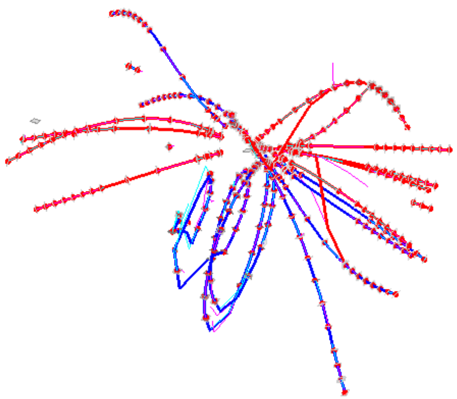
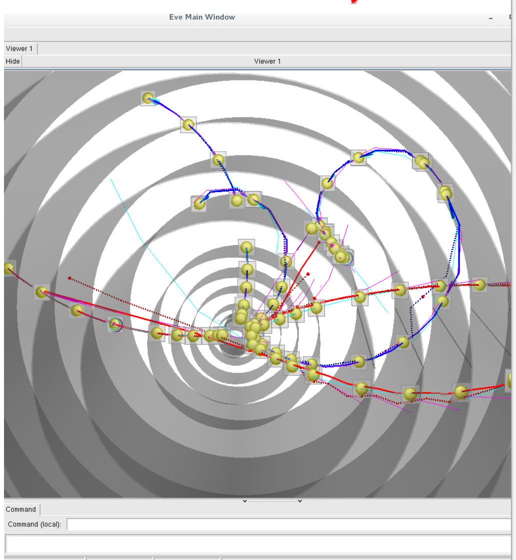
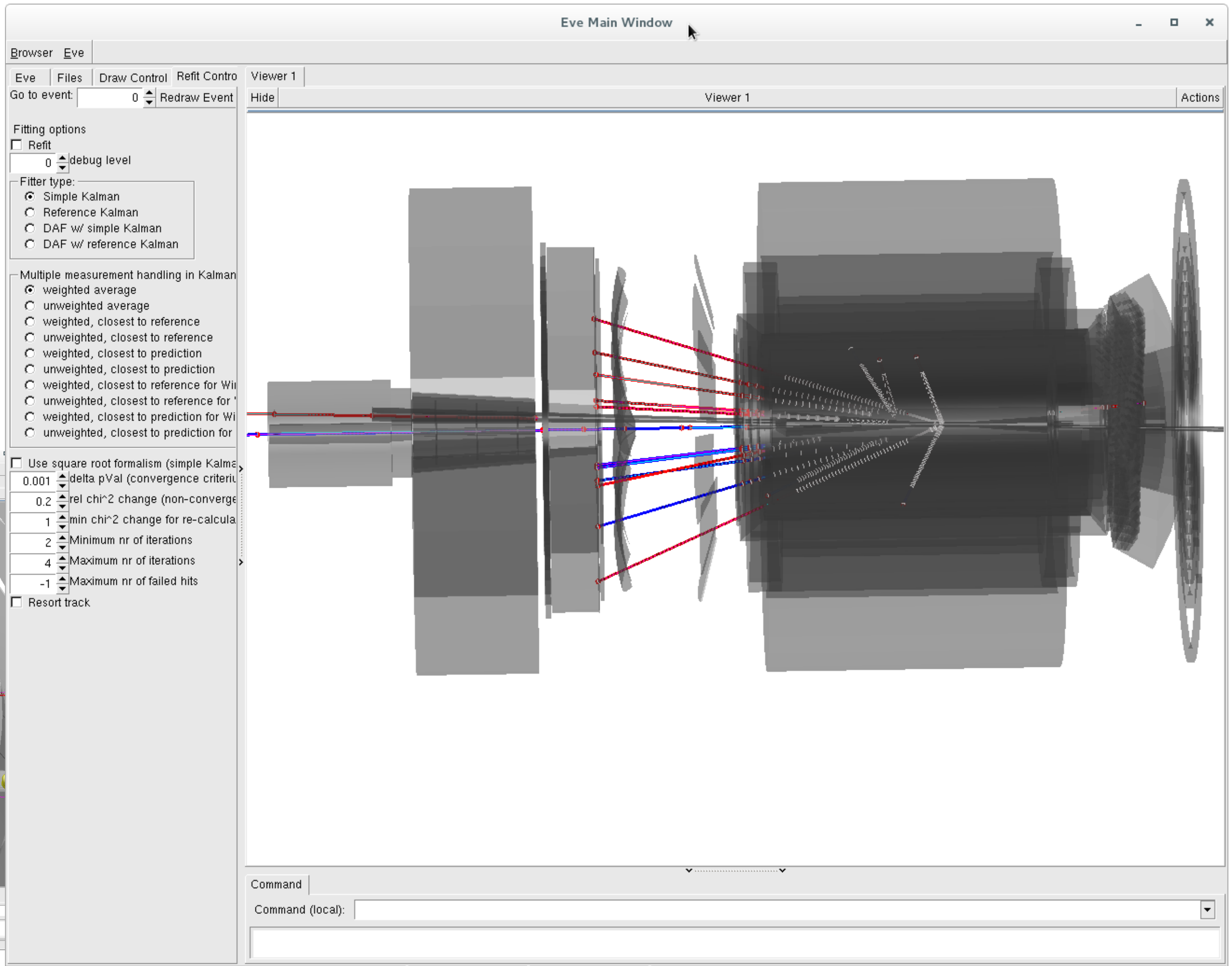
Track fitting/vertexing



- Fit hits to get a track
- Which hit belongs to which track?

