Machine Backgrounds Fast Detector Simulation and a Muon Collider

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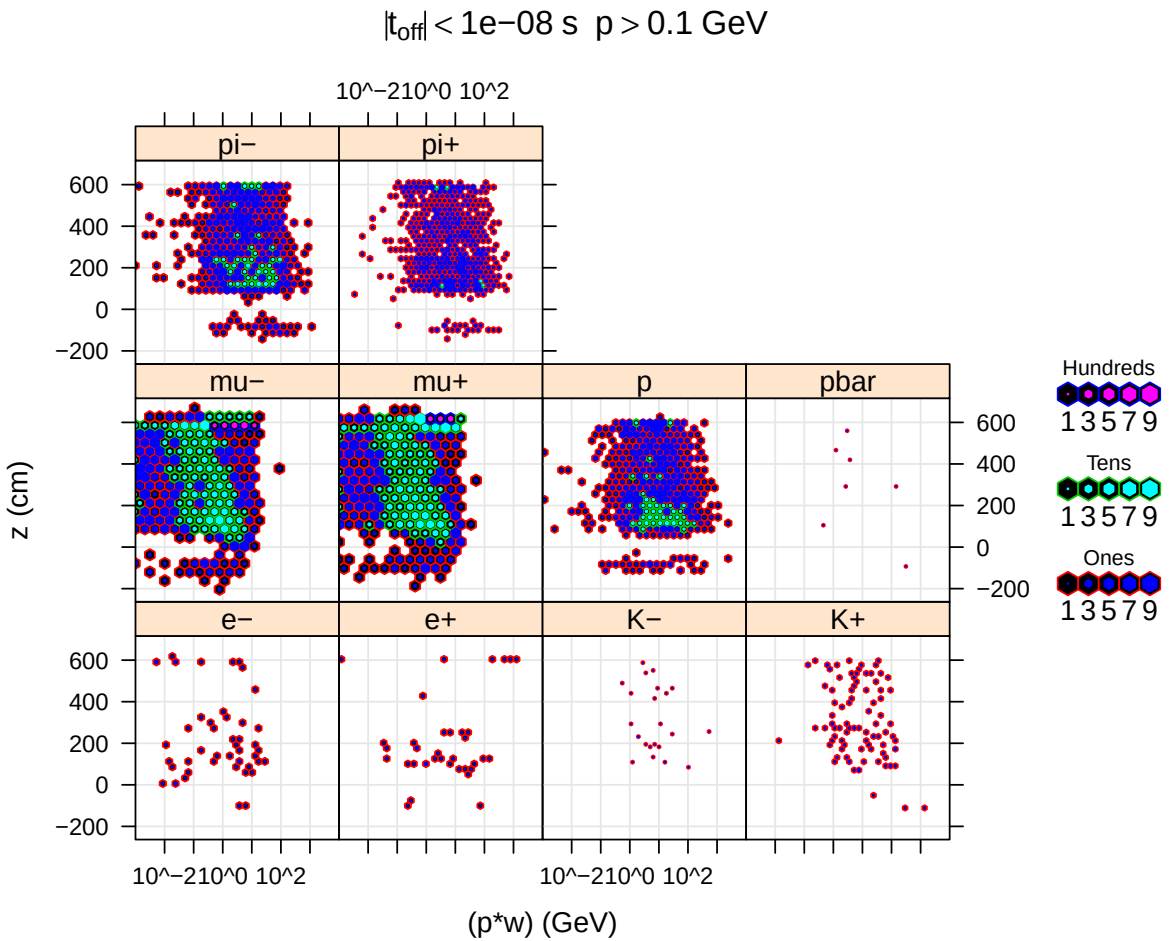
Machine Backgrounds at a Muon Collider

Large flux of particles appearing on the boundaries of the detector.



Need to Understand the Impact

Physics Issues:

- Can we distinguish W from Z boson hadronic decays?
- Does the limited geometry allow sensitivity to t-channel (e.g. vector boson fusion) processes?
- What is the mass resolution for new particle measurements?

! These questions can only be answered with Monte Carlo studies.

!! This must be done without a clear specification of the geometry, or with the flexibity to study the affect of changes.

!!! We require some computing framework for these studies.

Path:Fast Simulation

Fast≡

Smear the properties of MC truth particles.

Why?

it is easy ⇒ limited resources

exploratory tool ⇒ easy to iterate

Machine Backgrounds

Potential show-stopper.
Study `MARS` simulation to see how to incorporate into this simple picture.

Deciphering the MARS file

```
NI - decay #
JJ - particle ID, reaching detector
X,Y,Z - coordinates on interface surface (cm)
PX,PY,PZ,PA - momentum components and total momentum (GeV/c)
TOFF - time with respect to bunch crossing
W - particle weight
Z0 - coordinate of particle origin (cm)
```

