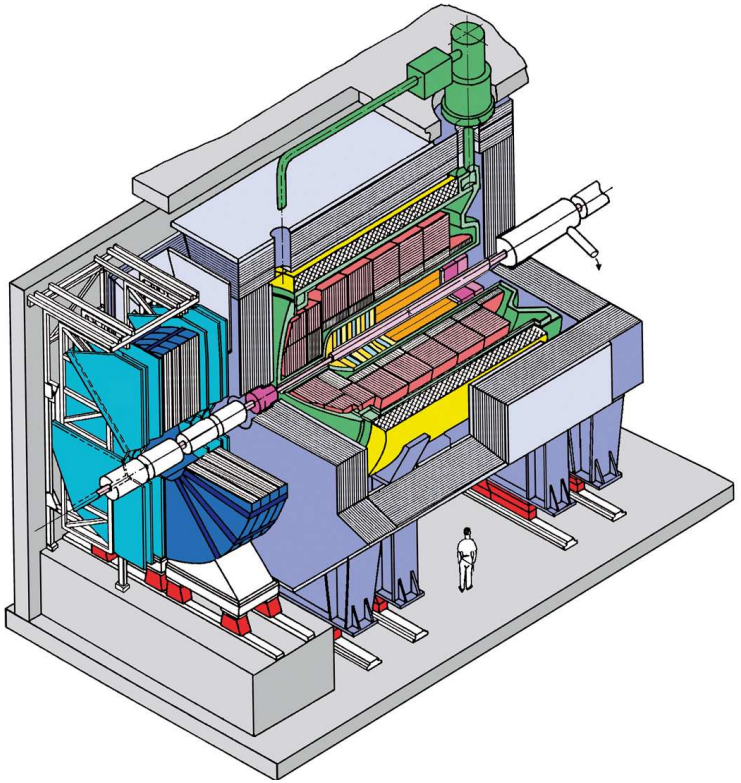
S. Levonian, DESY, November 17, 2009

XTALKS 2009

H1 Detector Simulation

- Mission and Conception
- Challenges and Solutions
- H1SimRec: Basic Facts
- Practical Information



In the beginning was the Idea...

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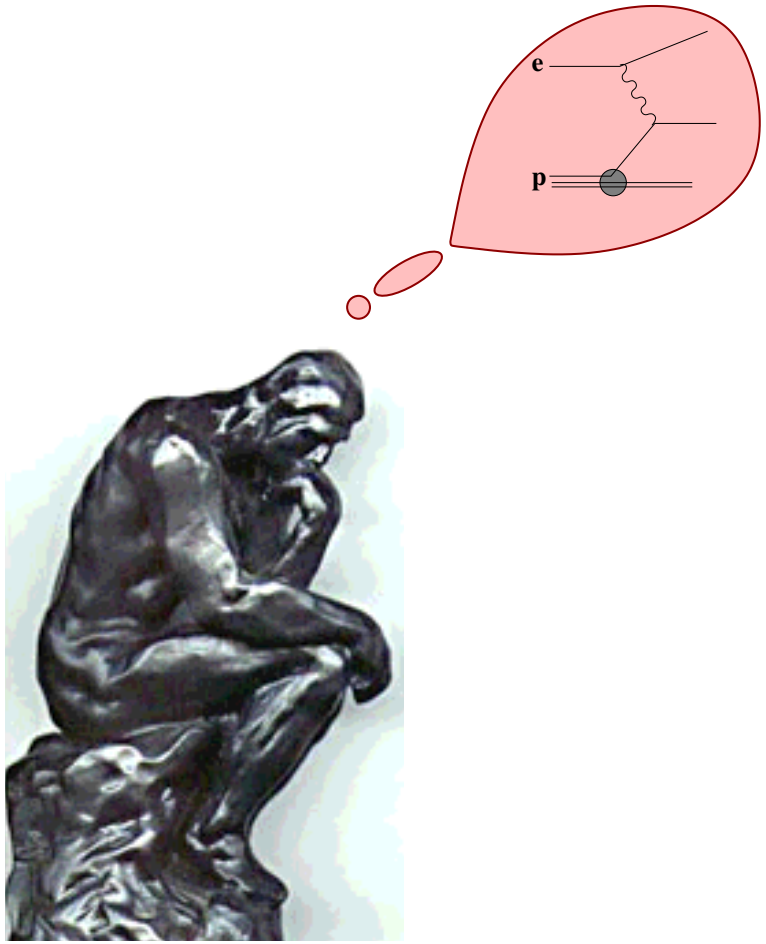

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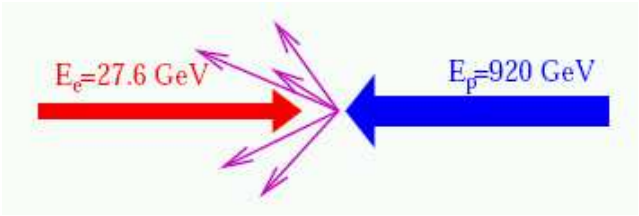

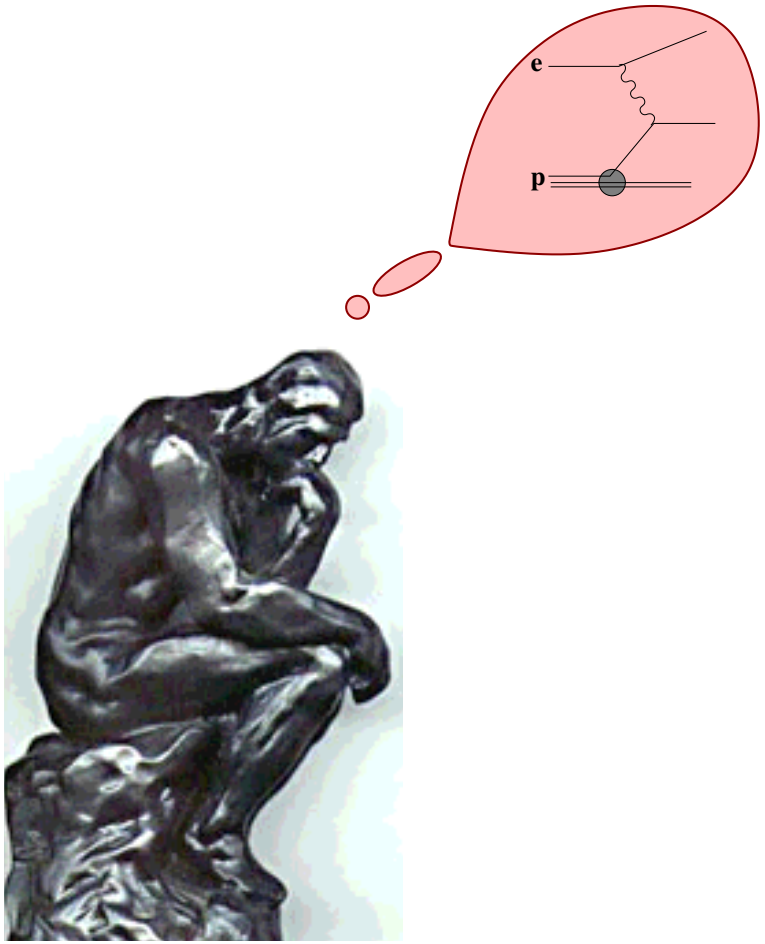

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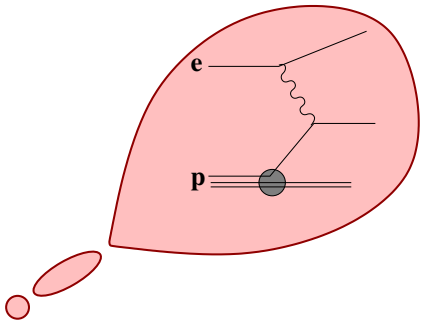

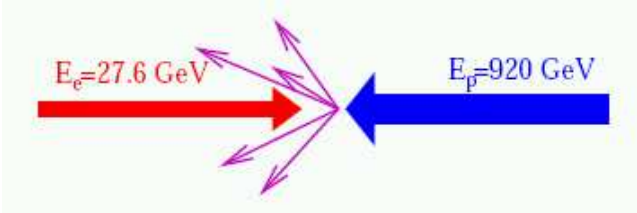

As simple as that (not discussing $$)

The Devil is in the details

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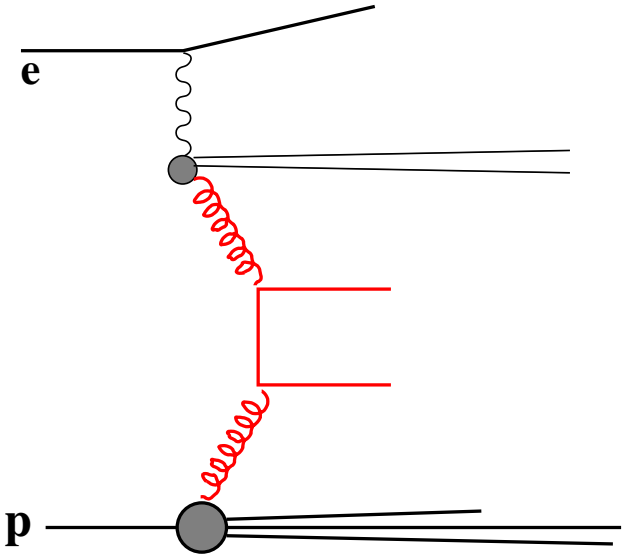
Collider produces not Feinman diagrams...