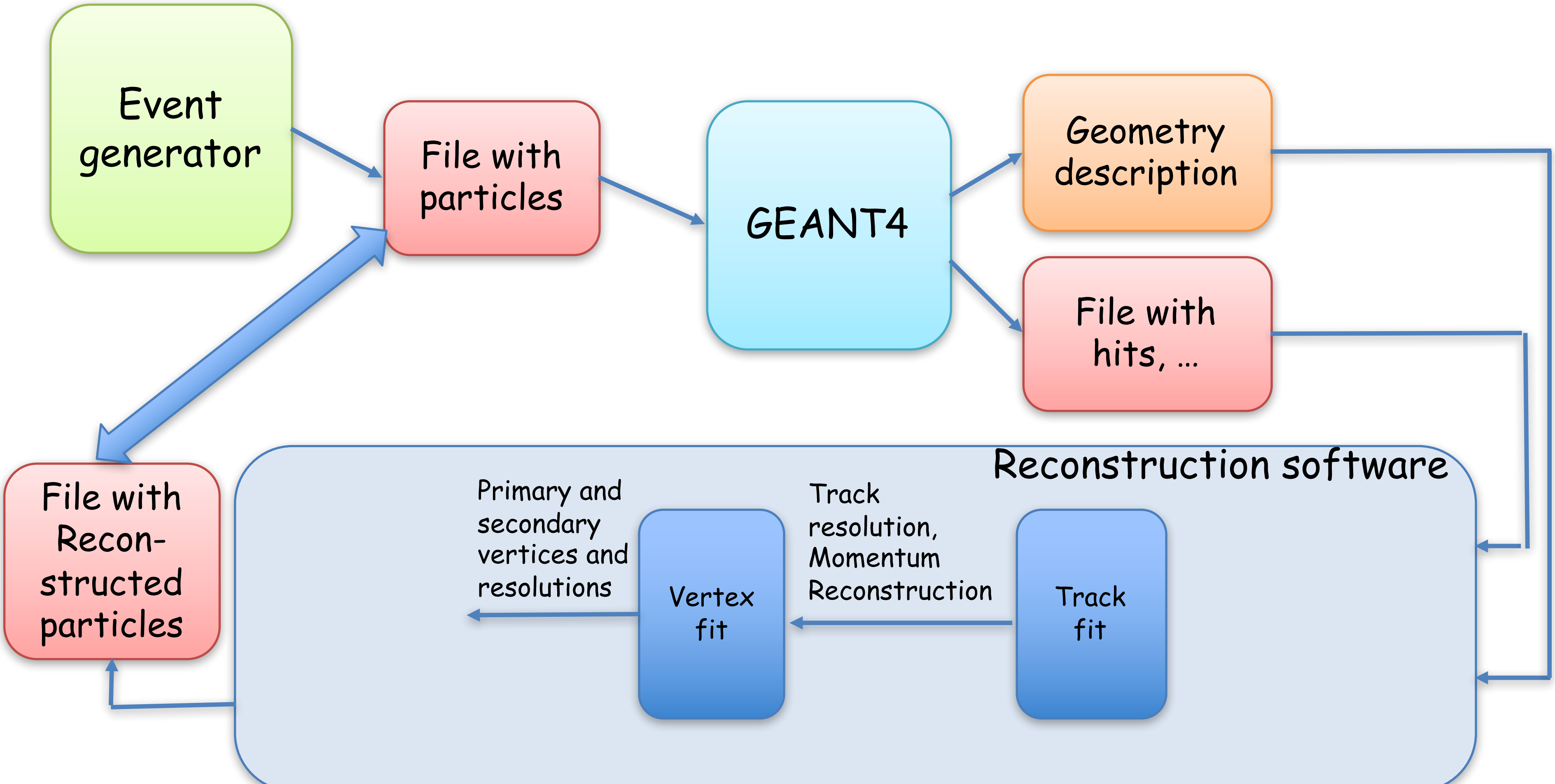






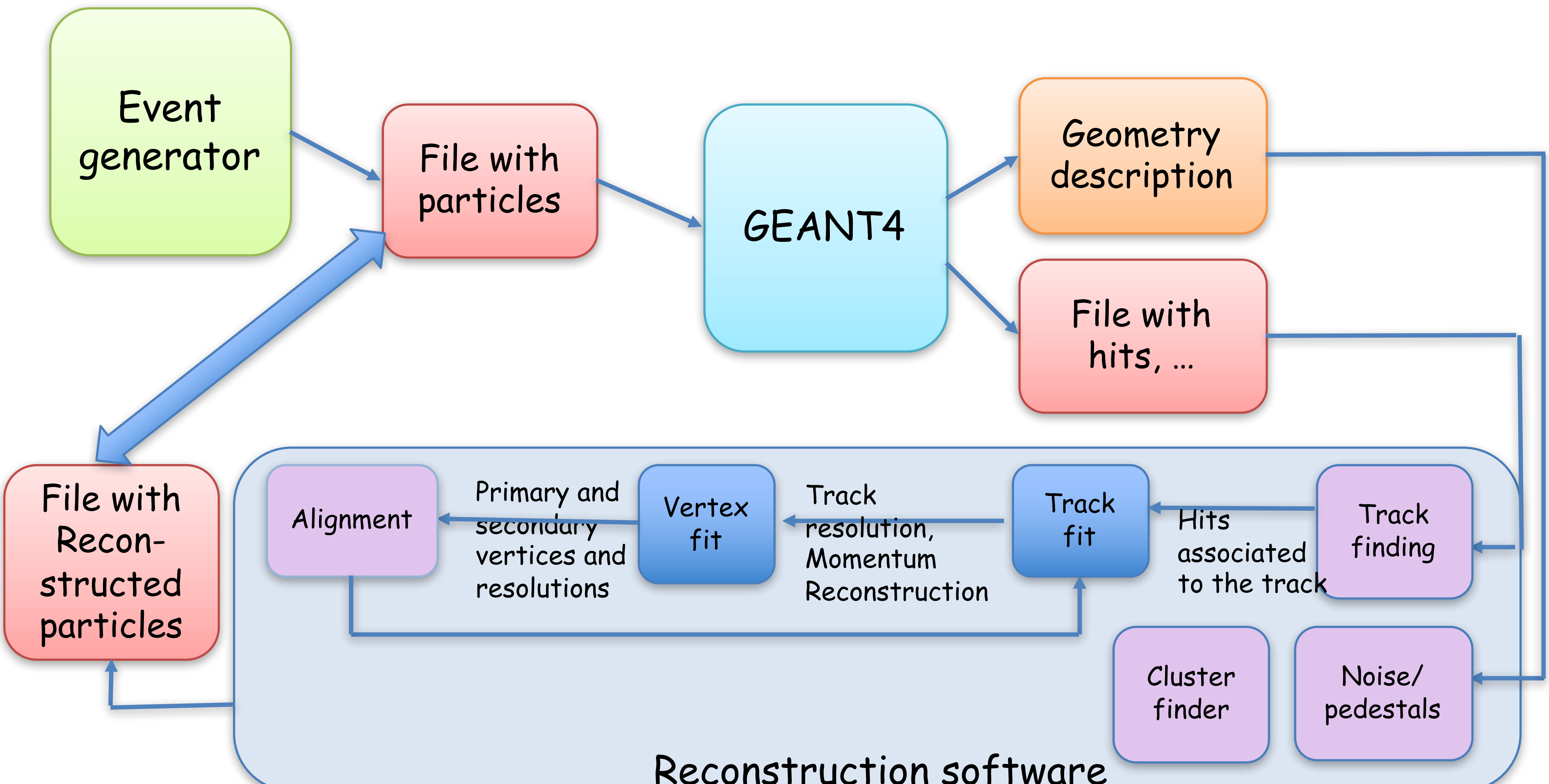
Reconstruction

- ✓ Convert hits and energy deposition into Momentum and Energy and PID
- ✓ Reconstruction chain: Track finding, Track fitting, vertex finding, (alignment),… etc