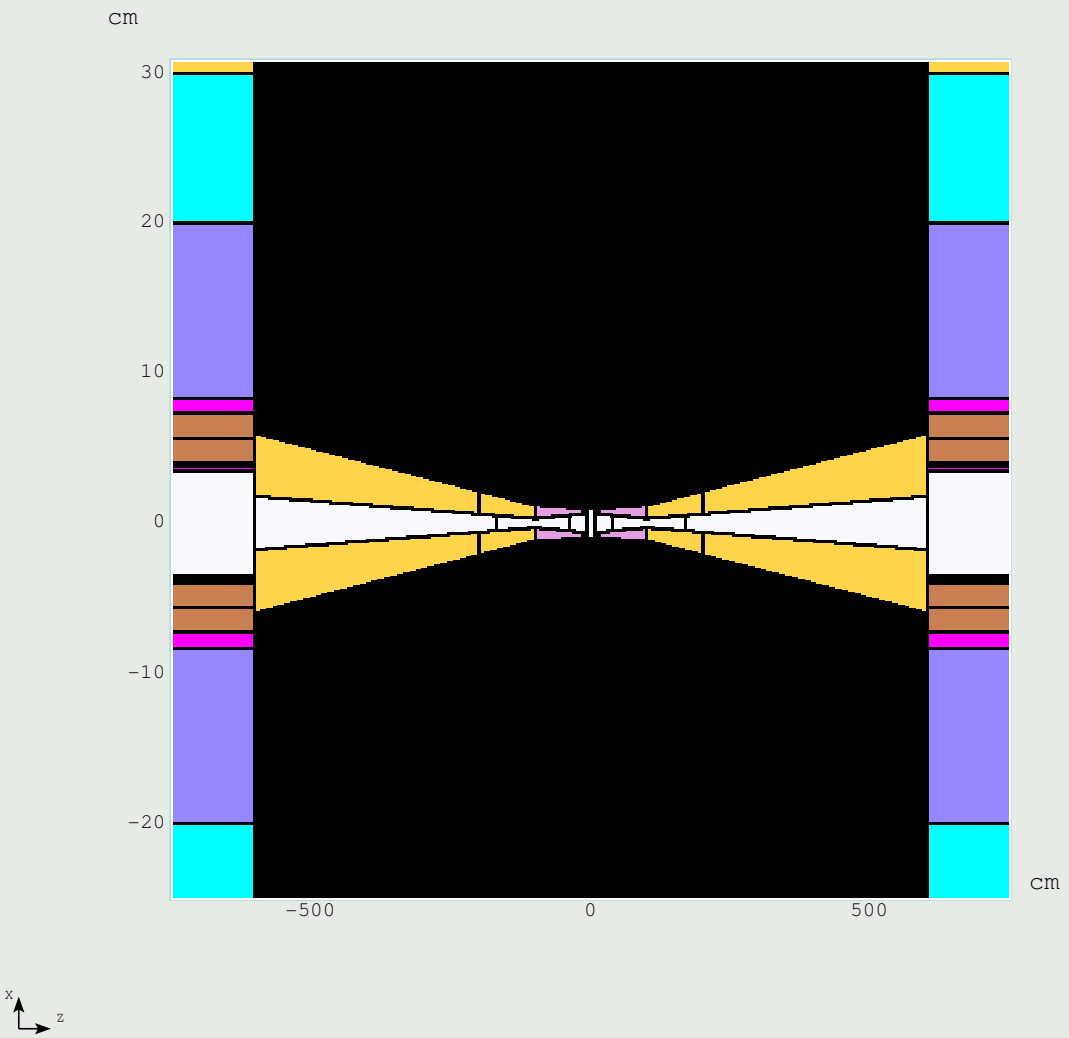
decay	id	x	y	z	px	py	pz	p	toff	w	z0
5	9	1.718	0.020	153.951	1.858623E-03	-5.183366E-04	-1.348825E-03	2.354247E-03	1.978998E-08	5.596592E+02	1.085038E+03
5	9	-0.786	-0.978	105.732	-4.792757E-04	-5.433809E-04	-3.780733E-04	8.172560E-04	2.107474E-08	1.850762E+02	1.085038E+03
5	9	-2.155	1.113	227.622	-6.915289E-03	9.044967E-04	-8.121261E-04	7.021316E-03	1.715434E-08	1.943835E+02	1.085038E+03
8	9	-0.638	-3.550	350.697	-4.297531E-04	-5.012345E-04	4.185087E-04	7.817117E-04	1.240415E-08	8.387614E-01	3.489513E+02
8	9	-2.596	1.179	271.998	-8.413413E-04	-1.588334E-04	-1.844254E-03	2.033312E-03	1.482912E-08	3.007497E+00	2.745177E+02
8	9	-2.653	0.787	263.243	-3.852254E-03	-1.052649E-04	-4.855235E-03	6.198730E-03	1.512186E-08	1.136565E+00	2.656267E+02
8	9	-1.556	2.171	253.253	-5.391744E-04	5.957302E-04	-1.105958E-03	1.367021E-03	1.545227E-08	3.130442E+00	2.542738E+02
8	9	-0.851	2.509	251.020	3.219239E-05	1.487776E-04	-1.313763E-04	2.010743E-04	1.552275E-08	1.100041E+01	2.517103E+02
8	7	-1.742	1.898	243.393	-1.621438E-01	-3.791175E-02	-1.145484E+00	1.157524E+00	1.576718E-08	8.387614E-01	3.544083E+02
8	2	2.637	-2.394	345.990	9.879301E-03	-1.227619E-03	-1.627891E-02	1.908168E-02	1.530569E-08	3.067177E+00	3.489513E+02
8	2	-4.863	1.556	506.874	-1.338025E-02	-1.913888E-02	-1.402610E-02	2.724077E-02	2.358759E-08	3.645443E+01	5.069991E+02
8	2	-4.561	2.317	507.920	-9.315572E-03	-2.385591E-03	1.152890E-02	1.501288E-02	1.902970E-08	3.699836E+01	5.069991E+02
8	2	-2.910	3.297	433.051	9.274771E-05	1.619071E-02	1.059491E-02	1.934941E-02	2.356280E-08	5.387367E+01	4.321329E+02
10	9	3.377	-0.669	333.588	2.333604E-03	-8.643112E-04	-9.541865E-04	2.665186E-03	1.589207E-08	3.015682E+02	9.215784E+02
18	9	-1.121	0.032	-66.272	-5.186077E-04	-1.595812E-04	-1.879028E-04	5.742191E-04	1.758482E-08	3.085919E+02	1.094569E+03
18	2	0.804	0.964	105.779	3.349366E-02	5.026503E-02	-6.712780E-02	9.030249E-02	1.225021E-08	6.156649E+01	1.074941E+02
18	2	-0.888	0.889	105.862	-3.436396E-02	4.968984E-02	-6.711616E-02	9.030249E-02	1.221144E-08	6.156649E+01	1.074941E+02
18	9	-0.368	-1.209	106.633	-7.754968E-03	-2.148885E-02	-2.086003E-02	3.093624E-02	1.148824E-08	2.467809E+02	1.074941E+02
18	11	0.405	-1.184	105.384	2.995978E-03	-8.277943E-03	-2.132998E-02	2.307527E-02	1.152321E-08	8.699417E+02	1.074941E+02
18	9	0.991	0.661	96.112	3.573725E-03	2.995901E-03	-7.695266E-03	8.998003E-03	1.184274E-08	5.322378E+01	9.925895E+01
18	2	1.085	0.486	95.470	7.670653E-02	4.822889E-02	-2.447501E-03	9.064165E-02	1.253357E-08	2.172680E+02	9.552392E+01
18	2	-0.769	-0.907	95.548	-4.200456E-02	-8.012370E-02	5.631764E-03	9.064165E-02	1.197890E-08	2.172680E+02	9.552392E+01
18	2	0.752	0.907	90.542	7.497166E-02	7.785410E-02	-5.633623E-02	1.218843E-01	1.256726E-08	8.752832E+01	9.159266E+01
18	2	-0.903	0.757	90.924	-2.113029E-02	1.067842E-01	-5.483092E-02	1.218843E-01	1.236334E-08	8.752832E+01	9.159266E+01
18	2	-0.879	-0.787	91.422	-7.530713E-02	-7.837764E-02	-5.515037E-02	1.218843E-01	1.207583E-08	8.752832E+01	9.159266E+01
18	9	0.119	-1.169	89.378	4.965077E-03	-8.011697E-03	-9.719564E-03	1.353917E-02	1.206494E-08	1.526185E+02	9.159266E+01

