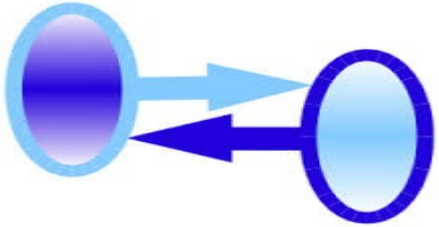


HepSim – Monte Carlo repository for physics and detector studies for future particle experiments

Introduction & Tutorial

S.Chekanov (ANL)

BNL FCC-ee workshop,

April 25, 2023

What is HepSim?

https://atlaswww.hep.anl.gov/hepsim/

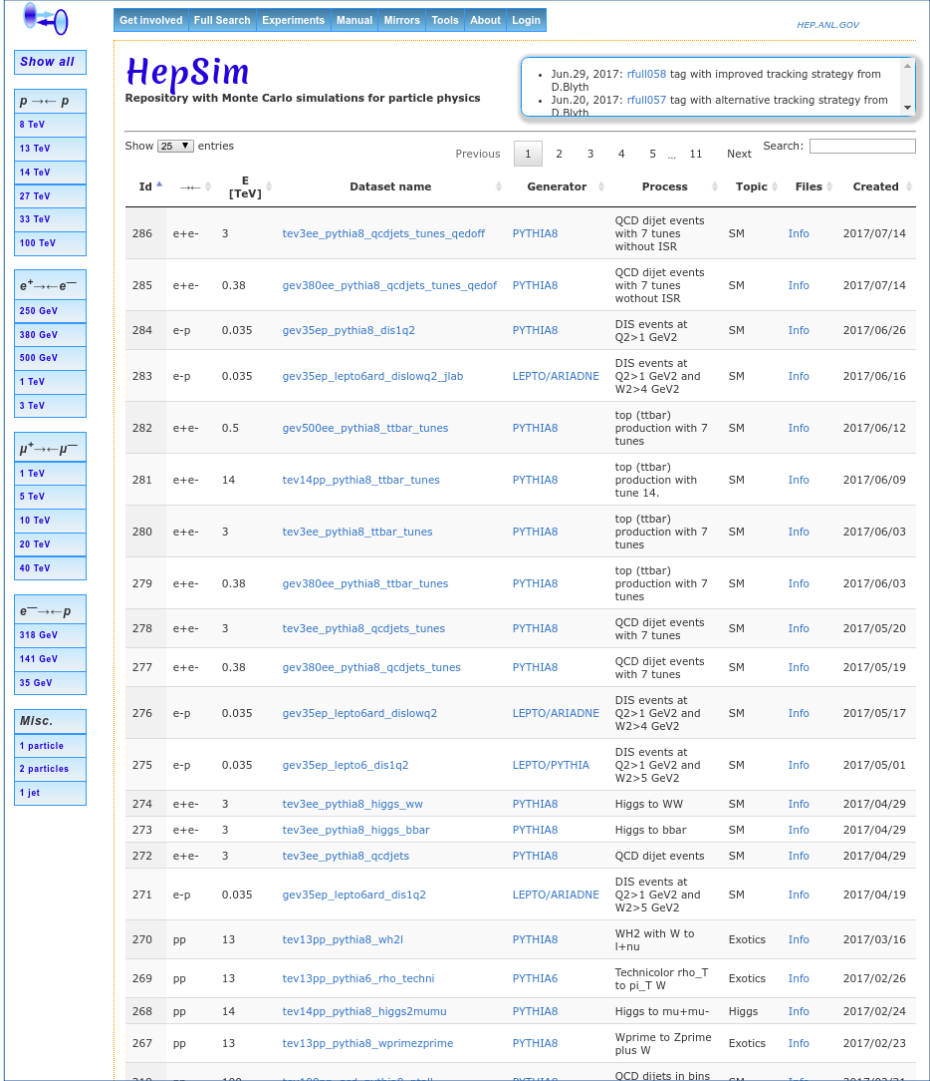
Repository with MC files & software for

- Physics studies (discovery potential, future precision measurements, etc.)
- Exploration of general aspects of detectors using fast and full Geant4 simulations

NOT a file storage: files hosted where convenient using “https” and linked by HepSim

Experiment neutral: Can be used for any current & future experiment & phenomenological paper

Event samples assigned to Digital Object Identifier (DOI) in the form xx.yyyy/zzzzz (see osti.gov link)



What is HepSim?