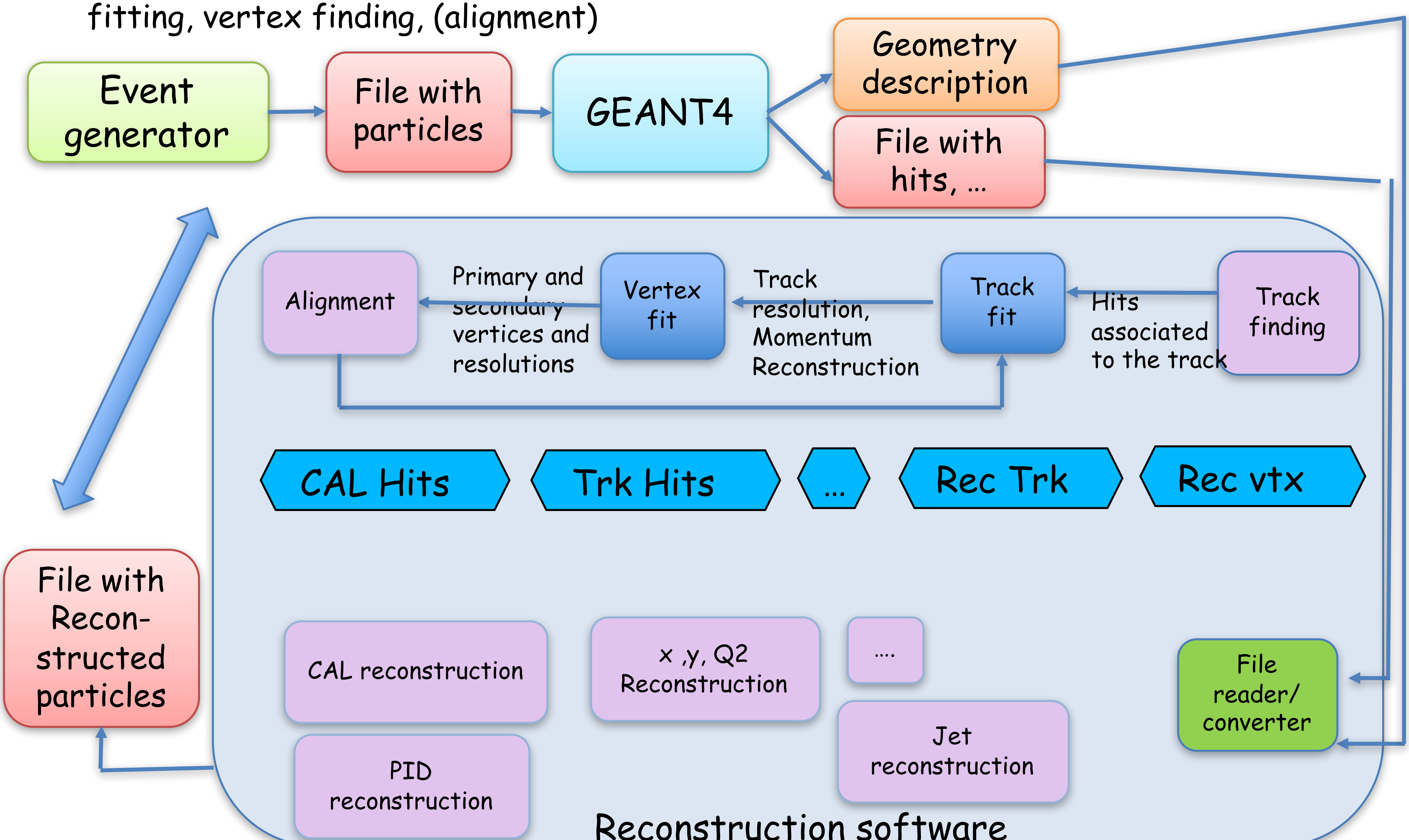
Reconstruction

- ✓ Reconstruction chain: Track finding, Track fitting, vertex finding, (alignment)



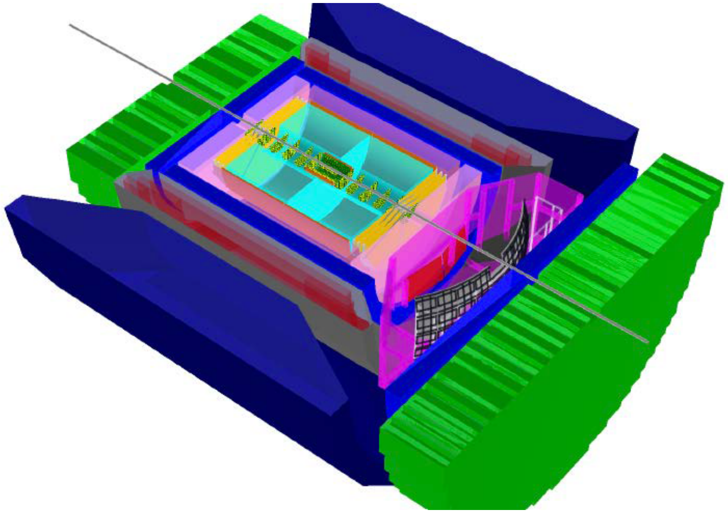
Simulation tools

- ✓ Reconstruction chain: Track finding, Track fitting, vertex finding, (alignment)

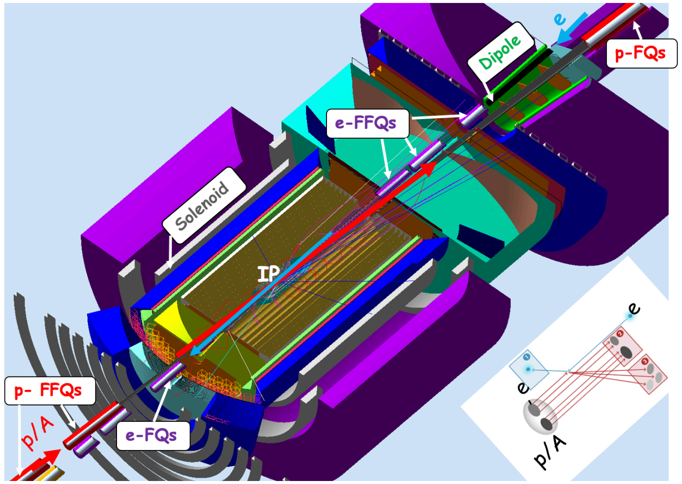


Many options for reconstruction

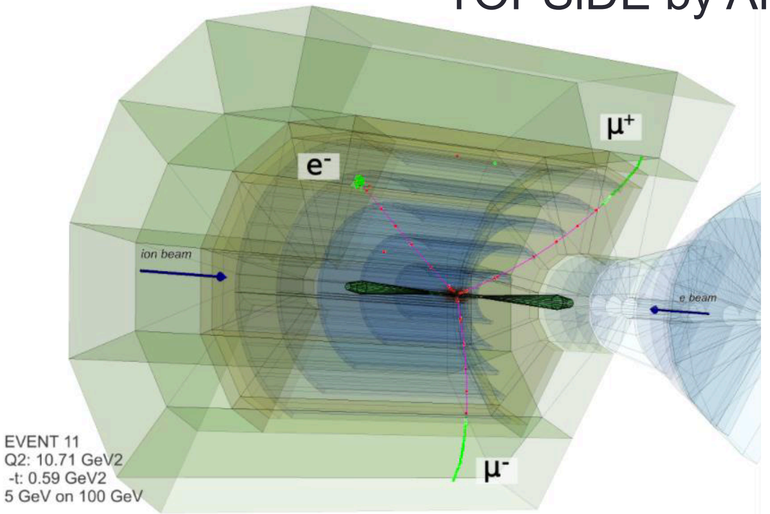
eRHIC Detector : “EICROOT”