Underlying physics of interest

The Devil is in the details

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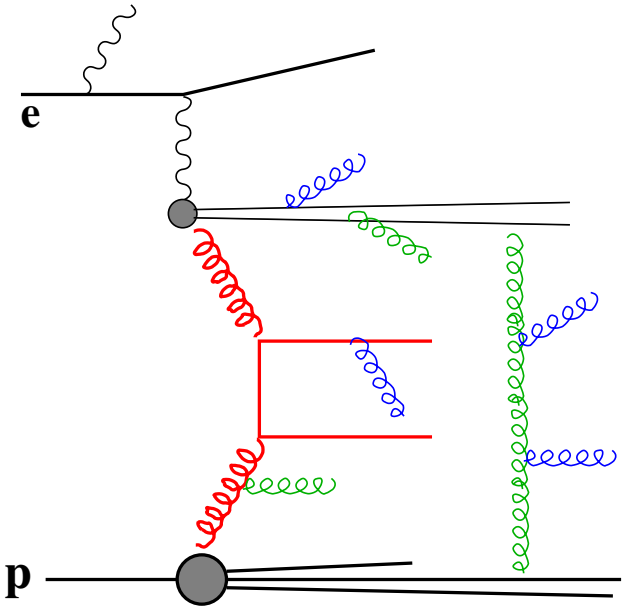

Underlying physics of interest

ISR, FSR (γ, g), partonic cascade

The Devil is in the details

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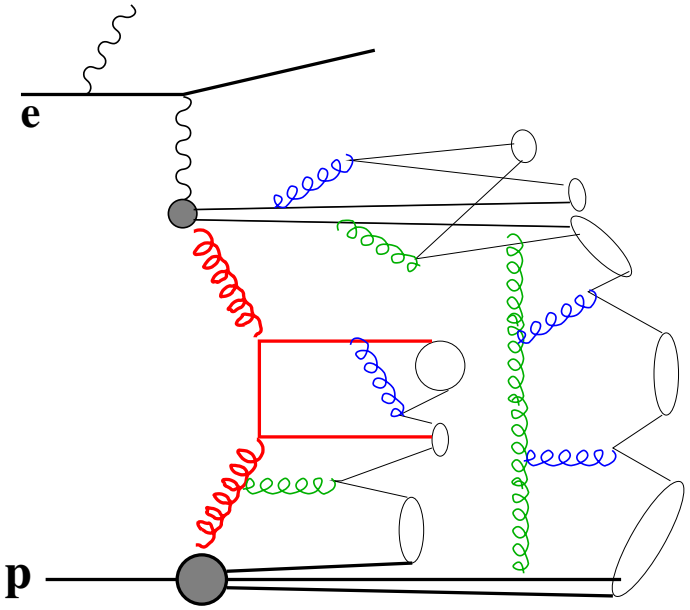

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Hadronization

The Devil is in the details

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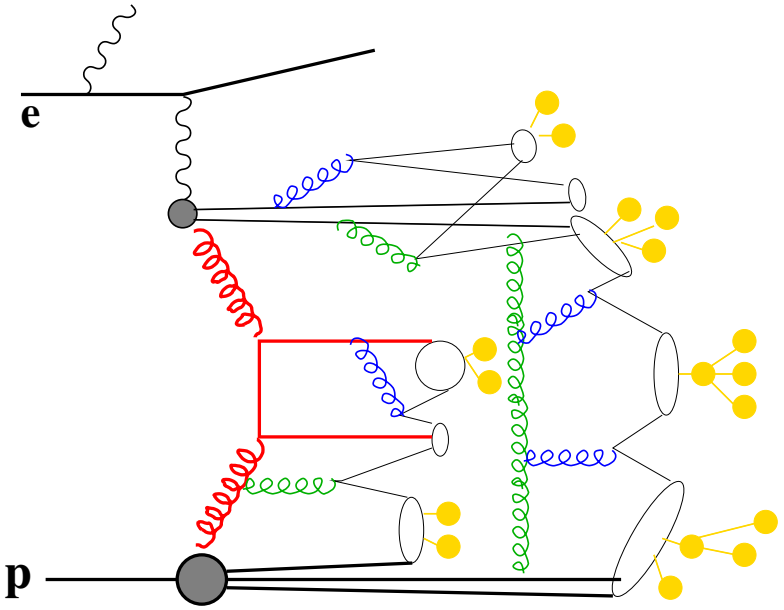


Underlying physics of interest

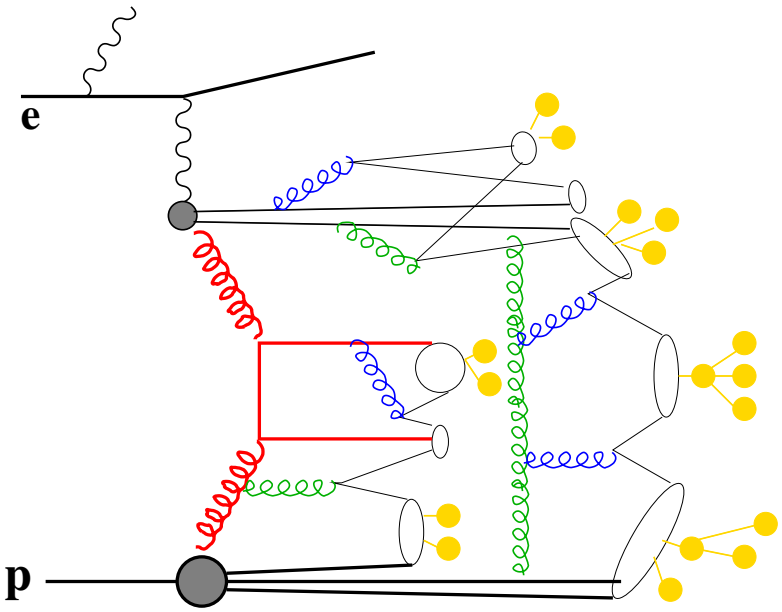
ISR, FSR (γ, g), partonic cascade

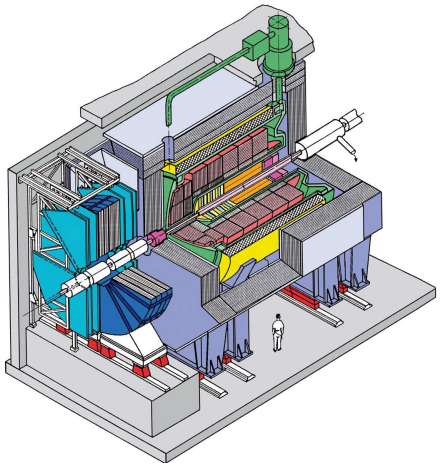
Hadronization

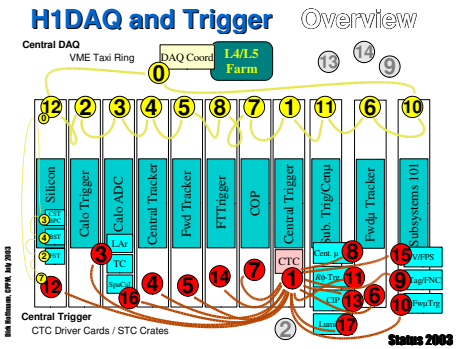
Hadronic decays

... but full events = particle's 4-vectors

The Devil is in the details







Underlying physics of interest

ISR, FSR (γ, g), partonic cascade

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Hadronic decays

Particle's 4-vectors $\Rightarrow$ Apparatus

The Devil is in the details

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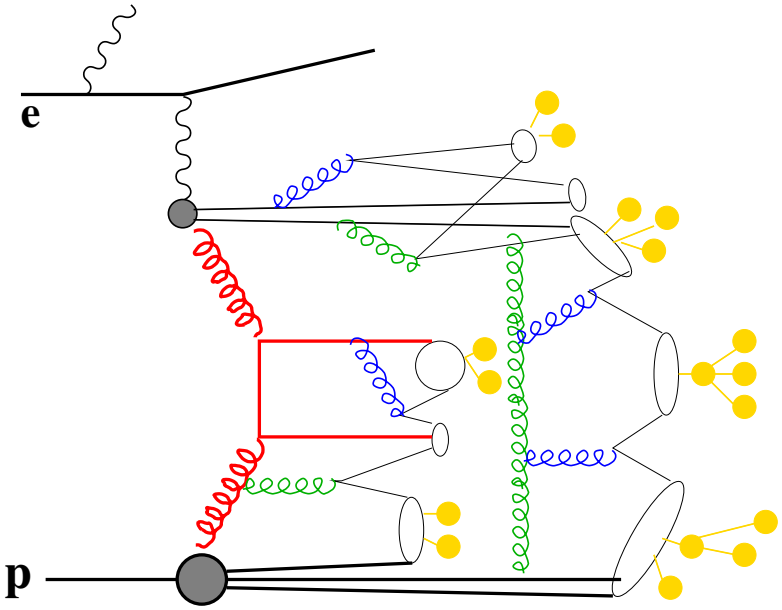