...

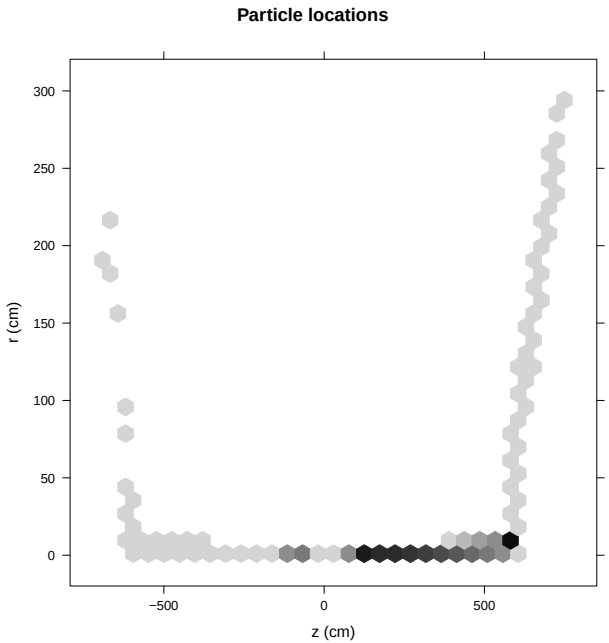
All of the elements of a generator particle record, but with weights

Interface Surface

x,y,z near detector surface



- Based on basic dimensions of SiD
- Particles on edge of detector region
- R dimension is cut off in figure



How to use the MARS output?

Continuum (Classical)

Bath of low energy particles

Degrades resolution

Blackens detector

Occupancy

- Volume
- Resolutions

Smearing functions

Discrete (Quantum)

10-100s High-energy particles

Like pile-up, minimum bias

- Cuts
- Isolation

Overlay particles

First Steps

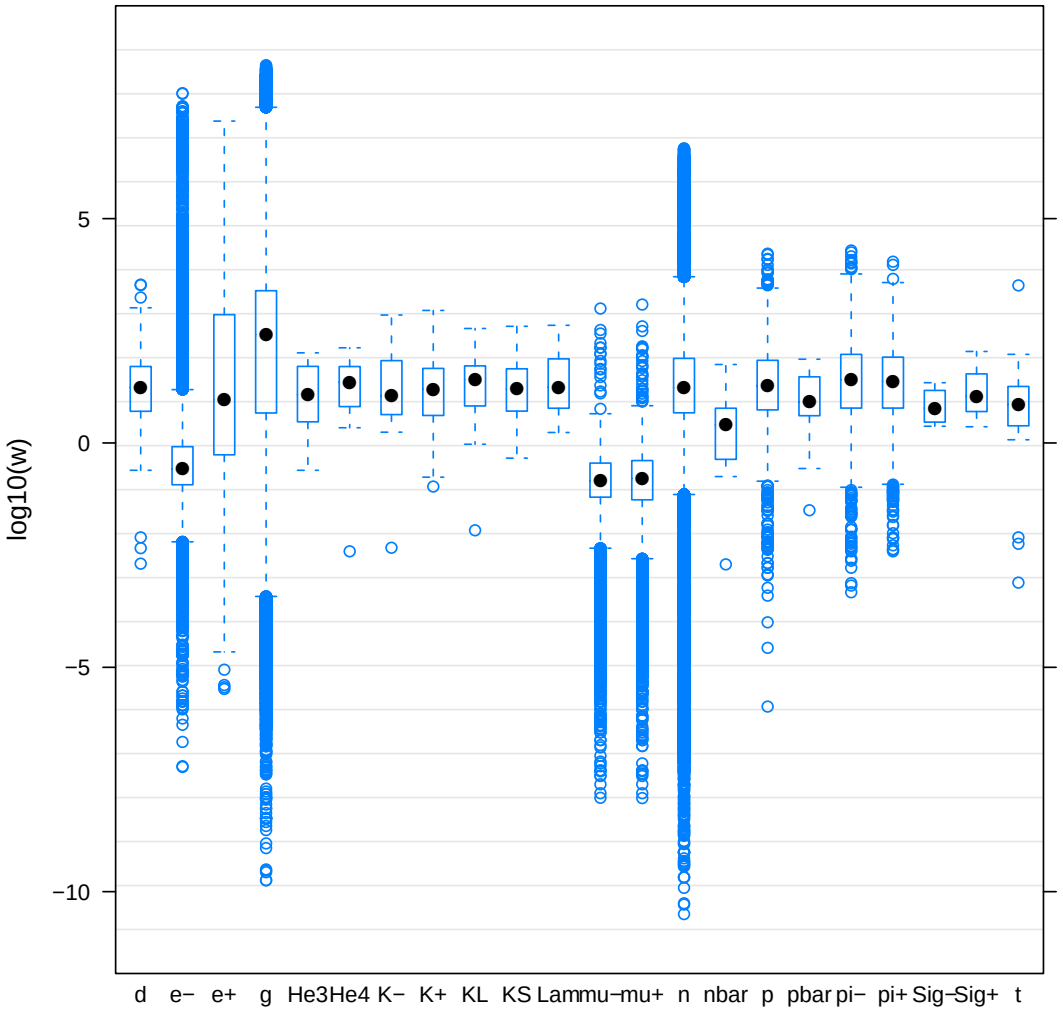
Considerations

Simulating a bunch with 10^{12} particles
Tails may be biased (high or low)
1 kinematic configuration = large number of pseudo-particles