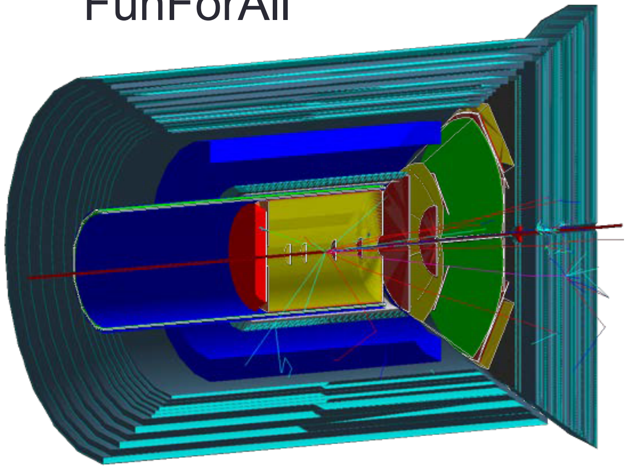
JLEIC Detector: “GEMC/ JANA”

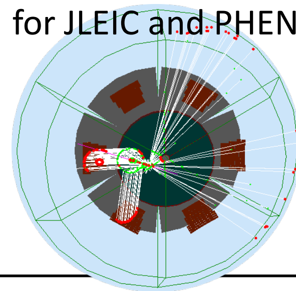
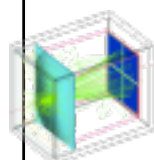
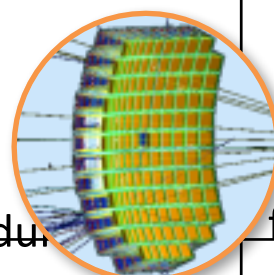
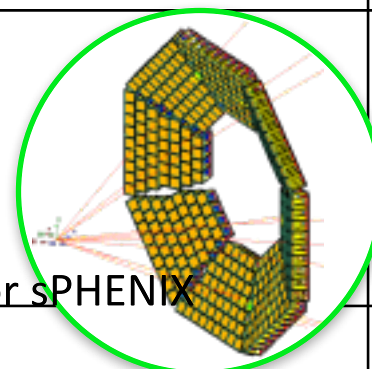
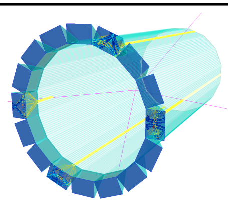
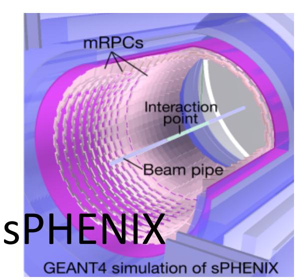


TOPSiDE by ANL: “ILC based”



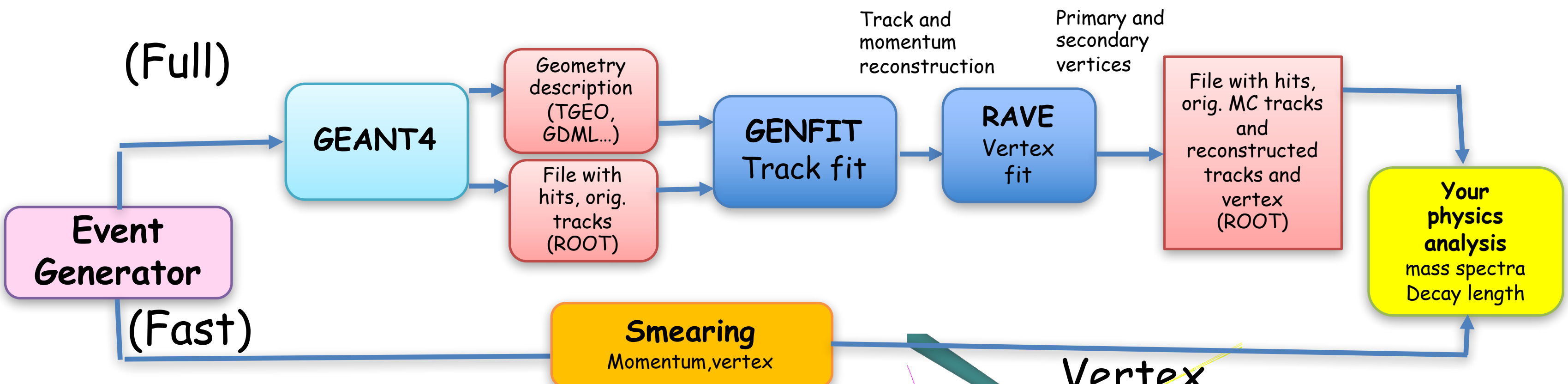
ePhenix “Day 1” Detector:
“FunForAll”



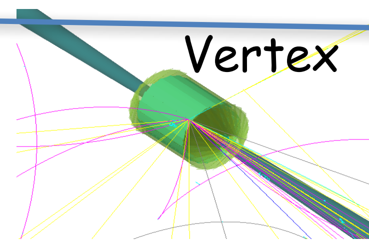
	Simulation			
	Generic Geant4	**GEMC**	**Fun4all**	**eicROOT**
dRICH		for JLEIC and PHENIX 	planned	
mRICH		 single modul for JLEIC 	for sPHENIX 	in progress
DIRC	 Full setup  prototype	planned	planned	straightforward (from FairROOT)
psTOF			for sPHENIX 	

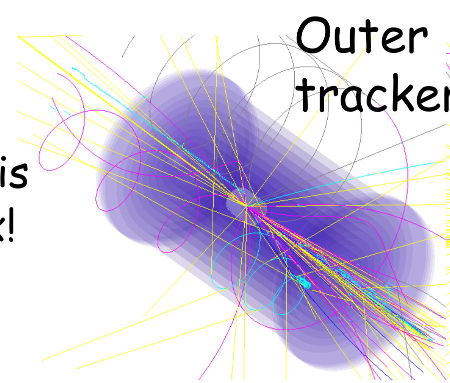
Reconstruction Chain (for LDRD)