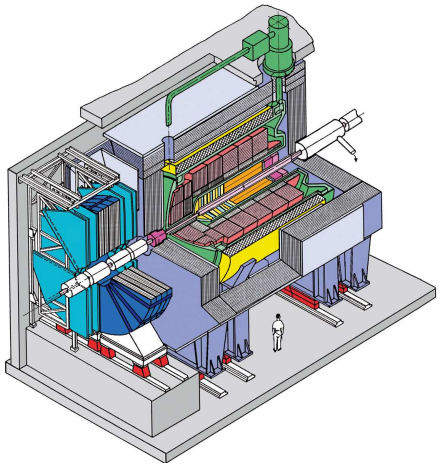

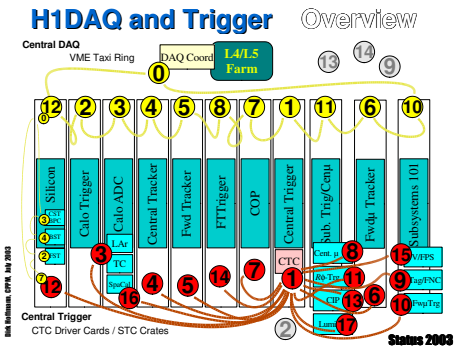

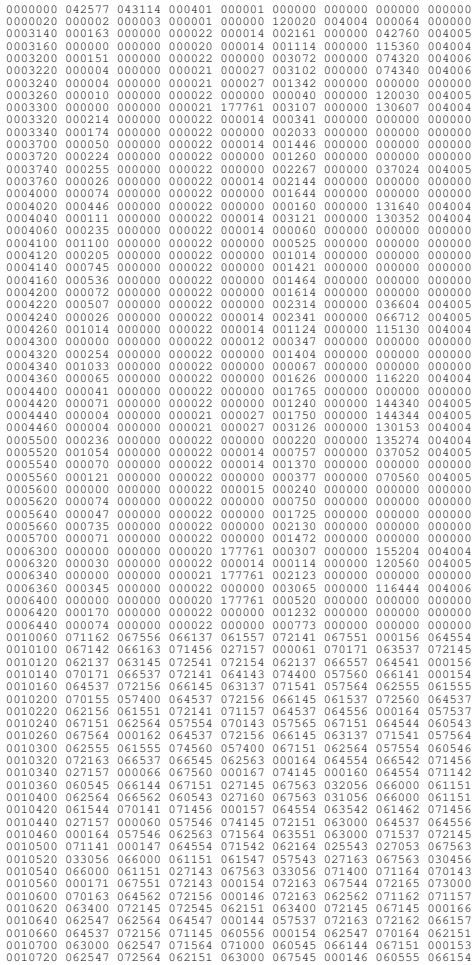

Underlying physics of interest

ISR, FSR (γ, g), partonic cascade

Hadronization

Hadronic decays

Particle's 4-vectors $\Rightarrow$ Apparatus $\Rightarrow$ Raw data

The Mission

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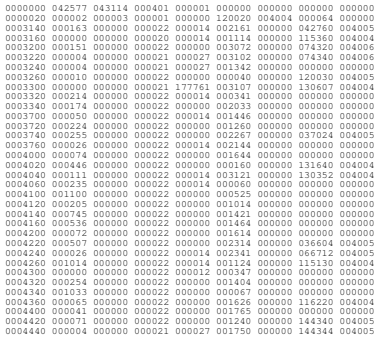
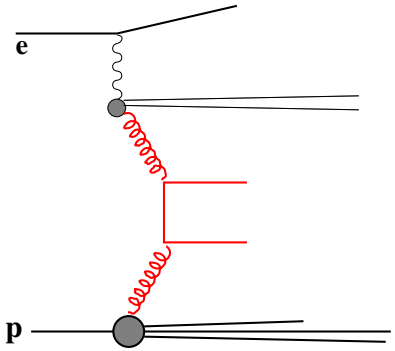
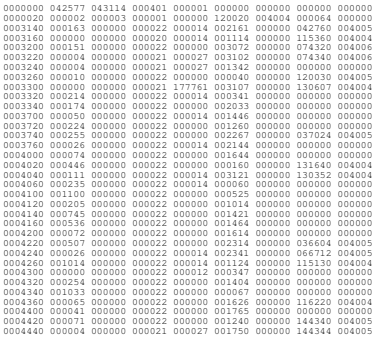


Raw data



The Mission

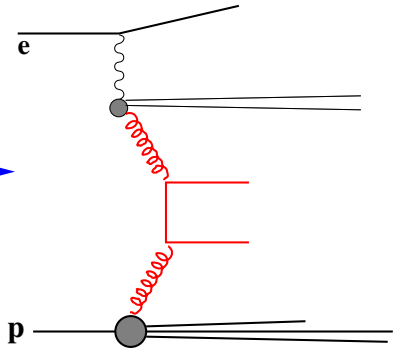
XTALKS 2009



Raw data

1) Reconstruct 4–vectors

2) Deduce underlying physics



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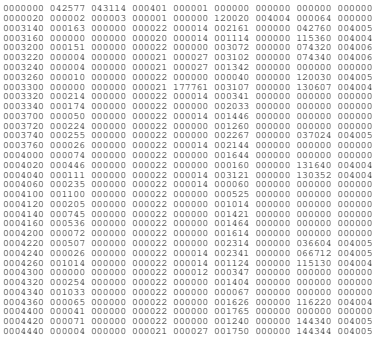

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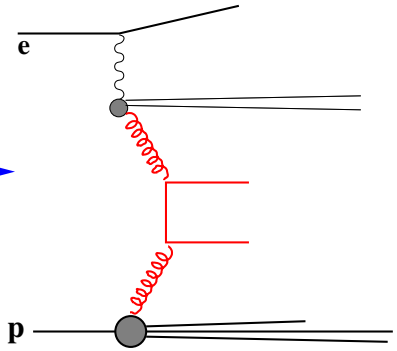
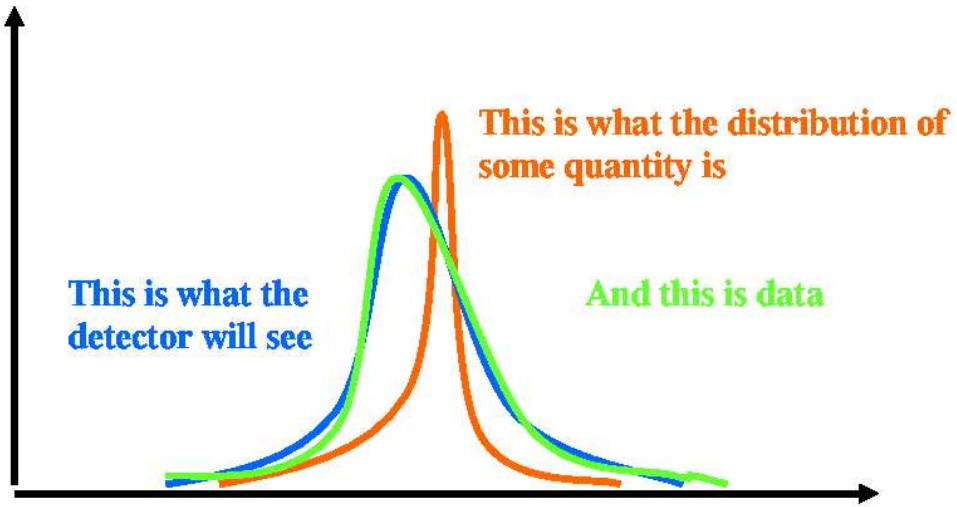


Why we need detector simulation



Step 1 (hadron level)

Detector Simulation

Step 2 (parton level)

MC Event Generator

The Conception

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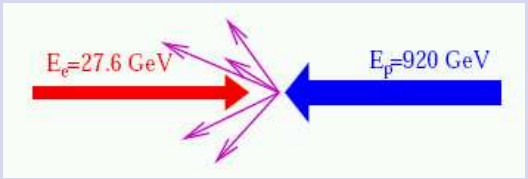
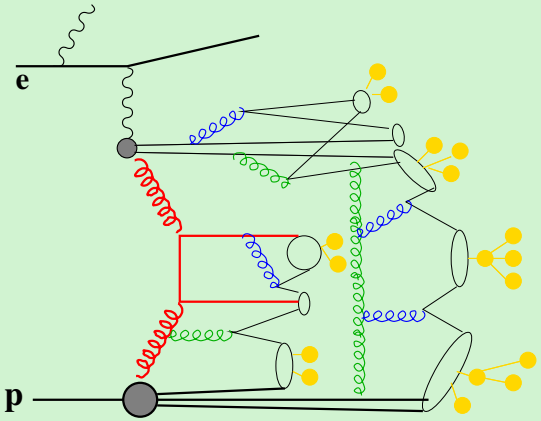
Real world



ep-events

Virtual world



(MC Event Generator)

H1Detector + DAQ → Raw data

Detector Simulation → MC data

Raw data, MC data → H1REC → DST / RooT → Analysis

The Conception

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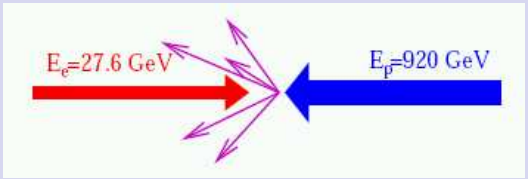
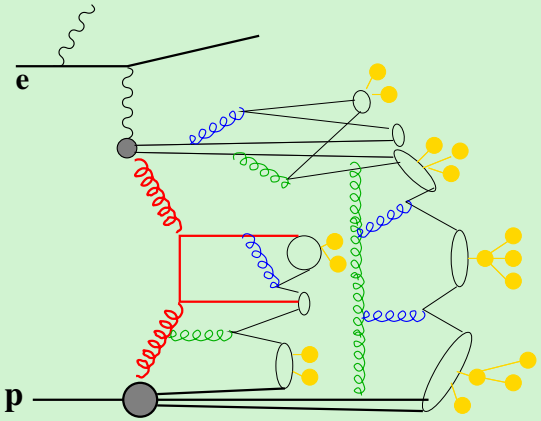
Real world



ep-events + bgr!