Basic Distributions

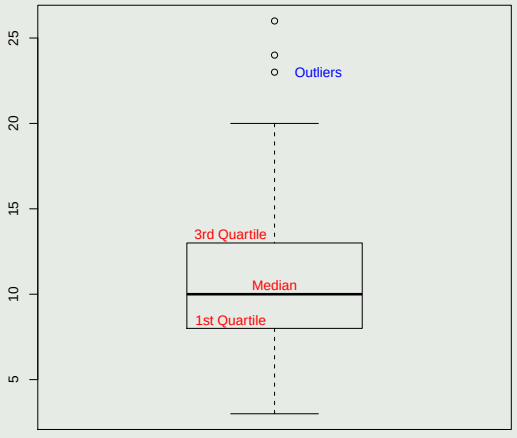
- what particles
- produced where
- with what energy
- timing
- smoothness/sparsity

What particles

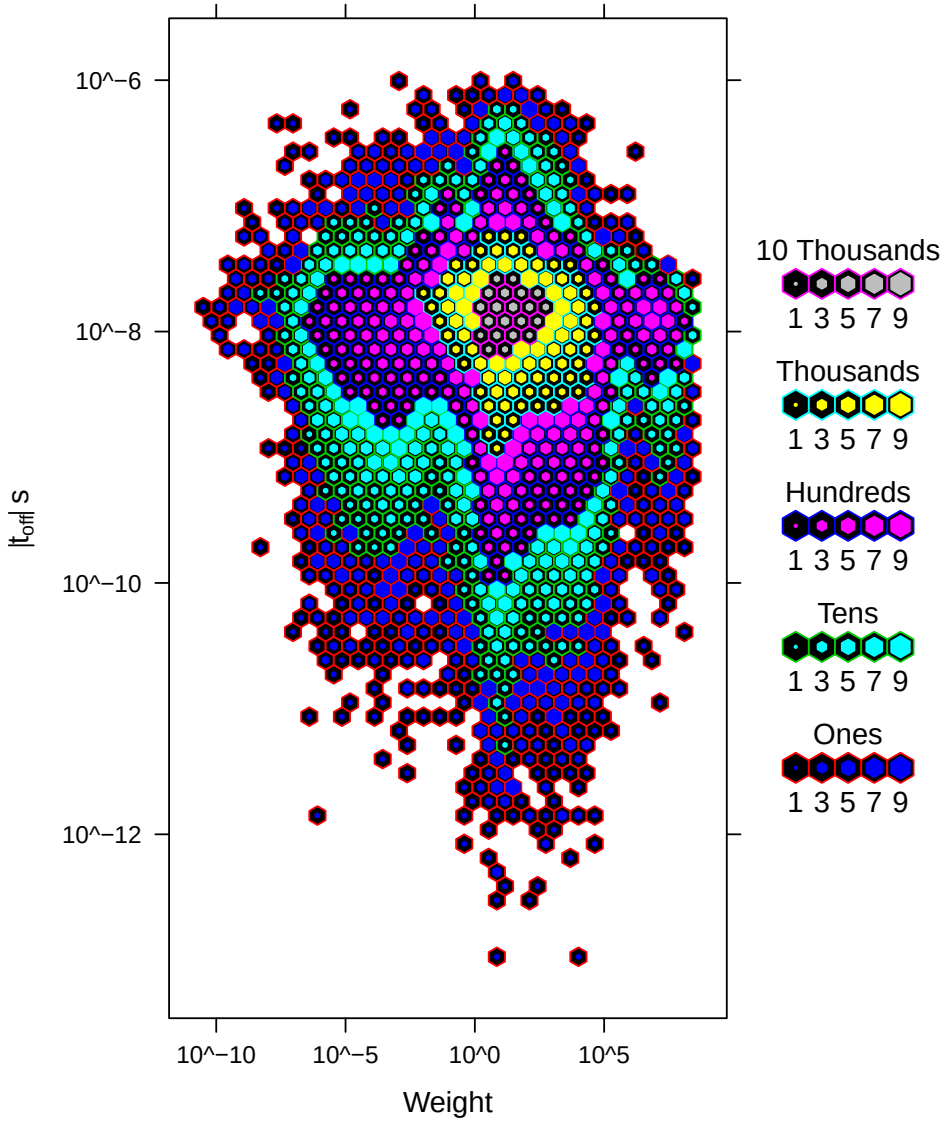


Overview

- many high-weight particles
- mostly $e^{\pm}/\gamma/\mathrm{n}$
- median w $\sim$ 10