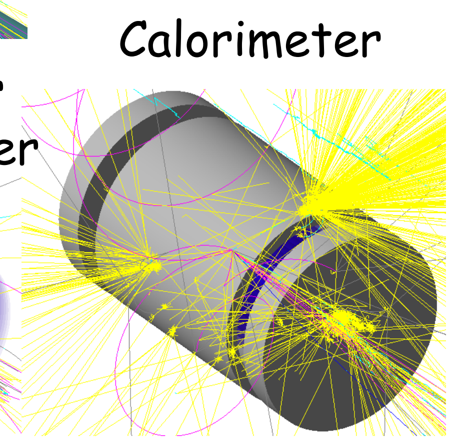
This chain has been developed to validate tracking and vertex parameters and was used for JLAB LDRD- 1601/1701 project ("Nuclear gluons with charm at EIC") to estimate a detector effect on a charm reconstruction. (Many thanks to Whitney Armstrong, Alexander Kiselev and "software consortium" for ideas and discussions)



- Geometry created/described **inside GEANT4**, and then distributed via **Root TGEO**
- All parts are connected via intermediate **Root files** (ntuples)
- Event generators (Pythia6, Herwig 6 and 7) HEPMC, Lund format.
- Original (MC) tracks are traced down to analysis
- No pattern recognition ! Only track fit and vtx!

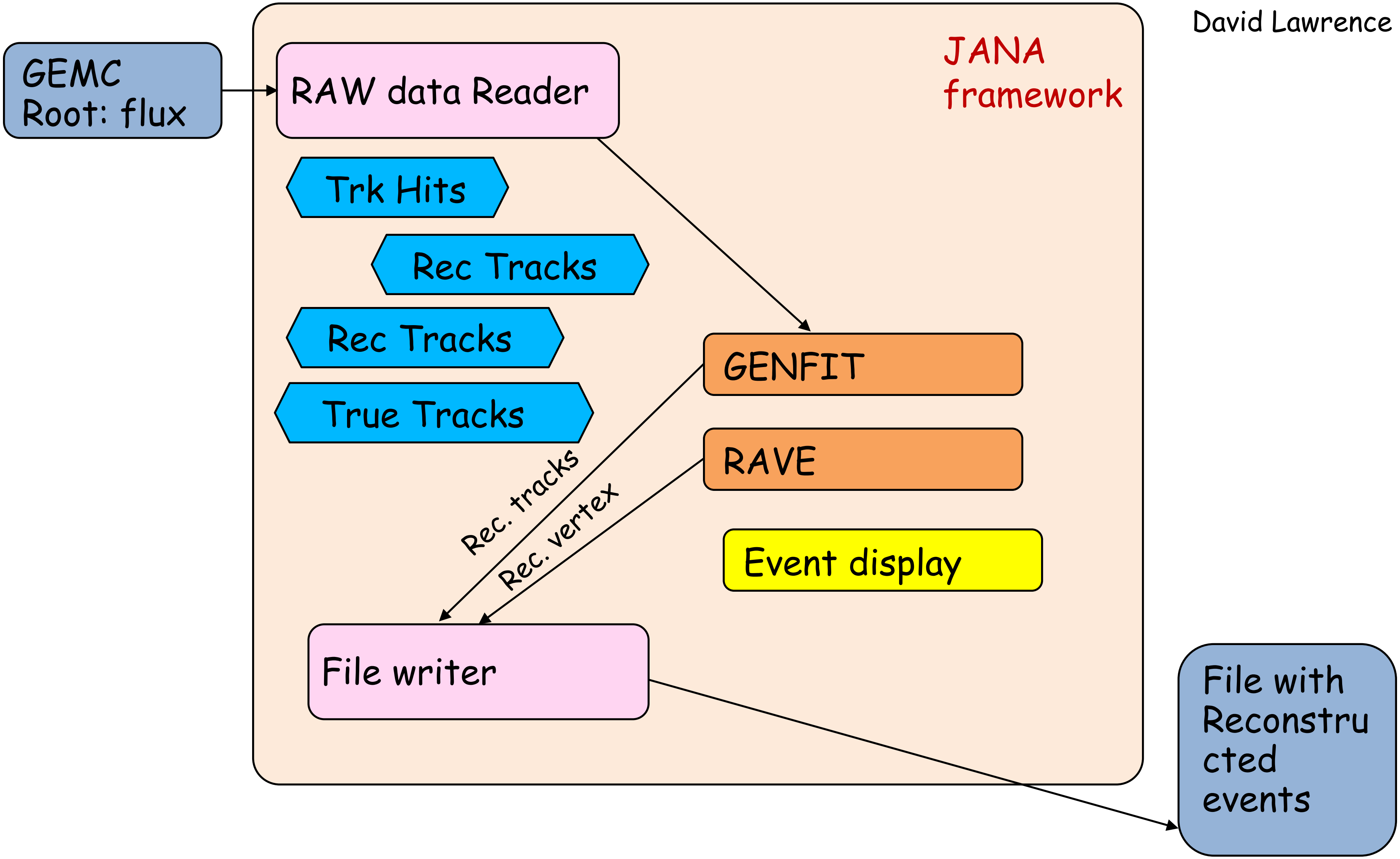






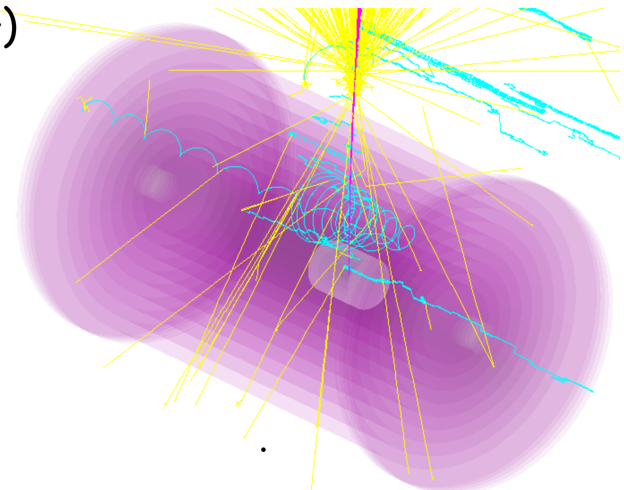
JANA based reconstruction (in progress)