Virtual world



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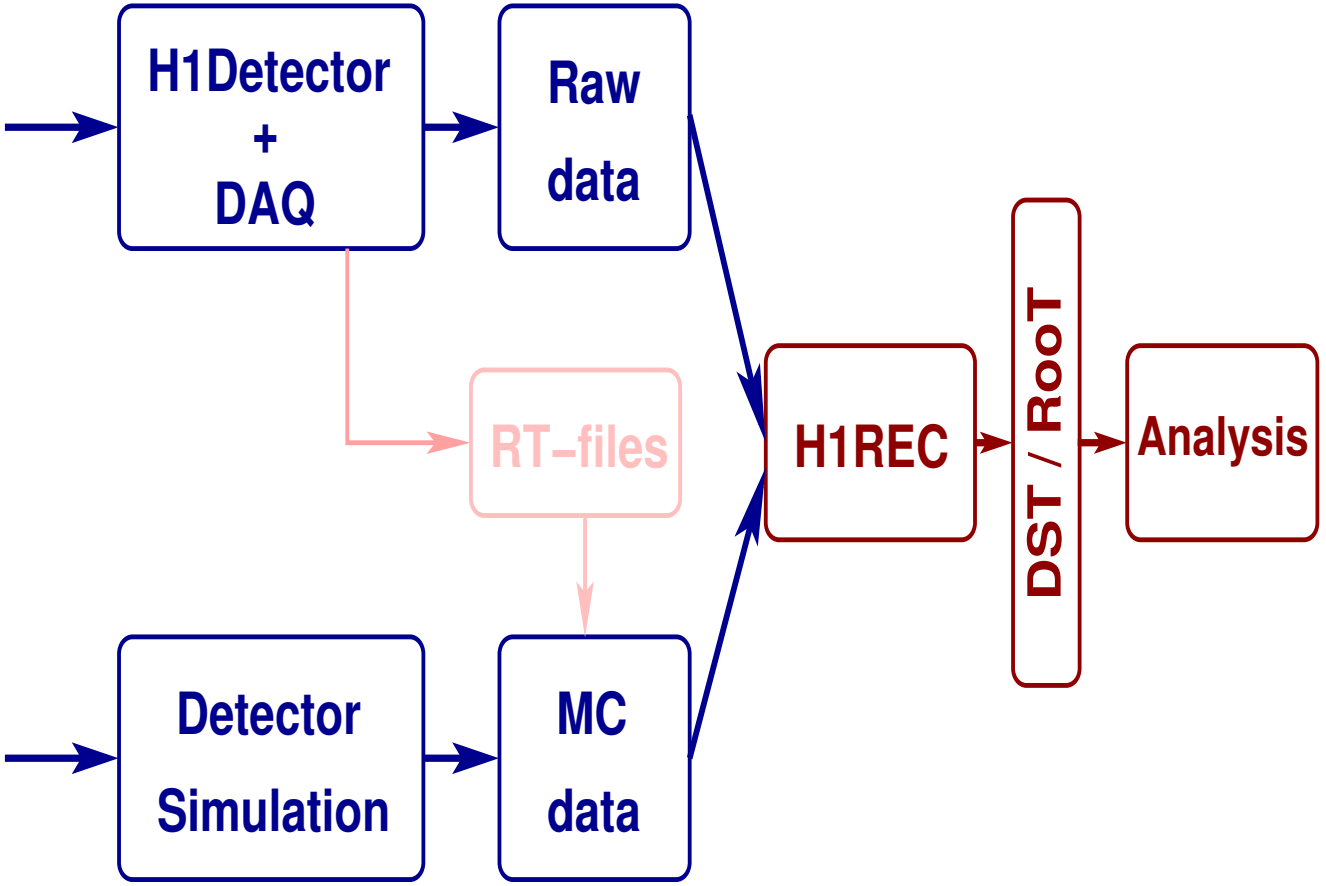
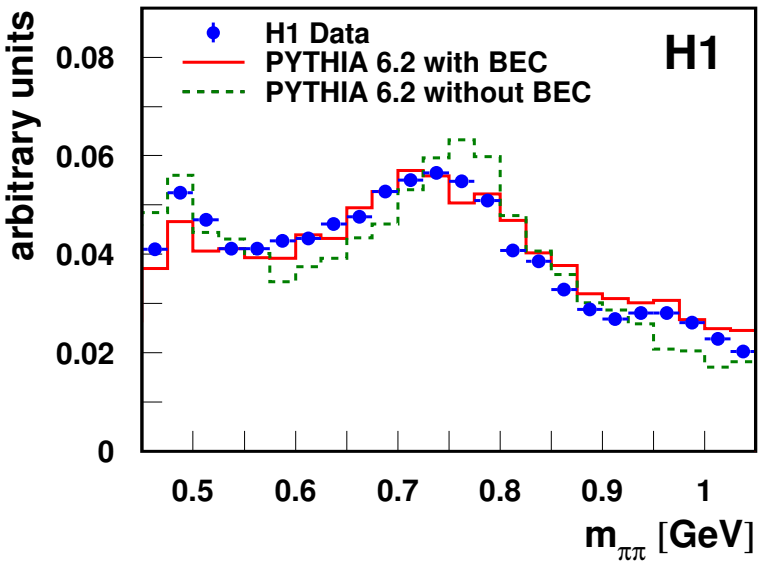
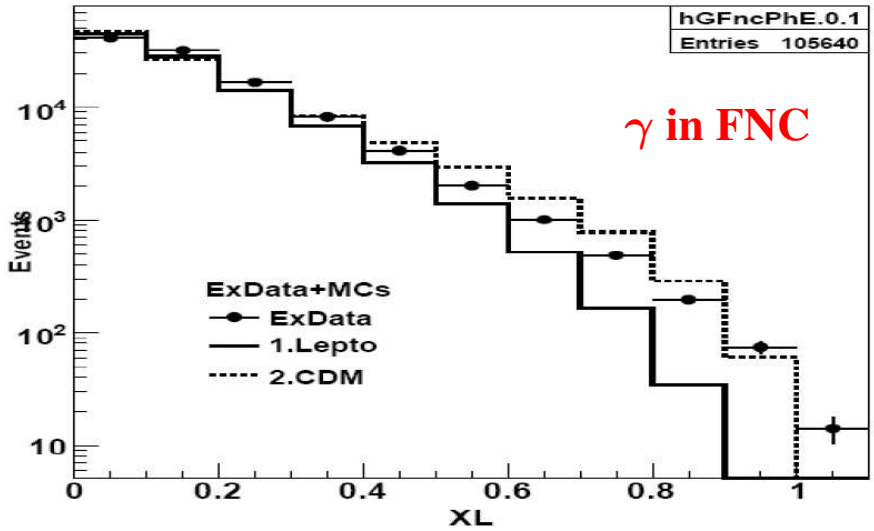


Word of caution

How to interpret the difference between Data and Monte Carlo?
Is it detector effect (SimRec problem) or physics (Event Generator problem)?





soft γp physics or tracking/trigger ineff.?

fragmentation or FNC preshower calibration?

Use "standard candles" to calibrate your detector:

- particle masses ($J/\psi \Rightarrow e^+e^-/\mu^+\mu^-$, $\pi^0 \Rightarrow \gamma\gamma$, $K^0 \Rightarrow \pi\pi$, ...)
- energy-momentum conservation (p_T ballance, $E - p_z$)
- simple and well understood final states (QEDC, KP, ...)

H1 simulation s/w facts

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- H1 simulation and reconstruction s/w consists of 16 packages
  - ▷ **940,000** source lines of code (SLOC) (SLOCcount profiler by D.A.Wheeler) ⇒
  - ▷ **265** Man×Y, ∼ **36**M USD
  - ▷ Fortran (**81%**), C/C++ (**19%**)

Project	SLOC
Rapgap 3.1	59,000
Pythia 6.4	140,000
GEANT3	200,000
GEANT4	630,000
H1OO	300,000
H1SIMREC	940,000
RooT 5.20	1,420,000
NASA Space Shuttle	1,800,000
Windows 95	15,000,000
Windows XP	40,000,000

- Survived 22 years, Moor's law and several computing revolutions

H1 simulation s/w facts

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- Based on GEANT3 (v. **3.15** – default, v. **3.21** as an option)

  ▷ CERN package for detector GEometry description ANd particle Tracking through the detector's material

  ▷ First GEANT version – **1974**
  GEANT3: **1982 – 1994** (last version 3.21)
  GEANT4: ***R&D*** **– 1994** (Driven by LHC needs)
  0.0 – first release, 1998 (first usable release by 2001)
  9.2 – current release, Aug, 2009

  ▷ H1 simulation s/w history:
  1986-1988 – data formats definition, s/w structure, coding conventions
  1989 – first complete release of H1SIM (+ User Guide)
  1988-1993 – lots of tuning, calibration (CERN tests, cosmics, HERA data)
  1995-2007 – several up/down grades (8 different configurations implemented)

Challenges

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- Precise geometry description of large setup with fine granularity, $\mathcal{O}(10^6)$ channels
- Accurate material description, especially inside tracking area
- Good model for particle interaction with detector material over large $E-$range
- Trigger simulation: noise, pedestals, thresholds (L1) and algorithms (L2-L4)
- Defects: dead channels, radiation damage, misalignment $\Rightarrow$ resolution, efficiency
- Backgrounds: cosmics, SR, beam-gas, p-halo, ...
- Changing conditions with time scales from year to seconds
- Going from 10% to 5% systematics is 'easy'; $5\% \Rightarrow$ 1-2% is extremely tough

H1 Experiment in GEANT3

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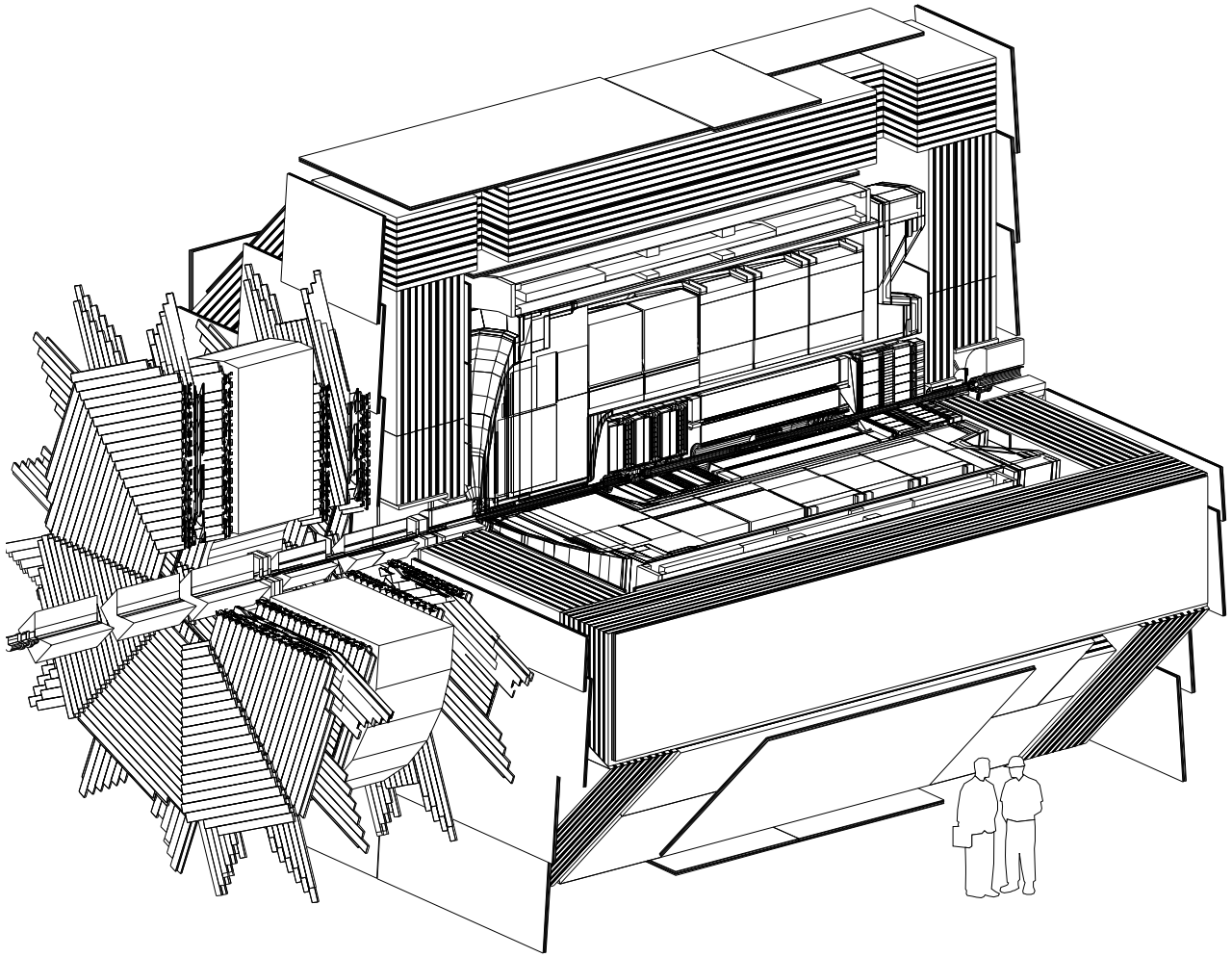