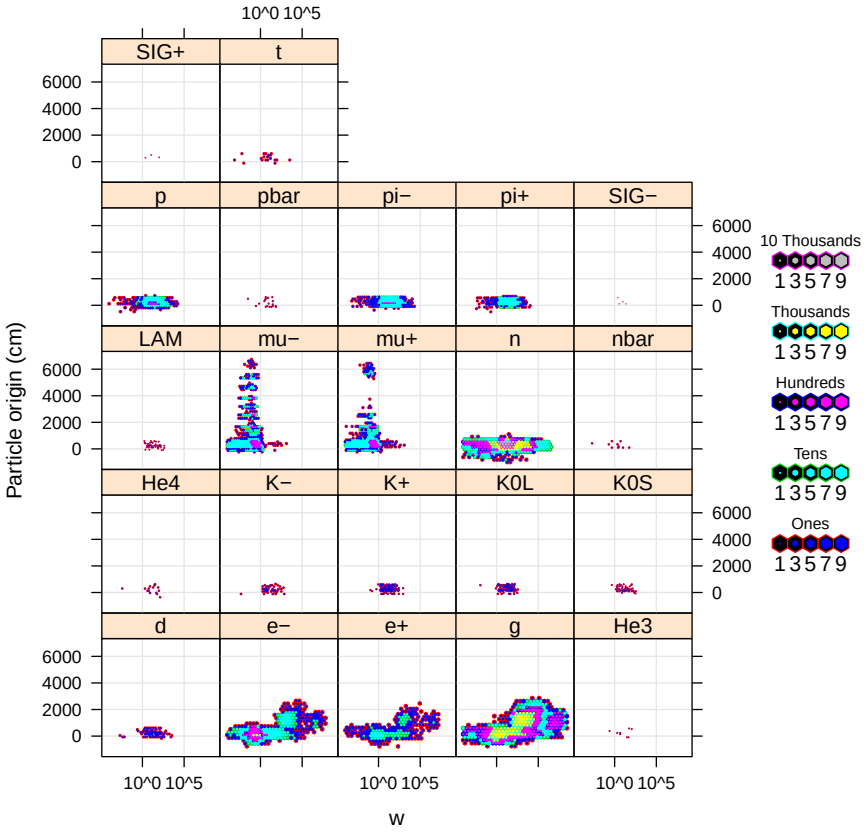
Arrival time

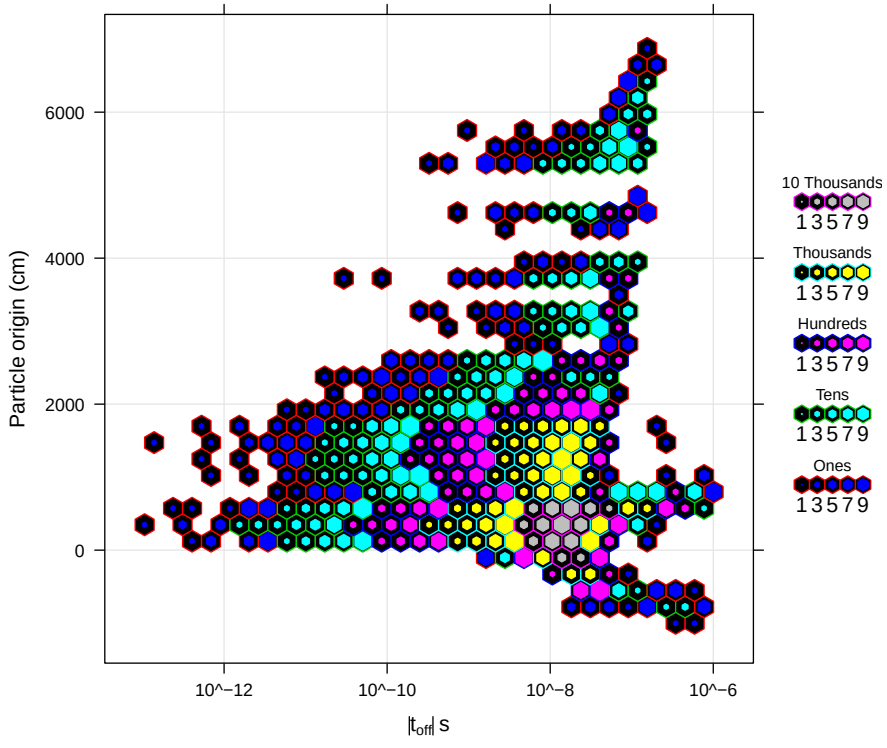


Overview

- particles concentrated around 10^{-8} s
- timing cut does not remove high weights