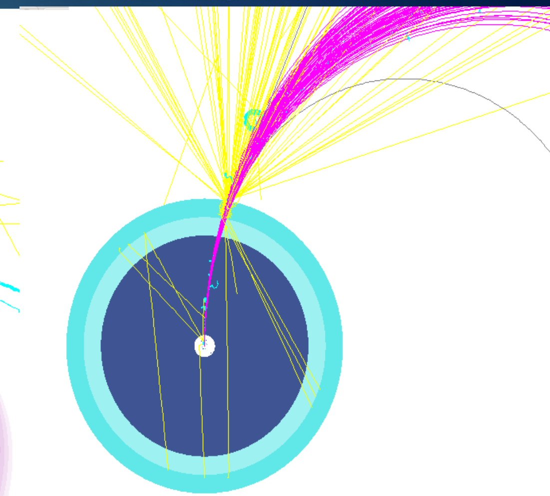
David Lawrence



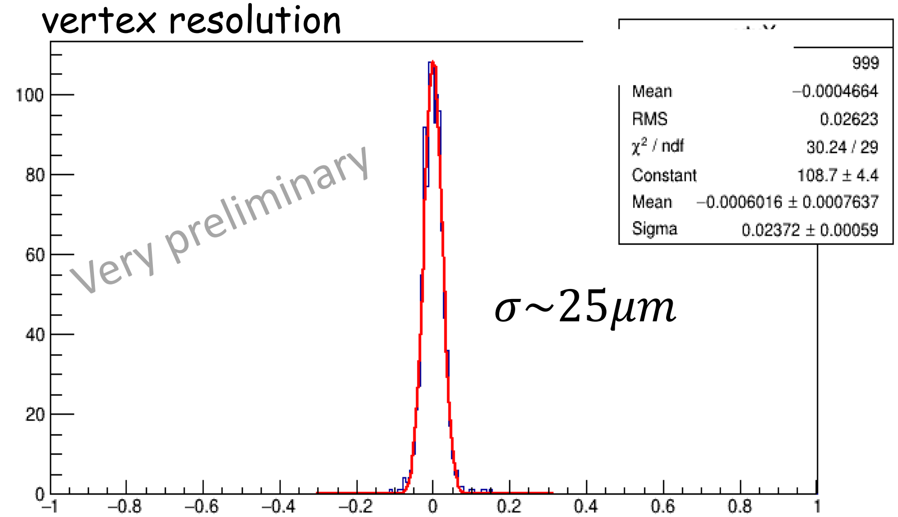
Tracking

- Event generator (Pythia /HERWIG) -> GEANT4 ->Genfit ->RAVE
- Position and granularity of first layers in vertex det. defines vertex resolution
- Benchmarks of tracking and vertex performance are ongoing