https://atlaswww.hep.anl.gov/hepsin

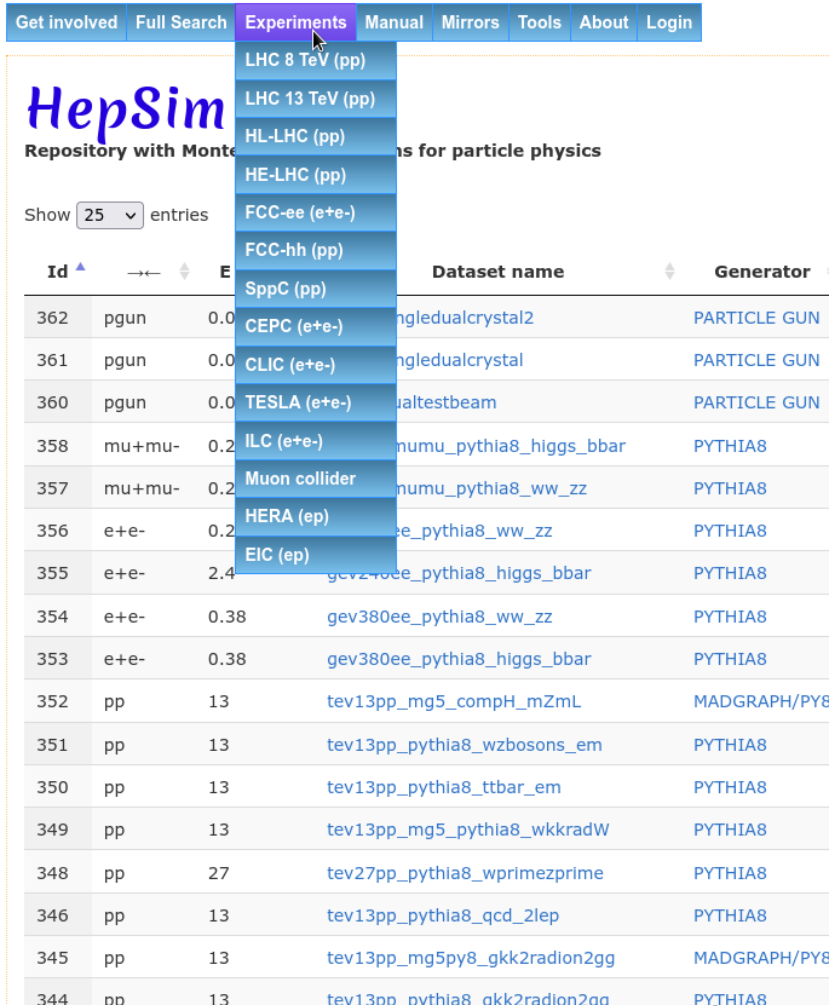
- Consists of a web interface, distributed web storage, command-line tools, Jas3pp event browser, containerized software (docker/singularity image)
- Began at Snowmass 2013 (Top/Higgs, see URL) and evolved to →
- Since 2015 used for physics and detector studies for future experiments (HL-LHC, HE-LHC, FCC, CLIC, CEPC, EIC, etc.) and several ATLAS papers
- 11 conceptual experiments, contributed to ~30 articles ~40 talks (see public results)

Show all

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

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

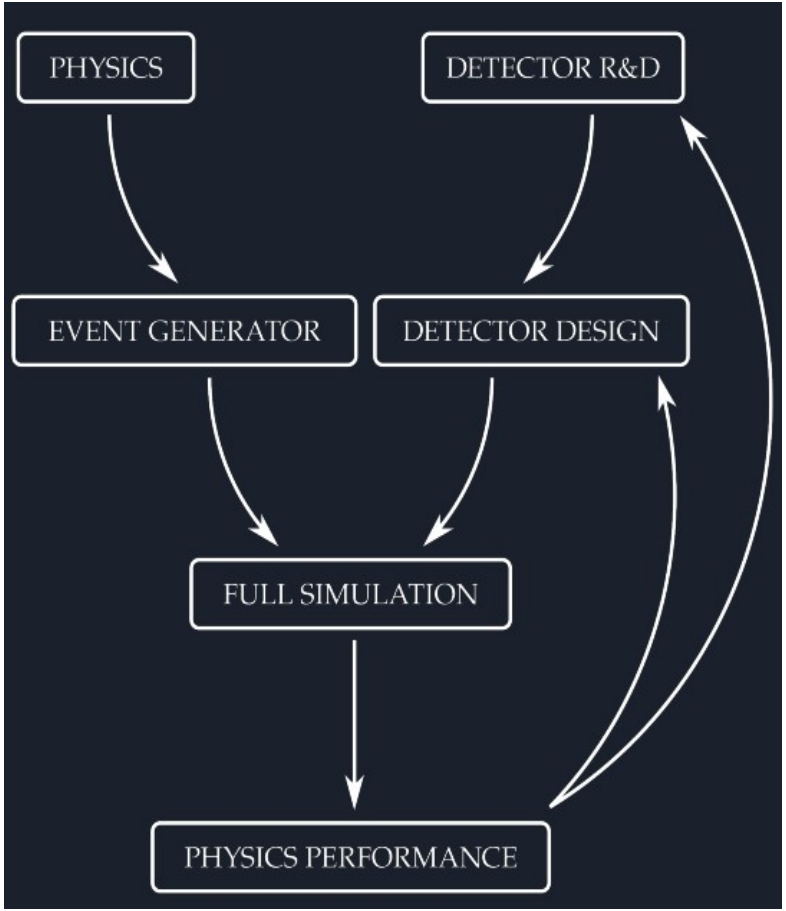
$\mu^+ \rightarrow\leftarrow \mu^-$
250 GeV
1 TeV
5 TeV
10 TeV
20 TeV
40 TeV



Why HepSim?

https://atlaswww.hep.anl.gov/hepsim/

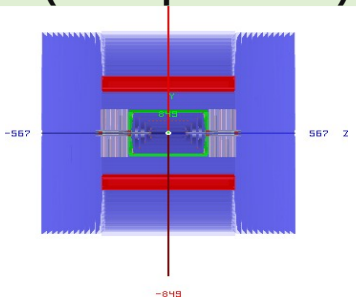
- **Open access**
  - No authentication for use of event files
  - Grab data with *hs-toolkit, wget, curl*, etc… your choice!
- **Preservation of MC data, MC settings and detector geometries**
- **Mitigate reproducibility problem in publications**
  - Published papers can cite HepSim samples using DOI identifies
- **Analysis using platform-independent software on Linux/Mac/Windows (+ URL data streaming)**
- **Cache for iterative experiment design process**