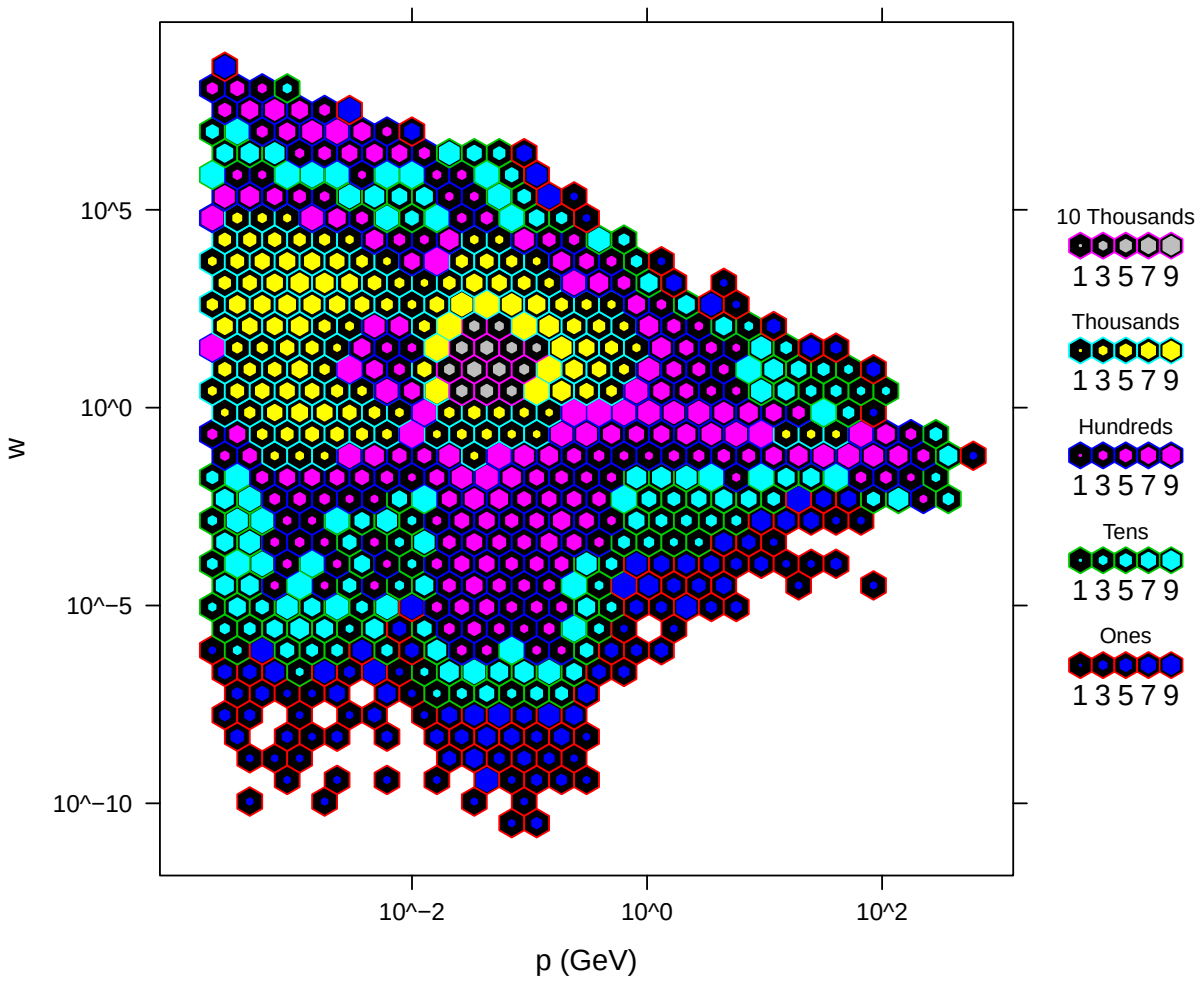
Origin and Timing





Most particles produced $<$ 20m

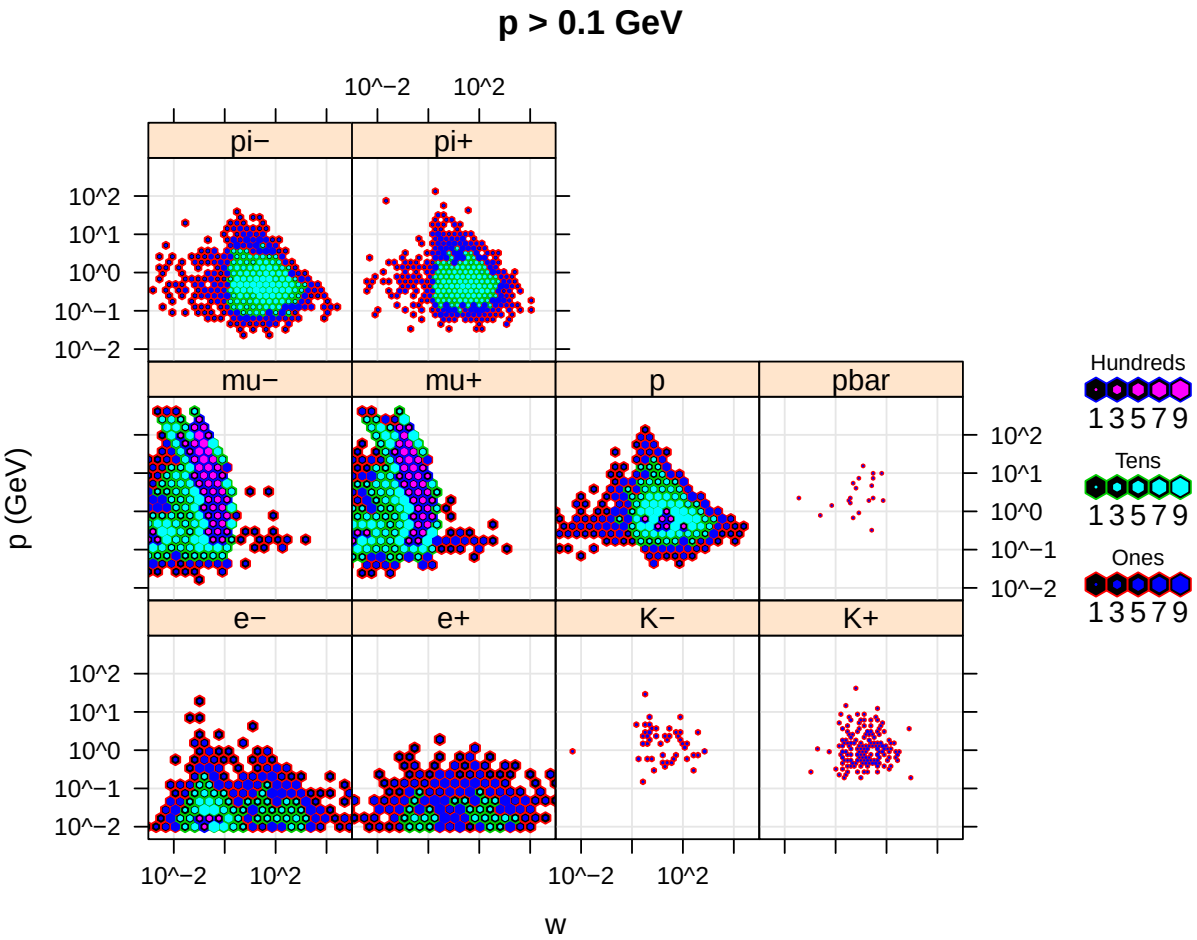
Momentum of particles