Dirk Hoffmann, DESY-FH1, 1998

H1 material description

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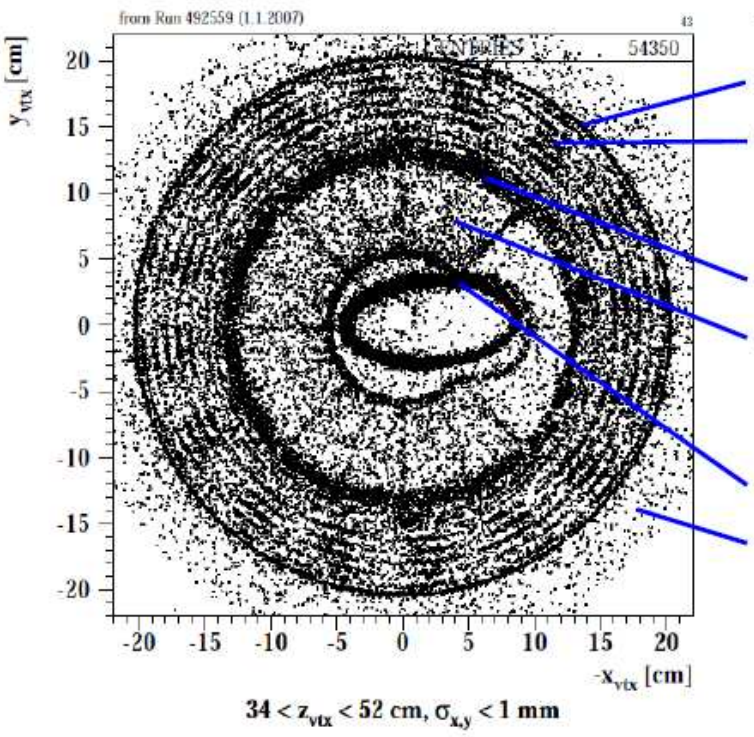
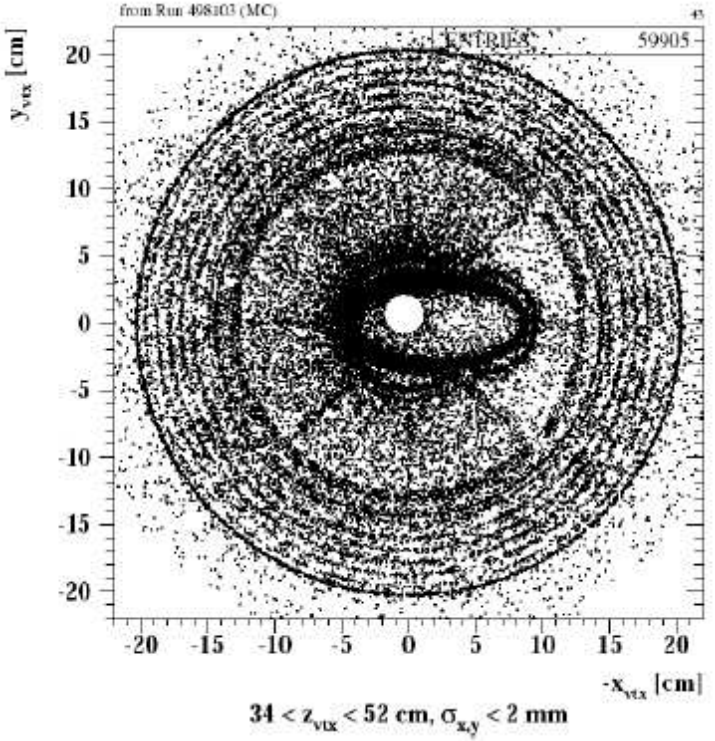
(D.Pitzl study)

Data



- Material map $\sim d\,A^{2/3}\,\rho\,/A$
- CJC wall
- CIP 5 layers with bundles of micro-coax readout cables.
- FST frontend hybrids.
- FST 12 silicon sectors with carbon fiber supports.
- beam pipe, too high.
- some noise from random combinations.

MC



Photon conversions: $\sim dZ^2(\rho/A)$, Nuclear interactions: $\sim dA^{2/3}(\rho/A)$

$\Rightarrow$ Sensitivity to amount of material AND its chemical composition

Shower models and Tracking options

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GEANT3 offers

- Ionization, mult.scat., nuclear int, bremsstr., pair production, annihilation, decays, ...
- Electro-magnetic showers: EGS
- Hadronic showers: GHEISHA (H1 default), FLUKA, CALOR (as options)

H1SIM implementations

1. GEANT tracking for all particles down to low cuts – precise but slow (20-25 sec/ev)
2. Parametrized e.m. showers + hadrons tracking with GEANT
3. Both e.m. and hadronic showers are parametrized (fast but poor)
4. Shower library option (for Spacal, FNC) based upon (1) – fast and precise (2-3 sec/ev)

Note, that only options (2) and (4) are tuned to the data acceptably!

Other H1SIMREC options

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- Detailed Run/time dependence simulation (SIMRUN module)
- RT ‘noise’ simulation option
- Run dependent z-vertex simulation
- Beam tilt option with ‘Forward particles veto’
- Inline generator (single particles; fixed event topologies; BH-generator)
- Options for output format: POT, DST, CDST (250, 45, 25 kb/event resp.)

Run dependence simulation

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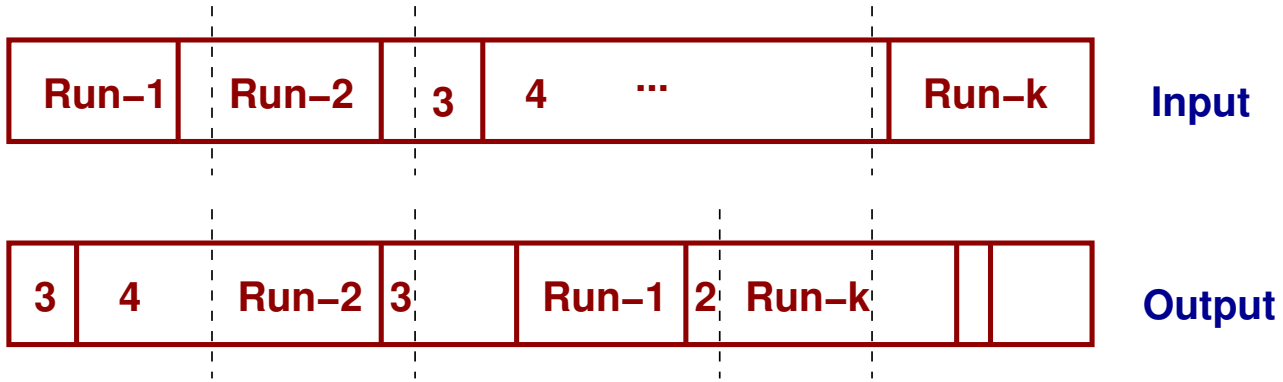
- Done in preprocessing (but can also be done within SIMREC job)
- After simulation on GRID/farm output file is not sorted anymore (also splitted runs possible and present) $\Rightarrow$ only complete file set is representative!



could be sorted again by simply renaming output files

- Allows identical run selection in data and MC
- May introduce some 'simulation inefficiency' by rejecting part of simulated statistics
- Trigger(s) downscaling and HV status in real data (via HVST bank) can be taken into account in distributing statistics according to 'useful' lumi ("HV off" is NOT simulated of course!)

RT-noise simulation

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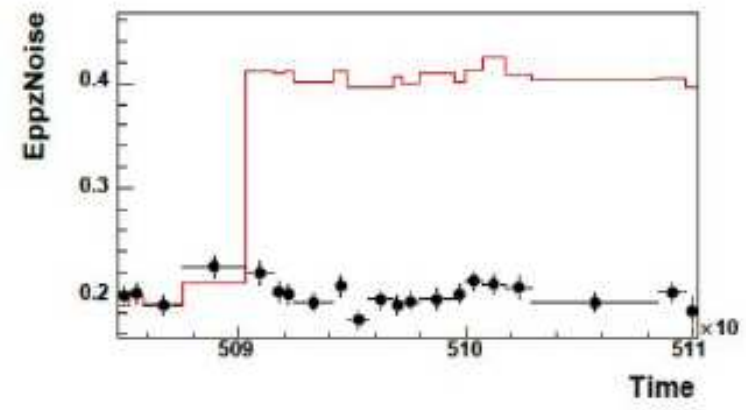
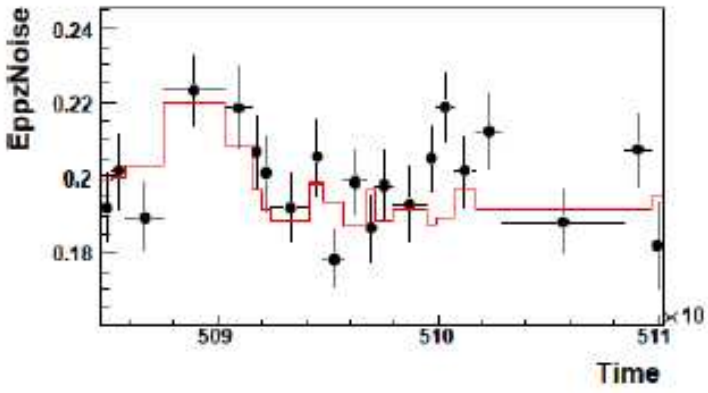
- Automatically follows real run/detector/beam conditions
  (Available statistics: $12M$ events $\Rightarrow \sim 1M$ per detector configuration)
- Contains all the stuff which cannot be otherwise reliably simulated:
  - ▷ electronic noise
  - ▷ beam related bgr (SR, beam-gas, beam-wall, halo μ's)
  - ▷ cosmics
  - ▷ $ep-$events (unbiased)
- Implemented for 12 subdetectors (steered via OSRN bank)