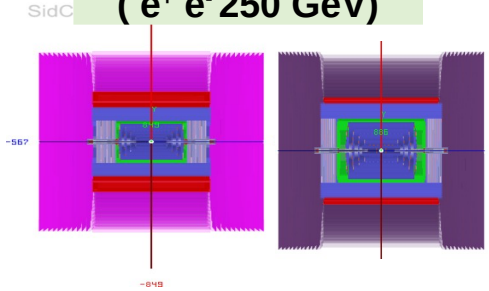
by W.Armstrong

‘All-silicon’ design concepts supported in HepSim

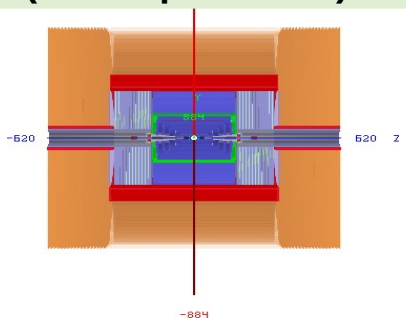
SiD (SiD LO3)
(e^+ e^- up to 1 TeV)



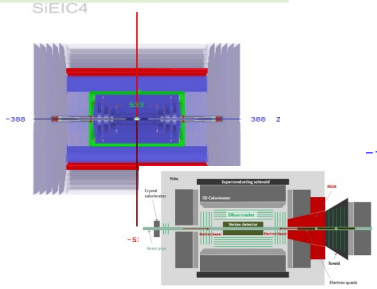
SiCPEC, SiDB
(e^+ e^- 250 GeV)



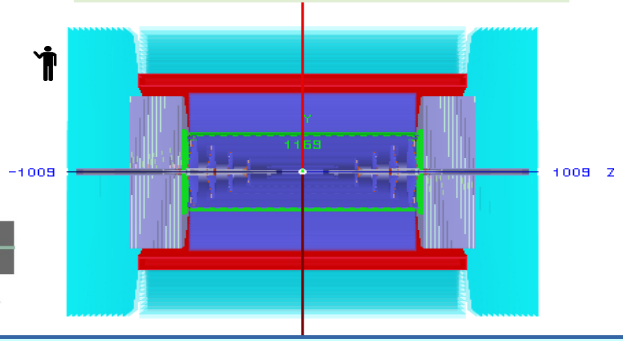
CLIC-SiD (CDR)
(e^+ e^- up to 3 TeV)



SiEIC, TopSide
(ep, 35-141 GeV)



SiFCC + 7 variations
(FCC-hh, pp 100 TeV)



Performance detectors:

- Physics reach studies using Geant4 simulations & full reconstruction
- Playground for various technologies and detector optimizations
- Fast turnover to modify detector & create events samples

Share similar design, but differ in sizes, calorimeter readouts etc

Interfaced with common Monte Carlo samples

Main event file format ProMC and ProIO

http://atlaswww.hep.anl.gov/asc/promc/ and https://github.com/proio-org

- Archive-style self-described format to keep MC events - **ProMC**:
  - Event records, NLO,original logfiles, PDG tables etc.
- 30% smaller files than any existing formats after compression

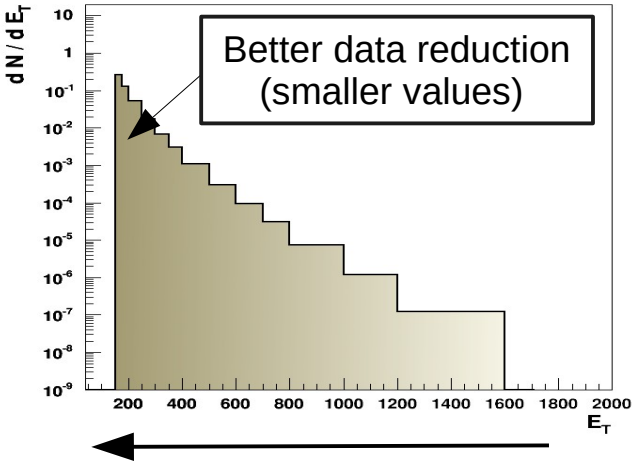
protobuf
Protocol Buffers - Google's data interchange format

Google's Protocol buffers

Number of used bytes depends on values.
Small values use small number of bytes

- Effective file size reduction for pile-up events where particles with small momenta use less bytes
- Separate events can be streamed over the Internet
- Other HepSim formats: **ROOT, LHE** and **LCIO** (full simulation)

8-bytes → varint



compression strength keeping precision of representation constant

ProMC: S.C., E.May, K. Strand, P. Van Gemmeren, Comp. Physics Comm. 185 (2014), 2629

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

HepSim

Repository with Monte Carlo simulations for particle physics

- Apr 15, 2019: Moving to globus (petrel)
- Sep.10 2018: Zprime/DM event samples
- Mar.15 2018: Charged Higgs event samples
- Sep.22 2017: ZHiggs ... nunuHXX event samples

Show 25 entries

Previous 1 2 3 4 5 ... 13 Next Search:

Id	→←	E [TeV]	Dataset name	Generator	Process	Topic	Files	Created
338	pgun	1	pgun_eta0_b0	PARTICLE GUN	Single particles at Eta=Phi=0 with B-field=0	Single particles	Info	2019/09/03
337	pp	14	tev14pp_pythia8_gammajet_weighted	PYTHIA8	Direct photon production	SM	Info	2018/12/16
336	pp	13	tev13pp_pythia8_minbias_a14	PYTHIA8	MinBias (ND+SD+DD) A14	SM	Info	2018/11/23
335	pp	14	tev14pp_pythia8_minbias_a14	PYTHIA8	MinBias (ND+SD+DD) A14	SM	Info	2018/11/22
334	pp	13	tev13pp_mg5_chaH4FNS	MADGRAPH/PY8	Charged Higgs (H+t) production in 4FNS	Exotics	Info	2018/11/10
333	pp	13	tev13pp_pythia8_qcd_jz	PYTHIA8	QCD multijets with filtered in pT slices	SM	Info	2018/10/31
332	pp	13	tev13pp_pythia8_qcd_em	PYTHIA8	QCD multijets with filtered leptons	SM	Info	2018/10/26
331	pp	13	tev13pp_pythia8_ttbarwz_wgt	PYTHIA8	SM EW and top processes	SM	Info	2018/10/25
330	pp	13	tev13pp_mg5_dm_a_boson	MADGRAPH/PY8	Zprime for dijet+W/Z events and interference	Exotics	Info	2018/10/09
329	pp	13	tev13pp_mg5_dm_boson	MADGRAPH/PY8	Zprime for dijet+W/Z events	Exotics	Info	2018/09/26
328	pp	13	tev13pp_pythia8_rmm	PYTHIA8	Various SM/BSM process for ML	SM	Info	2018/09/16
327	pp	13	tev13pp_qcd_pythia8_proio	PYTHIA8	QCD dijets for ProIO tests	SM	Info	2018/08/27
326	pp	13	tev13pp_qcd_pythia8_proio_tests	PYTHIA8	QCD dijets for tests of ProIO	SM	Info	2018/08/20

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

Show all

p →← p
8 TeV
13 TeV
14 TeV
27 TeV
33 TeV
100 TeV

e⁺ →← e⁻
250 GeV
380 GeV
500 GeV
1 TeV
3 TeV

SM
Higgs
Top
Exotic

HepSim

Repository with Mon arlo simulations for particle physics

- March 15 2018: Charged Higgs event samples
- Sep,22 2017: Z+Higgs → nunu+XX event samples
- Sep,15 2017: Higgs → mu+mu- event samples

Select by beam species, CM energy, and topic (SM, Exotic, etc)

ow 25

Previous 1 2 3 4 5 ... 13 Next Search:

Id				Generator	Process	Topic	Files
25	e-p			PYTHIA8	DIS events at Q2>1 GeV2	SM	Info
323	pp		tev13pp_mg5_chaHT_tbeta_hw	MADGRAPH/PY8	H- top with H- to HW and tan(beta)=1-7	Exotics	Info
322	pp	13	tev13pp_mg5_chaHT_tbeta_tb	MADGRAPH/PY8	H- top with H- to tb and tan(beta)=1-7	Exotics	Info
321	pp	13	tev13pp_mg5_chaHW_tbeta_tb	MADGRAPH/PY8	H+ W- with H+ decay to t-bbar tan(beta)=1-7	Exotics	Info
320	pp	13	tev13pp_mg5_chaHW_tbeta_hw	MADGRAPH/PY8	H+ W- with H+ decay to HW for tan(beta)=1-7	Exotics	Info
318	pp	13	tev13pp_pythia8_gamgam	PYTHIA8	Higgs to gamma gamma	SM	Info
315	pp	100	tev100pp_qcd_pythia8_weighted	PYTHIA8	QCD dijets (weighted)	SM	Info
314	pp	27	tev27pp_qcd_pythia8_weighted	PYTHIA8	QCD dijets (weighted)	SM	Info
313	pp	13	tev13pp_mg5_rho_techni	PYTHIA6	Technicolor rho_T to pi_T W	Exotics	Info

Show all

p →← p
8 TeV
13 TeV
14 TeV
27 TeV
33 TeV
100 TeV

e⁺→←e⁻
240 GeV
250 GeV
380 GeV
500 GeV
1 TeV
3 TeV

μ⁺→←μ⁻
250 GeV

HepSim

Repository with Monte Carlo simulations for particle physics

- Nov 1, 2022, Higgs, WW, ZZ production at 240, 250 GeV
- n at 380 GeV

Selected: e⁺ e⁻ collisions, all energies, all type **Show selection**

Choose dataset based on generator and process descriptions

Show 25 entries

Previous 3 Next Search:

Id	→←	E [TeV]	Dataset name	Generator	Process	Topic	Files	Created
356	e+e-	0.24	gev240ee_pythia8_ww_zz	PYTHIA8	Double boson production	Higgs	Info	2022/11/09
355	e+e-	2.4	gev240ee_pythia8_higgs_bbar	PYTHIA8	Higgs to bbar	Higgs	Info	2022/11/09
354	e+e-	0.38	gev380ee_pythia8_ww_zz	PYTHIA8	Double boson production	Higgs	Info	2022/10/27
353	e+e-	0.38	gev380ee_pythia8_higgs_bbar	PYTHIA8		gs	Info	2022/10/27
303	e+e-	0.38	gev380ee_pythia6_zhiggs_nu			gs	Info	2017/09/23
302	e+e-	0.38	gev380ee_pythia6_zhiggs_nunugg	PYTHIA6		gs	Info	2017/09/23
301	e+e-	0.25	gev250ee_pythia6_zhiggs_nunumumu	PYTHIA6	Z+Higgs to nunu+mumu	Higgs	Info	2017/09/23
300	e+e-	0.25	gev250ee_pythia6_zhiggs_nunugg	PYTHIA6	Z+Higgs to nunu+gg	Higgs	Info	2017/09/23
299	e+e-	0.38	gev380ee_pythia8_zhiggs_nunubbar	PYTHIA8	Z+Higgs to nunu+bbar	Higgs	Info	2017/09/21
298	e+e-	0.38	gev380ee_pythia8_zhiggs_nunugg	PYTHIA8	Z+Higgs to nunu+gg	Higgs	Info	2017/09/21

Then click on data set name to look at more closely

HepSim

Repository with Monte Carlo simulations for particle physics

- Apr 15, 2019: Moving to globus (petrel)
- Sep.10 2018: Zprime/DM event samples
- Mar.15 2018: Cha[illegible]ples

This brings up information page for dataset. Starting with basic parameters, integrated luminosity, and a link to the download page

Dataset: *"tev100pp_qcd_pythia8_ptall"*

Summary	
Name:	*tev100pp_qcd_pythia8_ptall*
Collisions:	pp
CM Energy:	100 TeV
Entry ID:	219
Topic:	SM
Generator:	PYTHIA8
Calculation level:	LO+PS+hadronisation
Process:	QCD dijets in bins of pT
Total events:	490000
Number of files:	490
Cross section (σ):	4.582E+07 ± 7.751E+05pb
Luminosity (L):	0.0107 pb^{-1} *(or)* 1.069E-05 fb^{-1} *(or)* 1.069E-08 ab^{-1}
Format:	ProMC
Download URL:	http://mc.hep.anl.gov/asc/hepsim/events/pp/100tev/qcd_pythia8_ptall
Mirrors:	http://portal.nersc.gov/project/m1758/data/events/pp/100tev/qcd_pythia8_ptall
EVGEN size:	36.169 GB

Estimated from file Nr 1

Status: Available

Tags:

Fast simulation: rfast005 | Info — 100 / 1.56 GiB — 10/16/2016

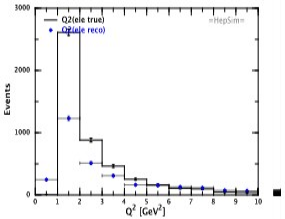
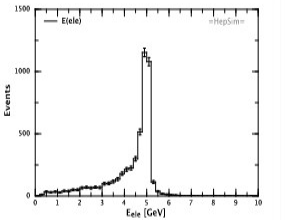
Full simulation: rfull015 | Info — 341 / 15.85 GB — 06/06/2017; rfull009 | Info — 434 / 57.82 GB — 06/23/2017

```
parameter EVGEN:ProcessID [int]
parameter EVGEN:DIS:Q2 [float]      // Truth-level Q^2
parameter EVGEN:DIS:W [float]       // Truth-level W
parameter EVGEN:DIS:XBJ [float]     // Truth_level x_bjorken
parameter EVGEN:DIS:YBJ [float]     // Truth_level y_bjorken
```

Please refer the HepSim manual

File metadata: Show

Validation:

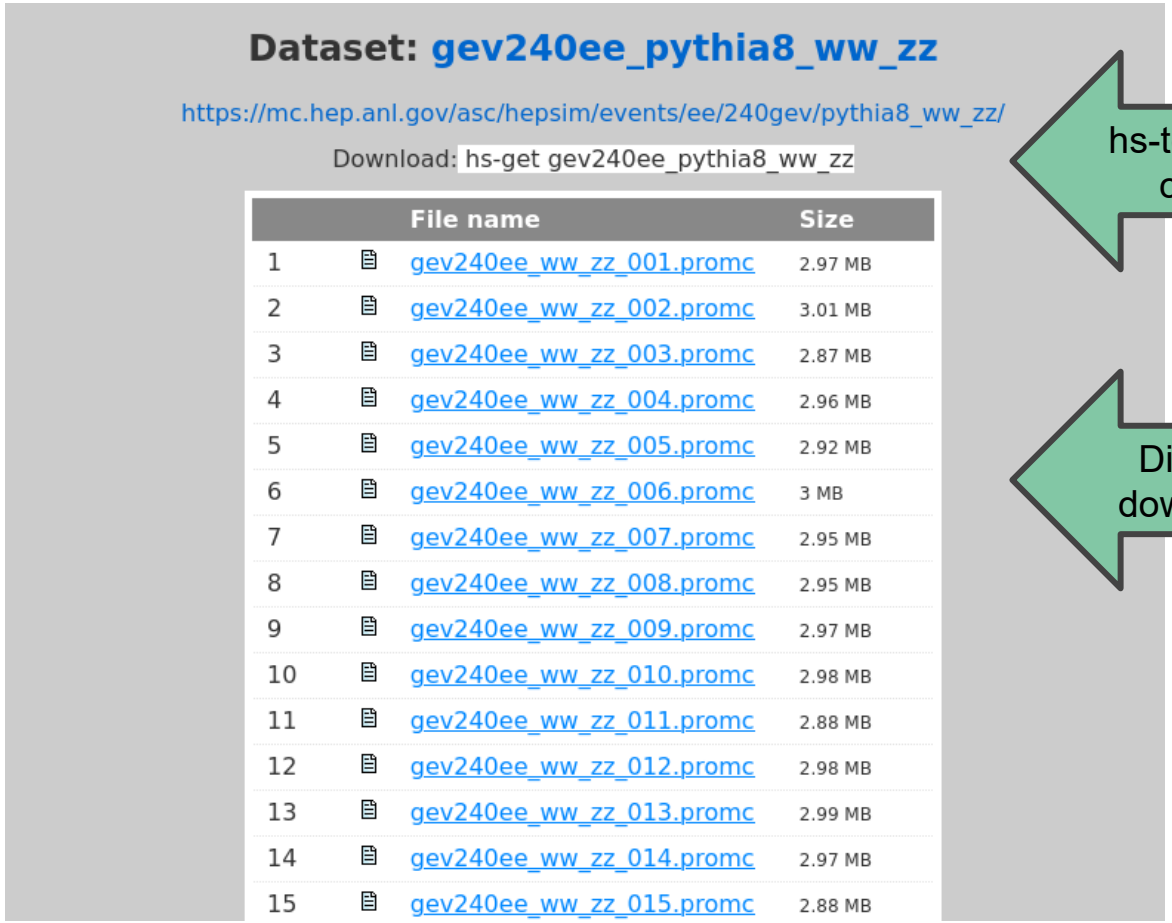
Nr	Analysis code	Output image	Output data
1	truth_q2_dislowq2_lcio.py Run		JDAT file
2	truth_ele_dislowq2_lcio.py Run		JDAT file