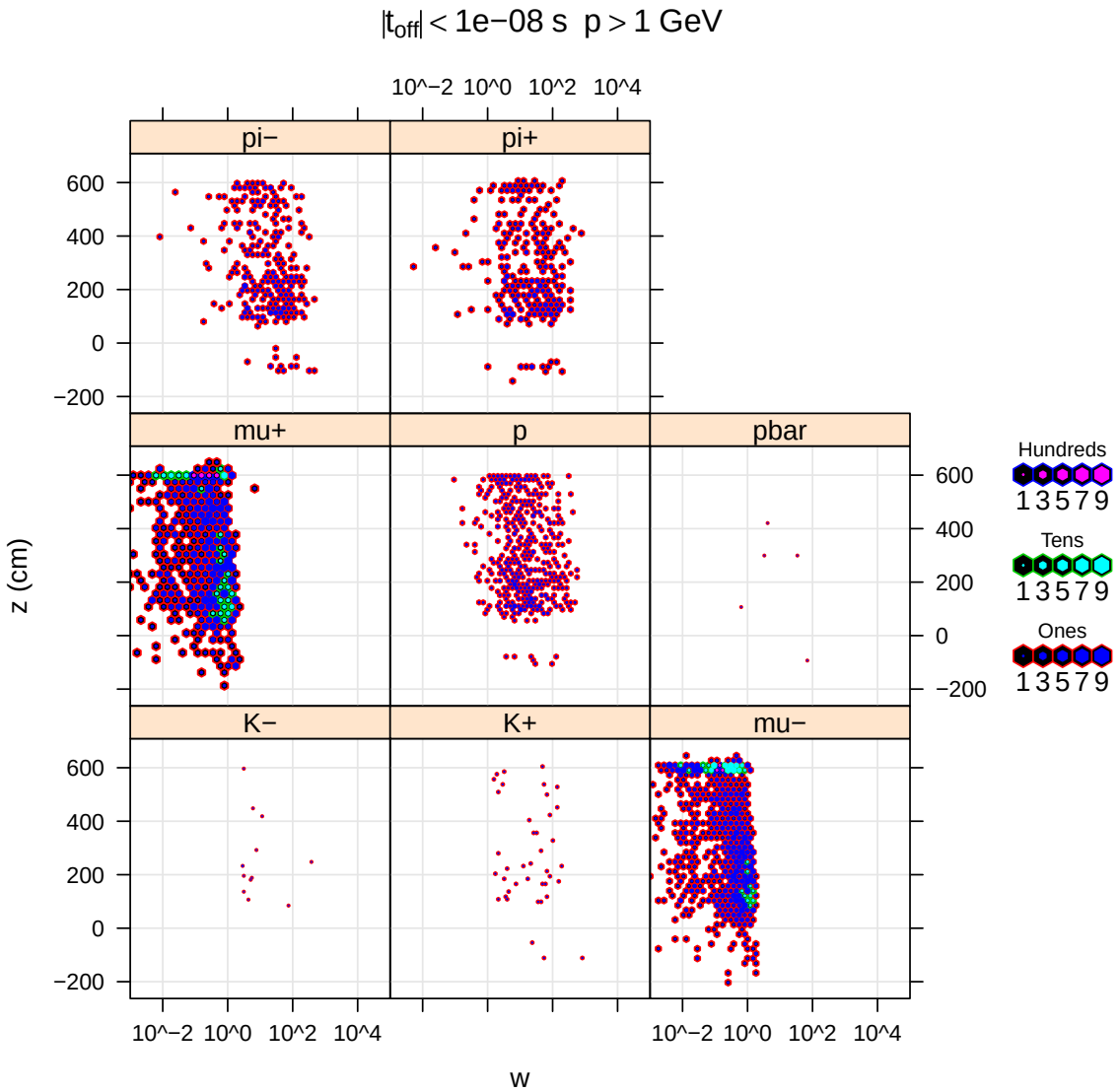
Overview

- particles concentrated around .001-1. GeV
- high-energy tail still has sizeable weights