LAr "noise" in 575 GeV sample before and after bug fix



Run dependent z-vertex simulation

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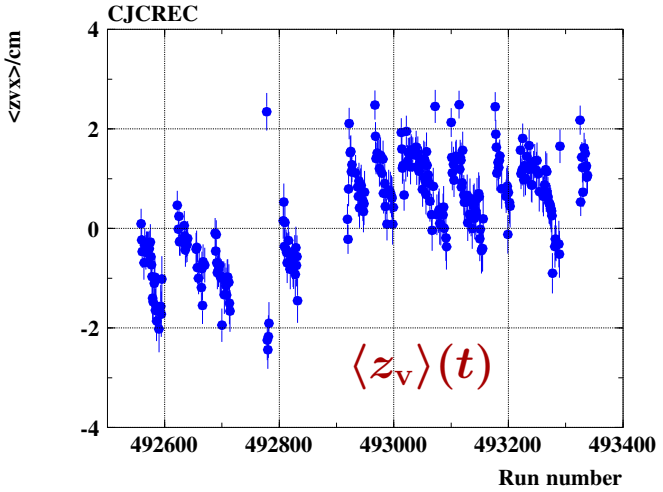
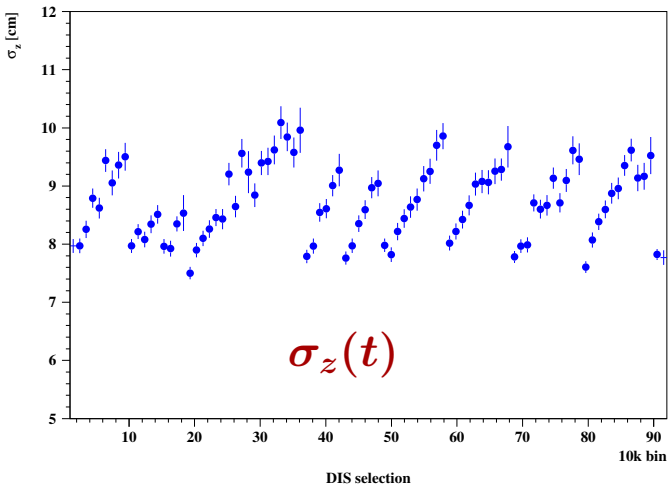
- Main bunch: $\langle zvx \rangle$(Run), $\langle \sigma(zvx) \rangle$(Run) $\Leftarrow$ (ZVEP bank)
  So far ZVEP defined only for HERA-2 periods; for HERA-1 LUZP bank is used (fill-dependent)

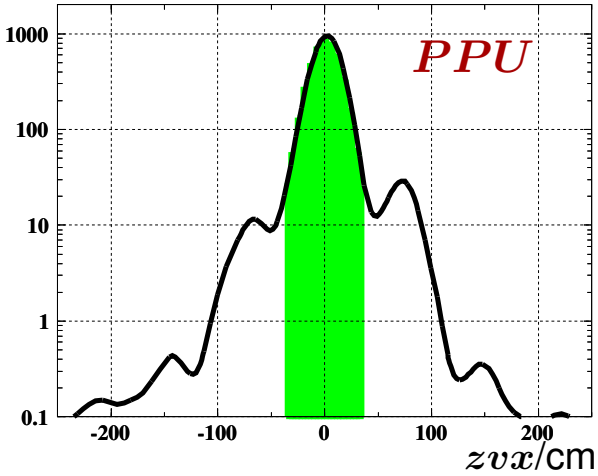
- p-satellites, tails - from LUZP (PPU profile) – both for HERA-1 and HERA-2

- Remaining (small) data/MC difference - due to different trigger selection - may require extra (analysis dependent!) reweighting

- Run-dependent $\langle x \rangle$, $\langle y \rangle$ offsets so far neglected
  (could be essential for beamline detectors: eTAG, FTS, FNC, FPS)







Beam tilt option

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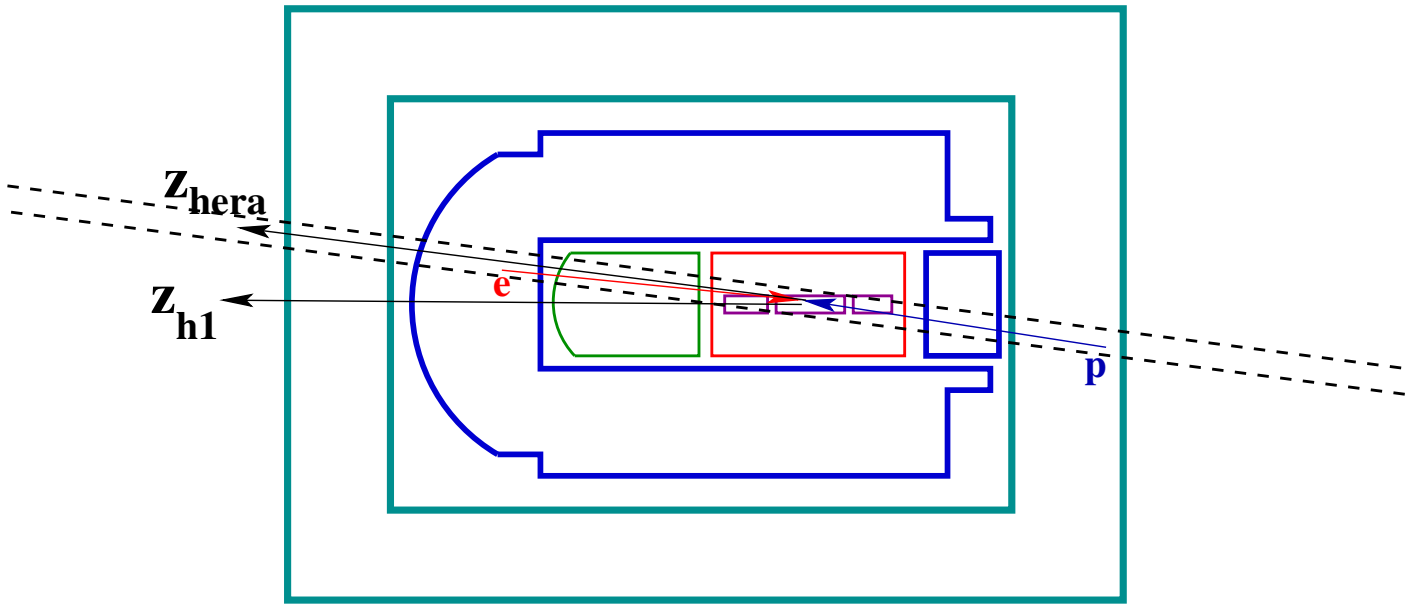
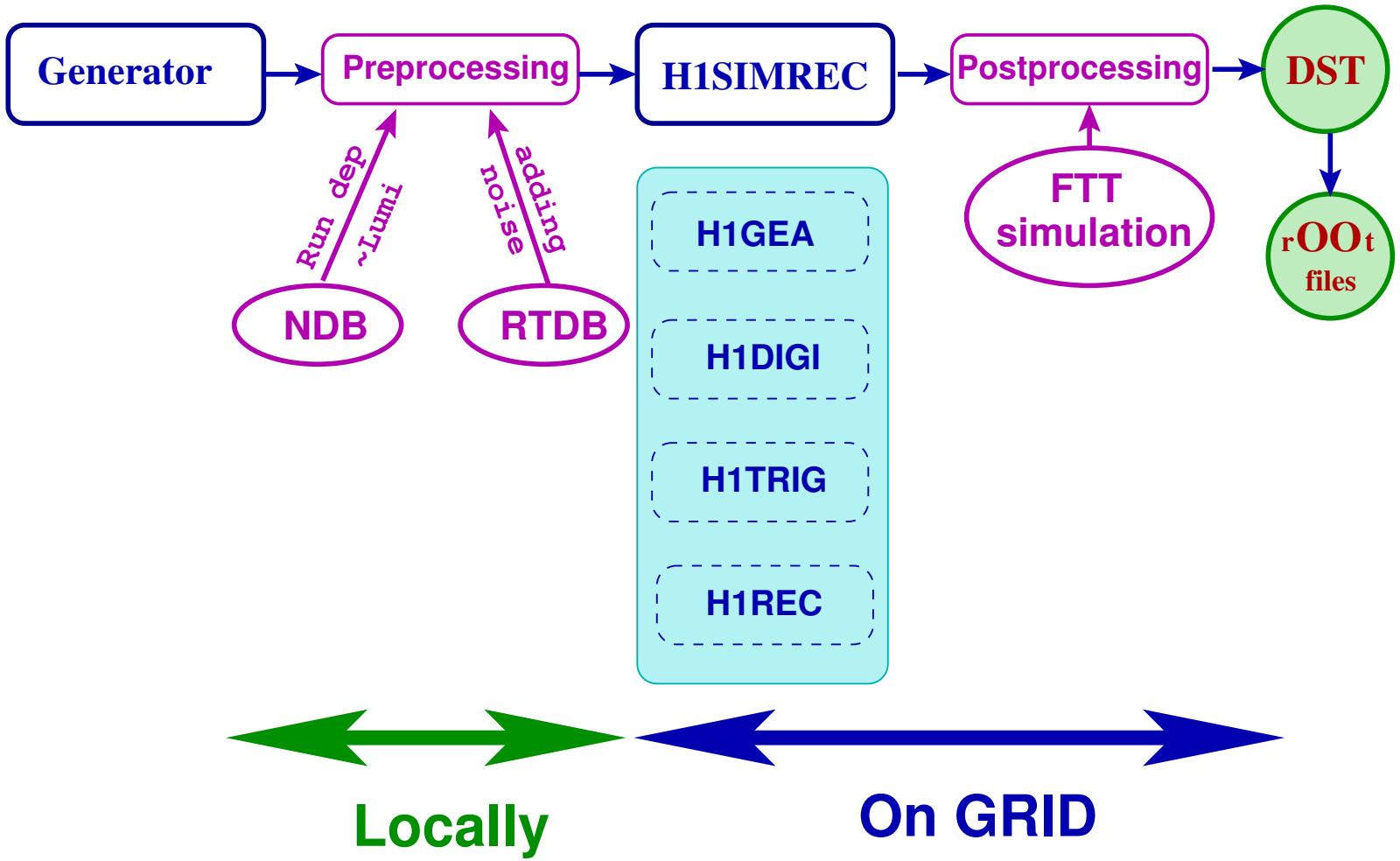
- Main effect: misalignment of H1 wrt HERA coord.system $\Rightarrow \mathcal{O}(1\mathrm{mrad})$ – constant for each detector configuration
- Smaller effect: real run/time dependent beam tilt, $\mathcal{O}(0.1\mathrm{mrad})$ – so far neglected (but essential for distant beamline detectors)
- 'Forward particles veto' implemented to allow tilt for scattered electron, but do not spoil Fwd detectors responce for elastic diffraction