Validation

Uses Python (Jython) scripts

Can be executed on Web browsers, Windows etc

Web Interface - Truth Level Navigation



Web Interface - Truth Level Navigation

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

HEP.ANL.GOV

Show all

p →← p

8 TeV

13 TeV

14 TeV

27 TeV

33 TeV

100 TeV

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

250 GeV

380 GeV

500 GeV

HepSim

Repository with Monte Carlo simulations for

Navigate by detector and/or experiment

29, 2017: rfull058 tag with improved tracking strategy from
yth
Jun.20, 2017: rfull057 tag with alternative tracking strategy from
D.Blyth

Here is a list of tags with simulation of detectors.

Tags with full simulations

Nr	Find data	Detector	Experiment	Description
1	rfull001	sidloi3	ILC	Info
2	rfull002	sidcc1	CEPC	Info
3	rfull003	sidloi4	ILC	Info
4	rfull006	sifcch4	FCC-hh, SppC	Info
5	rfull009	sifcch7	FCC-hh, SppC	Info
6	rfull010	sifcch8	FCC-hh, SppC	Info

5 TeV
10 TeV
20 TeV
40 TeV

$e^- \rightarrow \leftarrow p$
318 GeV
141 GeV
35 GeV

Misc.
1 particle
2 particles
1 jet

11	rfull015	sifcch7	FCC-hh, SppC	Info
12	rfull016	sifcch7	FCC-hh, SppC	Info
13	rfull017	sifcch7	FCC-hh, SppC	Info
14	rfull051	sieic1	EIC	Info
15	rfull052	sieic2	EIC	Info
16	rfull053	sieic3	EIC	Info
17	rfull054	sieic4	EIC	Info
18	rfull056	sieic5		Info
19	rfull057	sieic5		Info
20	rfull058	sieic5	EIC	Info
21	rfull059	sieic5	EIC	Info
22	rfull101	sidcc2	CEPC	Info
23	rfull201	sidclic1	CLIC	Info

Use Info link to learn more about a tag

Tags with fast simulations

Web Interface - Simulation Tag Navigation

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

$e^- \rightarrow \leftarrow p$
318 GeV
141 GeV
45 GeV
35 GeV

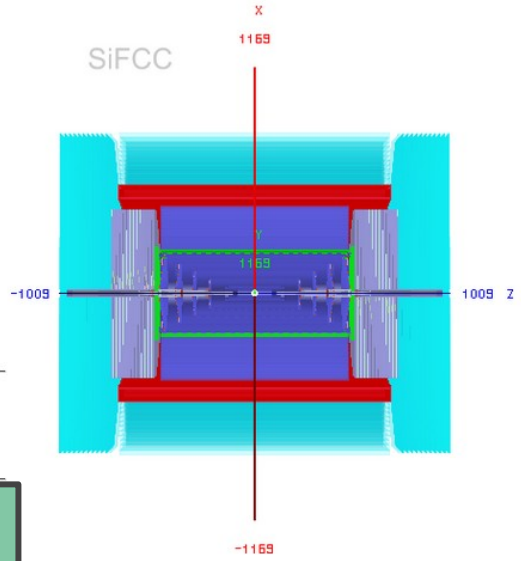
Misc.