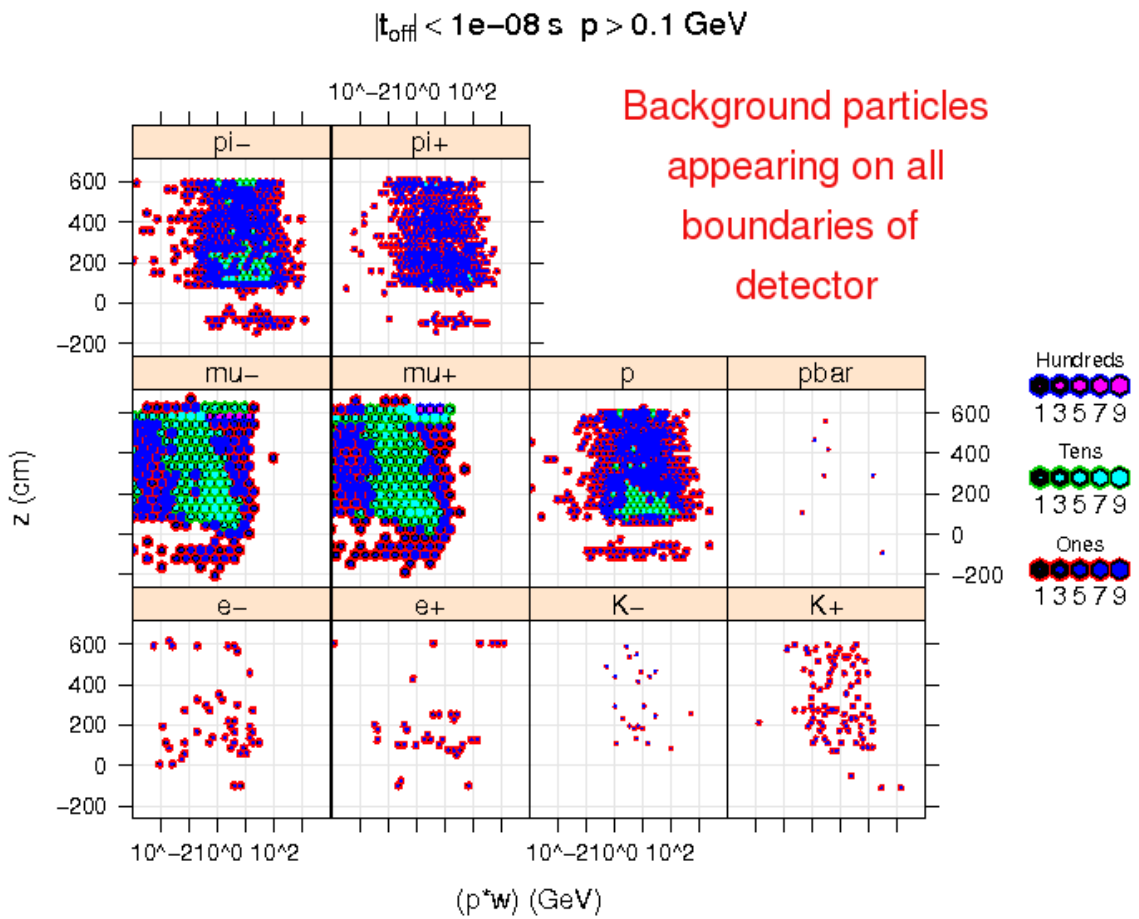
Charged particles



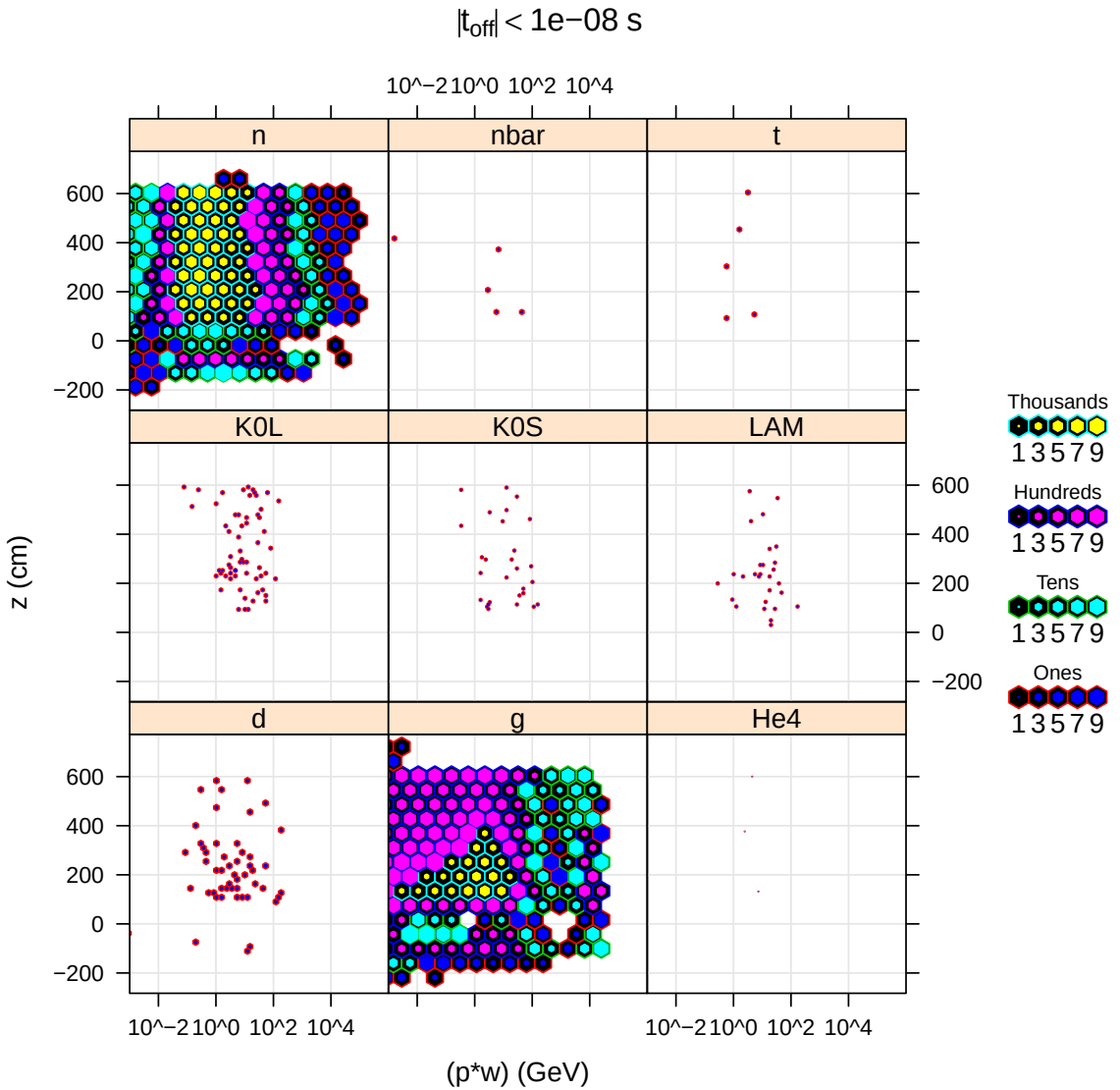
Location of produced particles



Weighted momentum:Charged



Weighted momentum:Neutrals



Analysis

- Too many high-weight particles (even at high energy)
- Locations on interface surface too lumpy

Feedback

- MARS is already producing runs with smaller weights.
- Identified positional symmetries.
- Dedicated MARS runs to produce only high-energy tails.
- Can a continuum approximation be used for low-energy bulk? Cross check full calculation.

Framework Considerations

How to incorporate Machine backgrounds?

1. Smearing functions (E<1 GeV, position dependent)
2. Particle overlay (E$\geq$ 1 GeV, all vertices)

Inadequate FastSims

- PGS (Fortran), Delphi (C++)
  Assume particles originate from Origin

Potential FastSim

- MCFast (C, C++, F90)
  Requires dedicated validation
  Geometry Mapping
  Sophisticated tracking

Framework: Generator Considerations

Some Basic Requirements

Standardization

- HepMC is the standard event info container
- FastJet is the standard Jet algorithm tool

Plug-and-Play

- Different variations of Event Generators (Pythia, Pythia8, Herwig++ ...)
- Different methods of Event Generation (Pythia, Sherpa, MC@NLO ...)

Chaining of Tools

- MadGraph+Pythia+EvtGen+Tauola+Photos(+MARS overlay)

Framework: Fast-Sim Considerations

Validation

- Is the generator doing what is expected?
  Undecayed taus?
  Wrong top mass?
- Is the simulation doing as expected?
  Efficiencies?
  Acceptances?

Automatic Checks

- Basic Histograms + KS tests

Possible Workflow