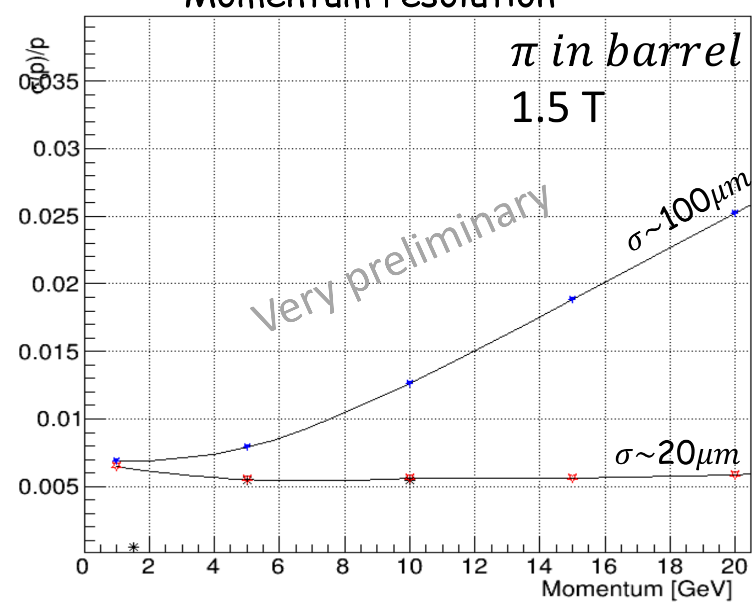




vertex resolution



Momentum resolution

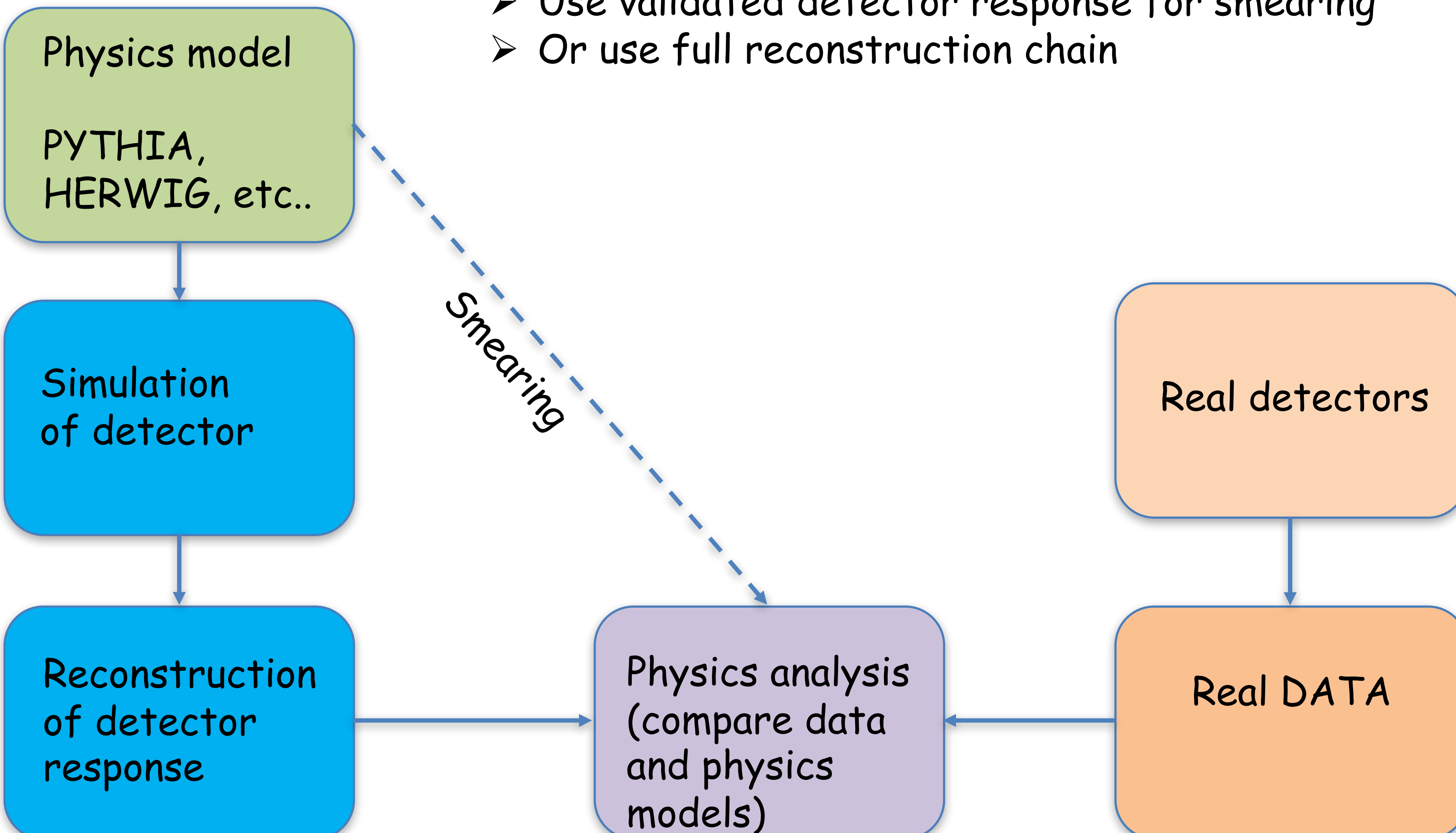


Yulia Furletova

Yulia Furletova

Simulation chain

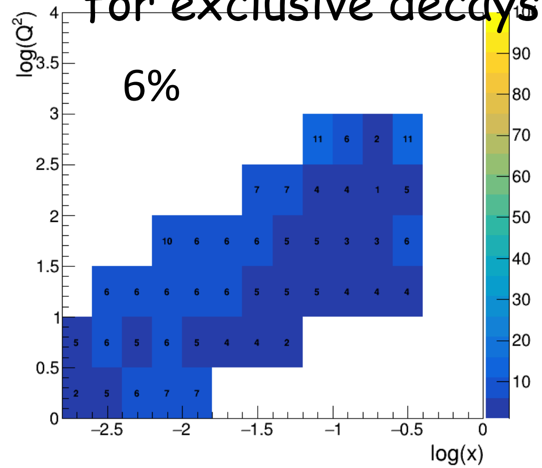
- Use validated detector response for smearing
- Or use full reconstruction chain

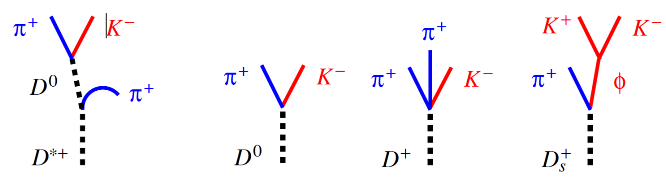


Analysis

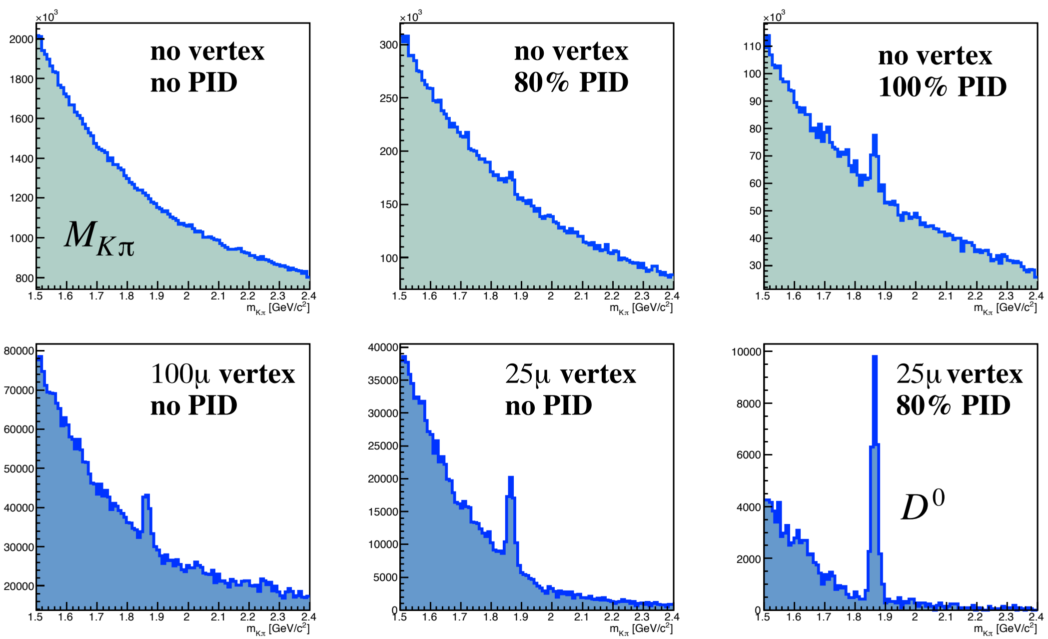
- ✓ Process charm (BGF)-only events
- ✓ Process and add all "background" events (all other non -BGF DIS events)
- ✓ Estimate efficiency and set a requirements for detector (PID, vertex, etc)

Charm efficiency
for exclusive decays



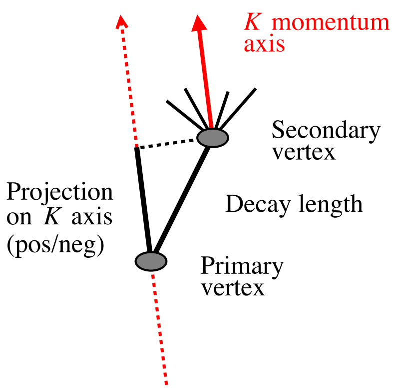


D^0 on top of DIS background

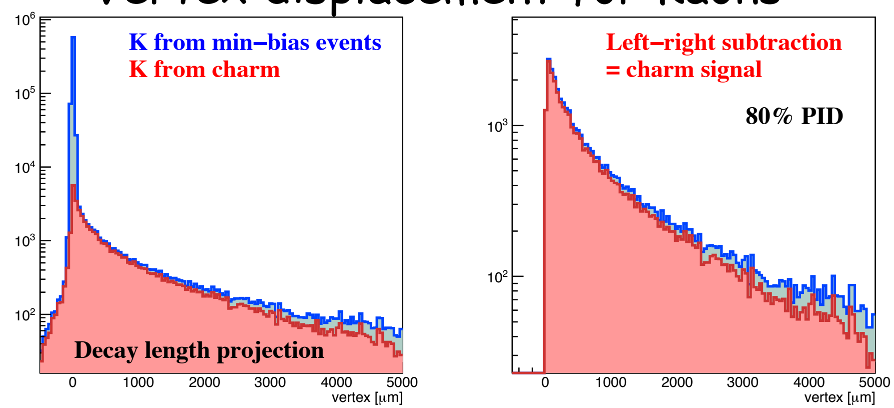


Analysis

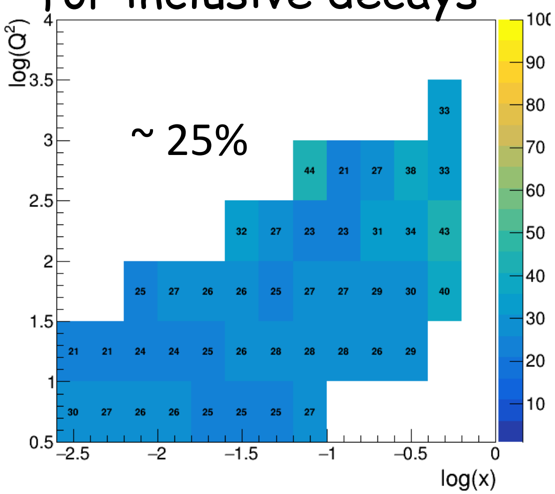
- ✓ Process charm (BGF)-only events
- ✓ Process and add all "background" events (all other non -BGF DIS events)
- ✓ Estimate efficiency and set a requirements for detector (PID, vertex, etc)