MC Production chain



- DST files ⇒ `/acs/mc/generator/YY/nnnn/*.DST.Ckkkkkkk` (YY = year; nnnn = SIMREC ID)
- OO-files ⇒ `/acs/mc/oo-x.y/generator/nnnn/*.root` (x.y = OO release)
- Capacity: $200 - 250M$ events/month ⇒ MC statistics is no longer a limiting factor

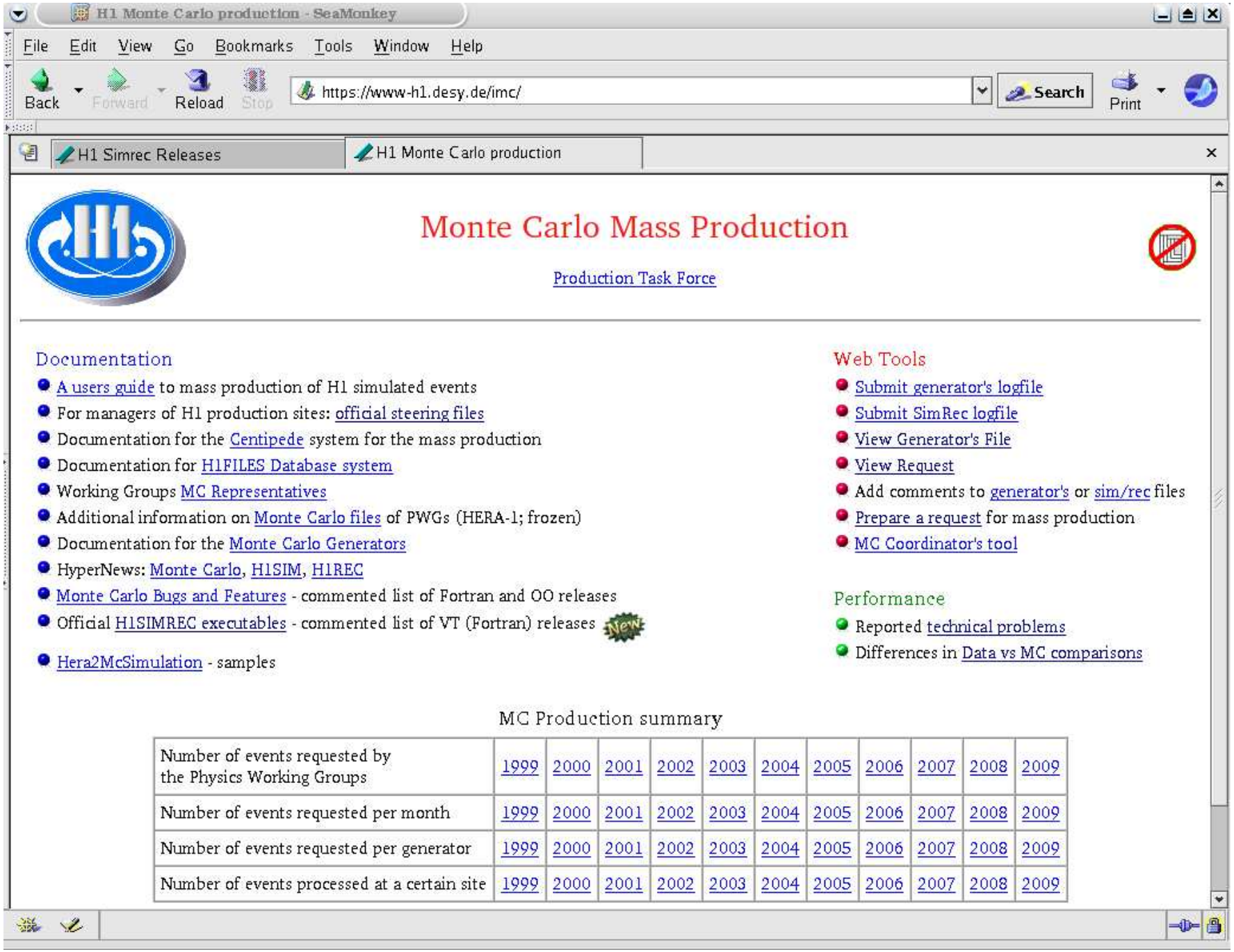
Web Tools and useful Links

/h1/VERSION_TABLE

XTALKS 2009

Row	H1REC8	H1REC9	H1REC	H1PHAN	H1L4	H1ECLASS	H1SIM	H1UTIL	H1TRIG	H1LOOK	H1BSTREC	H1FTTEMU	
70	-	-	97606	31200	63600	20700	39100	64300	19100	-	11900	50900	!new !mc5_dst7
69	-	-	97605	31200	63600	20700	39000	64300	19100	-	11900	50900	!mc4_dst7
68	-	-	97604	31200	63600	20700	38900	64300	19000	-	11900	50900	!mc3_dst7
67	-	-	90743	31200	63300	20700	39100	64300	19100	11907	-	-	!test_hera1
66	-	-	97603	31200	63600	20700	38900	64300	19000	-	11900	50900	!mc2_dst7
65	-	-	97602	31200	63600	20700	38800	64200	19000	-	11700	50900	!mc_dst7
63	-	-	97601	31200	63600	20700	38700	64200	19000	-	11700	50900	!pro !dst7
62	-	-	97400	31200	63600	20700	38400	64200	19000	-	11700	50900	!mc2_dst6
61	-	-	97301	31200	63600	20700	38400	64200	19000	-	11300	50900	!mc6_dst5
60	-	-	97301	31200	63600	20700	38100	64200	18900	-	11300	50500	!mc5_dst5
59	-	-	97400	31200	63600	20700	38200	64200	18900	-	11700	50500	!mc_dst6
58	-	-	90732	31200	63300	20700	38100	64200	18900	11907	-	-	!hera1_08d
56	-	-	90732	31200	63300	20700	38000	64100	18500	11907	-	-	!hera1_08c
55	-	-	97400	31200	63600	20700	38000	64100	18500	-	11400	-	!dst6
54	-	-	97301	31200	63600	20700	38000	64100	18500	-	11300	-	!mc4_dst5
53	-	-	97301	31200	63600	20700	37900	64100	18500	-	11300	-	!mc3_dst5
51	-	-	97301	31200	63600	20700	37700	64100	18500	-	11300	-	!mc2_dst5
50	-	-	90732	31200	63300	20700	37900	64100	18500	11907	-	-	!hera1_08b
49	-	-	96540	31200	63300	20700	37700	64100	18500	-	10800	-	!mc6_dst3
...													

- Hera1: VT-16 (data), VT-58 (MC) – (completed) analyses $\Rightarrow$ VT-67 (test DST7)
- DST3: VT-32 (data), VT-49 (MC) – most of HERA2 REX publications
- DST4: VT-38 (data), VT-43 (MC) – F_L 2008 publication
- DST5: VT-45 (data), VT-61 (MC) – most of the current HERA2 analyses
- DST6: VT-59 (data), VT-62 (MC) – F_L, F_L^D analyses (H1 preliminary for DIS-2009)
- DST7: VT-63 (data), VT-69/70 (MC) – All final analyses (prime consumers: high Q2, HQ)



Monte Carlo Mass Production

Production Task Force

Documentation

- A users guide to mass production of H1 simulated events
- For managers of H1 production sites: official steering files
- Documentation for the Centipede system for the mass production
- Documentation for H1FILES Database system
- Working Groups MC Representatives
- Additional information on Monte Carlo files of PWGs (HERA-1; frozen)
- Documentation for the Monte Carlo Generators
- HyperNews: Monte Carlo, H1SIM, H1REC
- Monte Carlo Bugs and Features - commented list of Fortran and OO releases
- Official H1SIMREC executables - commented list of VT (Fortran) releases New
- Hera2McSimulation - samples

Web Tools

- Submit generator's logfile
- Submit SimRec logfile
- View Generator's File
- View Request
- Add comments to generator's or sim/rec files
- Prepare a request for mass production
- MC Coordinator's tool