Information about the "*sifcch7*" detector

Summary

Name:	*sifcch7*
Title:	*A silicon Detector for FCC-hh studies. Described in JINST 12 (2017) P06009 (arXiv:1612.07291)*
Author:	*S.Chekanov, A.Kotwal, J.Zuzelski, etc.*
Status:	*development*
Version:	*$Id: compact.xml,v3.0 2016/09/09 23:46:56 Sergei Chekanov Exp $*
Level:	Geant4 simulation and full event reconstruction
Summary:	view
3D View:	
GeoManager:	
Calibrations:	view
Tracking:	view
Last modified:	September 07, 201

Interactive 3D Visualization



Reconstruction tags

Tag lists: rfull009 | rfull015 | rfull016 | rfull017

Detector geometry files

HEPREP:	sifcch7.heprep
GDML:	sifcch7.gdml.gz
JSON:	sifcch7.json.gz
LCDD:	sifcch7.lcdd
Pandora:	sifcch7.pandora

Geometry in various formats

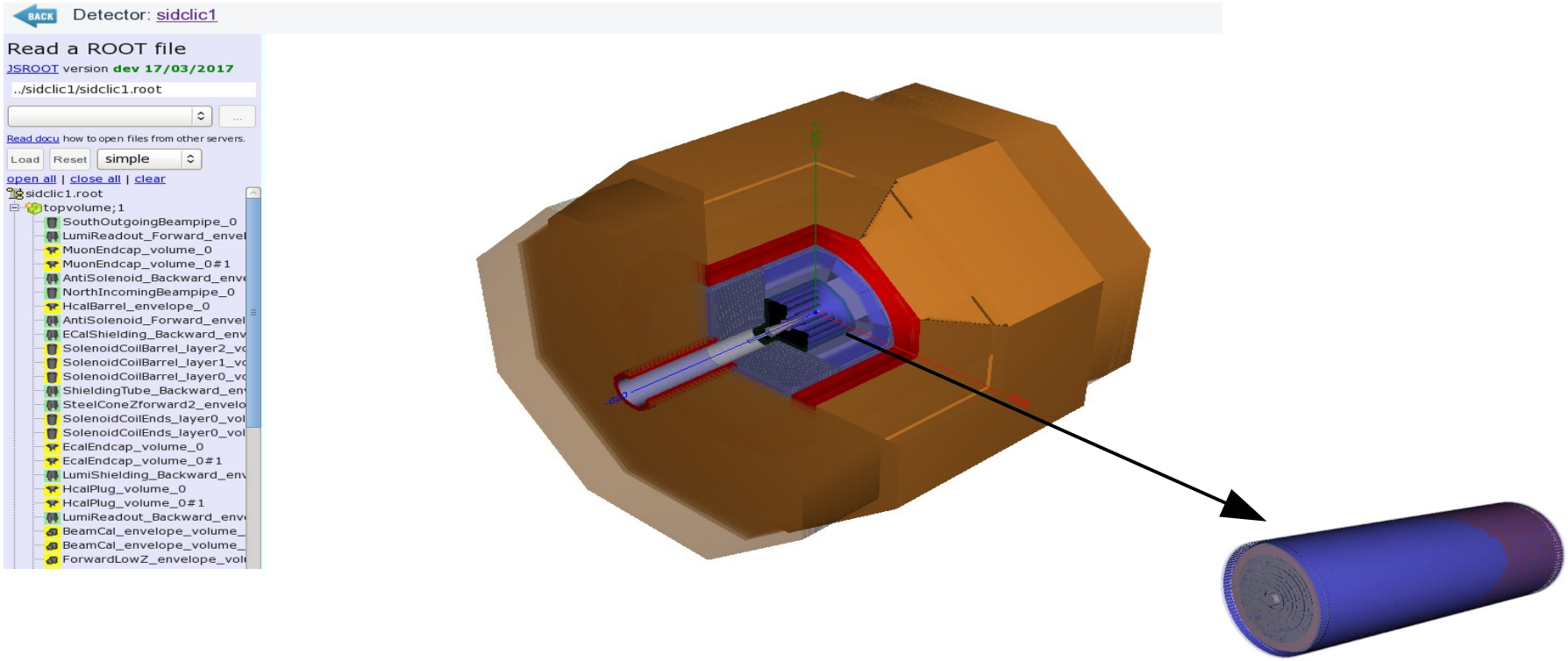
Download of complete detector

Download: sifcch7.zip

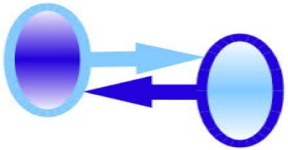
Comment

Web-based 3D browser for detector geometries

- Detector volumes can **interactively** be studied in 3D using GeoManager

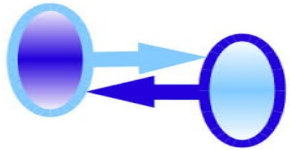


How your work can benefit from HepSim



- **Physics studies:**
  - Use truth-level Monte Carlo samples
  - Use fast detector simulations using Delphes
- **Detector design: full simulation and reconstruction software chain**
  - Using HepSim's truth-level samples as input
  - Produce simulated/reconstructed samples at key points
  - HepSim simulation tags serve as a means to distribute and organize samples
- **Comparisons with previous experiments (+ experiments that have never been built!), technical single particle samples or Geant4 samples for detector designs**

Thanks!



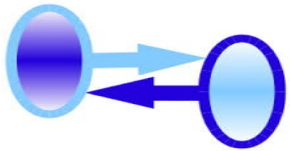
For more information, see the HepSim web manual and **hs-help** on the command line.