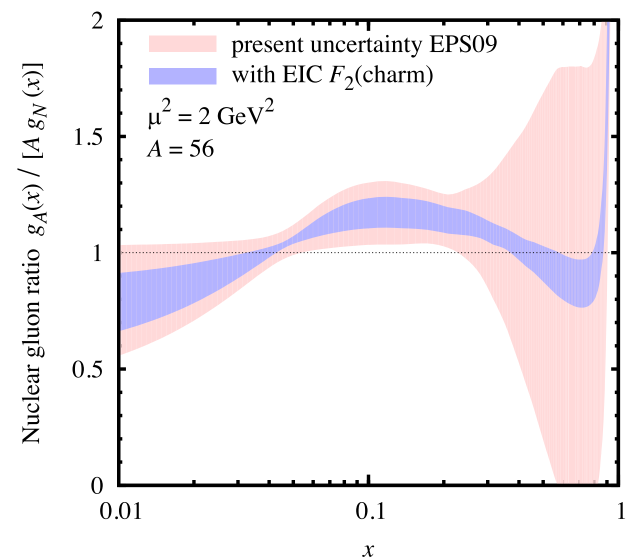


Vertex displacement for Kaons



Charm efficiency for inclusive decays





Next step: Database of Reconstructed events

Get involved | Full Search | Experiments | Manual | Mirrors | Tools | About | Login

Full documentation

Show all

$p \rightarrow\leftarrow p$
- 8 TeV
- 13 TeV
- 14 TeV
- 27 TeV
- 33 TeV
- 100 TeV

$e^+ \rightarrow\leftarrow e^-$
- 250 GeV
- 380 GeV
- 500 GeV
- 1 TeV
- 3 TeV

$\mu^+ \rightarrow\leftarrow \mu^-$
- 1 TeV
- 5 TeV
- 10 TeV
- 20 TeV
- 40 TeV

List of colliders and their center of mass energies

HepSim

Repository with Monte Carlo simulations for particle physics

Summary of "*gev35ep_lepto6ard_dislowq2*"

Information about event generator and sample size

Name:	*gev35ep_lepto6ard_dislowq2*
Collisions:	e-p
CM Energy:	0.035 TeV
Entry ID:	276
Topic:	SM
Generator:	LEPTO/ARIADNE
Calculation level:	LO+PS+hadronisation
Process:	DIS events at Q2>1 GeV2 and W2>4 GeV2
Total events:	25000000
Number of files:	500
Cross section (σ):	4.376E+05 ± 1957.1871 pb
Luminosity (L):	57.1245 pb^{-1} *(or)* 0.0571 fb^{-1} *(or)* 5.712E-05 ab^{-1}
Format:	ProMC
Download URL:	http://mc1.hep.anl.gov/web/hepsim/events/ep/35gev/lepto6ard_dislowq2/
Status:	Available
Mirrors:	http://eicsim01.jlab.org/hepsim/events/ep/35gev/lepto6ard_dislowq2/ http://mc.hep.anl.gov/asc/hepsim/events/ep/35gev/lepto6ard_dislowq2/ http://portal.nersc.gov/project/m1758/data/events/ep/35gev/lepto6ard_dislowq2/
EVGEN size:	[illegible] GB
	Tags:
Fast simulation:	
Full simulation:	rfull058 | Info 519 / 13.03 GB 06/28/2017 rfull057 | Info 484 / 15.50 GB 06/19/2017 rfull056 | Info 496 / 12.43 GB 05/17/2017
Fast/Full size:	[illegible] GB
Record slimmed:	No
Events weighted:	No
Submission time:	Wed May 17 16:30:14 CDT 2017
Updated on:	Mon Jul 24 14:44:56 CDT 2017

Full detector simulations + reconstructions

Next steps

- Pattern recognition (track finding).
- Global PID (information from all detectors):Machine learning?
- Jet finding (jet identification : gluon vs quark vs tau?): machine learning ?
- add “non-physics” background (synchrotron, cosmic, halo, etc)

- Move part of reconstruction into online event processing (FPGA, trigger)

EIC offers lots of opportunities for you!

Center for Frontiers in Nuclear Science

CFNS activities in 2018

http://www.stonybrook.edu/cfns/

- **Funded by Simon's Foundation and New York State**
- An initiative supported by Stony Brook University and BNL
- **All members of EIC Users Group are welcome to participate & lead the Center's activities**
- **Physics topics/Workshops:**
  - Pre-DIS workshop on EIC and its connections to other areas (April 2018)
  - GPD measurements at the EIC (Workshop in June, 2018)
  - Short Range Nuclear correlations EIC at FRIB (September 2018)
  - Entropy Entanglement and connections to Confinement (September 2018)
  - Ultrahigh energy gamma rays and EIC (TBD 2018)
  - Inaugural meeting of the Center (November 2018)
- Bi-Monthly Seminars on Blue Jeans (see web pages)
- Post doctoral fellow program launched
- Visitor program to start in Summer 2018
- A EIC QCD summer school planned 1st one in 2019.
- If you want to participate: Please contact me (Abhay Deshpande)

EIC²
EIC Center at Jefferson Lab

Center for EIC at Jefferson Lab

https://www.eiccenter.org/eic-center-jefferson-lab

EIC Center at Jefferson Lab (EIC²@Jlab) is organized to advance and promote the science program at a future EIC facility. Particular emphasis is on the close connection of EIC science to the current 12 GeV CEBAF program.

Consolidates and connects EIC Physics and detector development activities at/around Jlab including:

- Weekly meetings, hosting and organizing adhoc meetings, keeping documentation on EIC and JLEIC
- LDRD projects, EIC Detector R&D funded activities, HUGS Summer School, local hosting of visitors and planning of EICUG activities
- Graduate student and post doctoral fellow program
- Participation & activities coordinated by Rik Yoshida

Thank you!