Performance

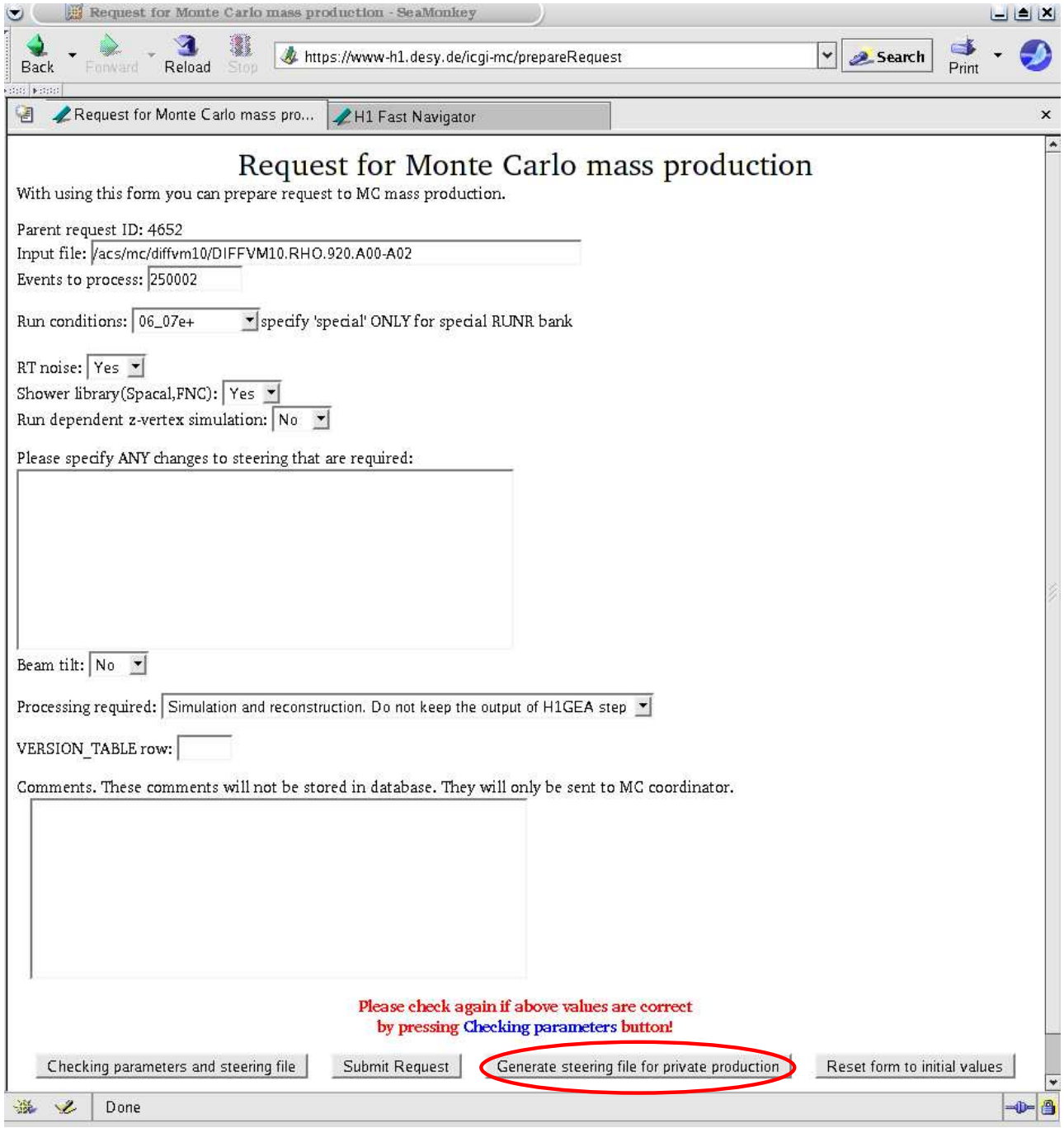
- Reported technical problems
- Differences in Data vs MC comparisons

MC Production summary

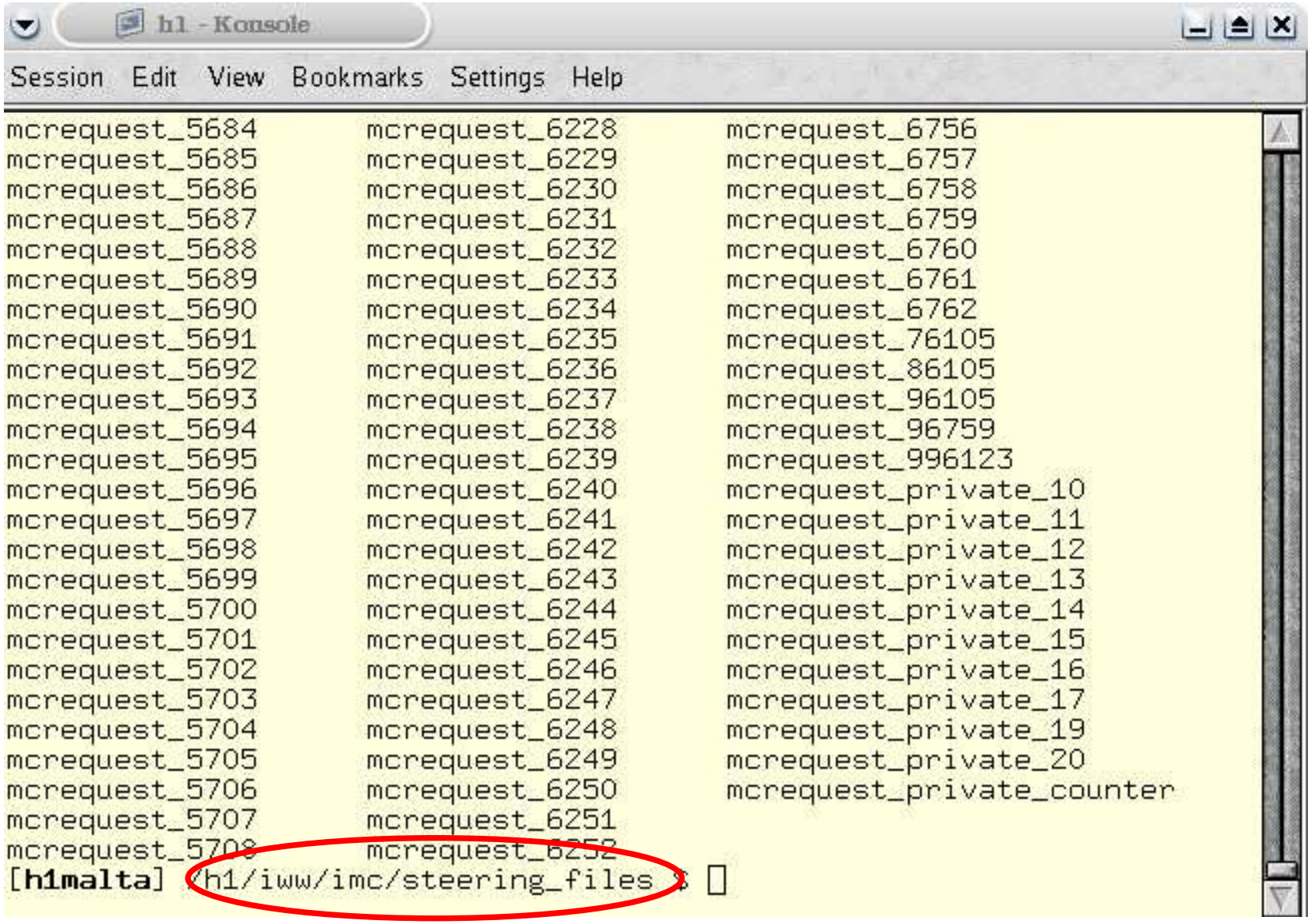
Number of events requested by the Physics Working Groups	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Number of events requested per month	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Number of events requested per generator	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Number of events processed at a certain site	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009

Official H1SIMREC releases

VT row	VT tag	Date	Applicability	Description
70	mc5_dst7	05-Oct-2009	HERA2, DST7	New RT-noise simulation for Spacal (at the moment disabled by official steering)
69	mc4_dst7	03-Sep-2009	HERA2, DST7	Bug fixes: BB-parametrization affecting CIP simulation; L2-L3 verified actual st in TLV3 bank; Detailed Spacal simulation in fine granularity repaired
68	mc3_dst7	11-Aug-2009	HERA2, DST7	Bug fix for trigger simulation (banks TLV1,TEL1,TESI were dropped in versions VT 63-66)
66	mc2_dst7	11-Jul-2009	HERA2, DST7	Improved LAr noise treatment for MC; Run-dependent steering FSDD/BSDD to control non-operational FST/BST periods
65	mc_dst7	28-Jun-2009	HERA2, DST7	Adjustment of FTT simulation (calibration consistent with new dE/dx treatment); Improved BST and FST dead material description
63	dst7	22-May-2009	HERA2, DST7	Implementation of new dE/dx simulation for HERA-2; New (DST7) tracking (all benefits of TTF developments during last year)
62 61	mc2_dst6 mc6_dst5	8-May-2009	HERA2, DST6 HERA2, DST5	Bug fix for Spacal shower library option; Bug fixes in calculation of magnetic fields for forward beamline elements (relevant for VFPS)
60 59 58	mc5_dst5 mc_dst6 hera1_08d	17-Dec-2008	HERA2, DST5 HERA2, DST6 HERA1, Repro-2000	Another bug fix in FMD RT-noise simulation; New option for run-dependent z-vertex simulation; First correct implementation of Jet trigger simulation; Bug fix and tuning of BCREC module
56 55 54	hera1_08c dst6 mc4_dst5	27-Aug-2008	HERA1, Repro-2000 HERA2, DST6 HERA2, DST5	Bug fix in the new CIP RT-noise simulation; Updated BCREC module (improved combination of space points + clean-up of the code)
53	mc3_dst5	29-May-2008	HERA2, DST5	Bug fix in the new FMD RT-noise simulation; Release of the new RT-noise simulation for CIP and COP
51	mc2_dst5	15-May-2008	HERA2, DST5	Bug fix in PLUG reconstrution (read correct database bank for MC case)
50	hera1_08b	29-May-2008	HERA1, Repro-2000	Bug fix in the new FMD RT-noise simulation; Release of the new RT-noise simulation for CIP and COP


Request for Monte Carlo mass production - SeaMonkey
Back
Forward
Reload
Stop
https://www-h1.desy.de/icgi-mc/prepareRequest
Search
Print
Request for Monte Carlo mass pro...
H1 Fast Navigator
Request for Monte Carlo mass production
With using this form you can prepare request to MC mass production.
Parent request ID: 4652
Input file: /acs/mc/diffvm10/DIFFVM10.RHO.920.A00-A02
Events to process: 250002
Run conditions: 06_07e+ specify 'special' ONLY for special RUNR bank
RT noise: Yes
Shower library(Spacal,FNC): Yes
Run dependent z-vertex simulation: No
Please specify ANY changes to steering that are required:
Beam tilt: No
Processing required: Simulation and reconstruction. Do not keep the output of H1GEA step
VERSION_TABLE row:
Comments. These comments will not be stored in database. They will only be sent to MC coordinator.
Please check again if above values are correct
by pressing Checking parameters button!
Checking parameters and steering file
Submit Request
Generate steering file for private production
Reset form to initial values
Done

Automatically generated steering files for H1MC production



Practical information

XTALKS 2009

- Useful hints
  - ▷ Check/verify your generator file before requesting large scale production
  - ▷ Register generator file via web-tool and get unique generator ID
  - ▷ Think which options you need for simulation
  - ▷ Submit official MC production request via your PWG MC responsible
    (For private production use same tool to generate correct steering)
  - ▷ Do worry if dominant systematics in your analysis comes from detector simulation
- Give your feedback
  - ▷ Share your (positive and negative) experience with colleagues
  - ▷ Not happy with simulation performance? Complain!
  - ▷ Miss some useful option in H1SIMREC? Make justified request!

Good Luck!