HepSim manual: https://atlaswww.hep.anl.gov/hepsim/doc/

HepSim contributors:
https://atlaswww.hep.anl.gov/hepsim/doc/doku.php?id=hepsim:contributions

HepSim public results:
https://atlaswww.hep.anl.gov/hepsim/doc/doku.php?id=hepsim:public

HepSim Tutorial



- How to search and download a file with 10,000 e+e-: H→ bbar process
- What is inside the download file?
- How to fill histograms from truth-level MC files

Require Java

- How to create Pythia8 events in the HepSim format
- Conversions to ROOT, STDHEP, LCIO, HEPMC formats
- How to create fast Delphes simulations

Require Linux / ROOT / GCC compilers /
/cvmfs/sw.hsf.org/key4hep/

URL link with this tutorial:
https://atlaswww.hep.anl.gov/hepsim/doc/doku.php?id=fcs:fccee:tutorial

FCC-ee HepSim tutorial – part 1

This part of the tutorial does not use any C++ specific libraries and can be done on any computers with Java installed. Check java:

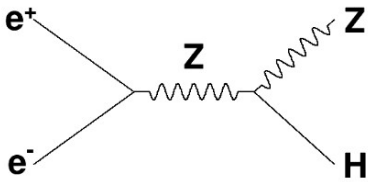
```
java -version
```

Typically, it tells “openjdk version “1.8.0_352” or higher Java version.

```
wget https://atlaswww.hep.anl.gov/hepsim/soft/hs-toolkit.tgz -O - | tar -xz;
source hs-toolkit/setup.sh
```

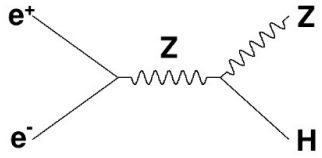
Let's look at a few events: Z→ Z H,
where Z→ nunu, and H decays to bbar.

The CM energy is 250 GeV.



The sample is described in https://atlaswww.hep.anl.gov/hepsim/info.php?item=353

FCC-ee HepSim tutorial – part 2



Print all files with Higgs processes: `# hs-find higgs`
Then grab the file with H to bbar: `# hs-ls gev250ee_pythia8_zhiggs_nunubbar`
Download 10 files (in 2 threads): `# hs-get gev250ee_pythia8_zhiggs_nunubbar data 2 10`

We should have 10 files in the directory “data”. Take a look at a single file. We what to check how many events in the file: `# hs-info data/gev250ee_zh_nunubb_001.promc`

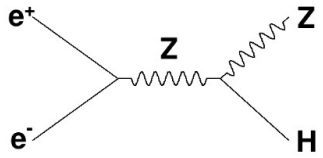
Do you want to print 1st event? Do this: `# hs-info data/gev250ee_zh_nunubb_001.promc 1`

Want to examine the log file? Do this: `# hs-log data/gev250ee_zh_nunubb_001.promc`

Let's study each event in the GUI mode (needs X-session!). Start this GUI and click on event number using the left panel: `# hs-view data/gev250ee_zh_nunubb_001.promc`

Run over this file using Python syntax and make a few simple distributions:
https://atlaswww.hep.anl.gov/hepsim/doc/doku.php?id=fcs:fccee:tutorial#validation

FCC-ee HepSim tutorial – part 3



Fast simulations: Use the key4hep setup with gcc11 + ROOT:

```
# source /cvmfs/sw.hsf.org/key4hep/setup.sh
# wget http://atlaswww.hep.anl.gov/asc/promc/download/current.php -O ProMC.tgz
# tar -zvxf ProMC.tgz
# cd ProMC
# ./build.sh                    # build all source files
# ./install.sh lib              # install into the "lib" directory
# source lib/promc/setup.sh     # make it available
```

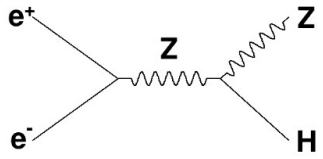
Install Delphes:

```
# wget http://cp3.irmp.ucl.ac.be/downloads/Delphes-3.5.0.tar.gz
# tar -zxf Delphes-3.5.0.tar.gz
# cd Delphes-3.5.0;  make
```

Run:

```
# ./DelphesProMC  ./cards/delphes_card_CircularEE.tcl \
  ../data/gev250ee_zh_nunubb_001.root  ../data/gev250ee_zh_nunubb_001.promc
```

FCC-ee HepSim tutorial – 4 part



Integration with EDM key4hep :

You need to convert PROMC to LHE or HEPMC (text files x8 larger than PROMC)
HEPMC3 is not fully supported. Convert to HEPMC2 first
After you did this, use: **hepmc2edm.py or lhe2edm.py** tools from ke4hep

Example:

```
# cd $RUNMC/examples
```

Check directories and Makefile:

```
# promc2hepmc/
# promc2lhe/
```

→ Advanced level

Event display (outreach)

```
# wget https://atlaswww.hep.anl.gov/asc/jas4pp/download/jas4pp-1.7.tgz
# tar -zvxf jas4pp-1.7.tgz
# cd jas4pp
# wget https://mc.hep.anl.gov/asc/hepsim/events/ee/250gev/pythia6_higgs_zz_4l/rfull001/
pythia6_higgs_zz_4l_0001_pandora.slcio
# jaspp pythia6_higgs_zz_4l_0001_pandora.slcio
```

Thanks to the software developed for SiD/ILC, many e+e- event samples from HepSim are viewable in a full event display (Jas4pp ->Wired4)

URL to more information