A brief introduction to tools for TPC ILD Optimization

Junping Tian, Keisuke Fujii (KEK)

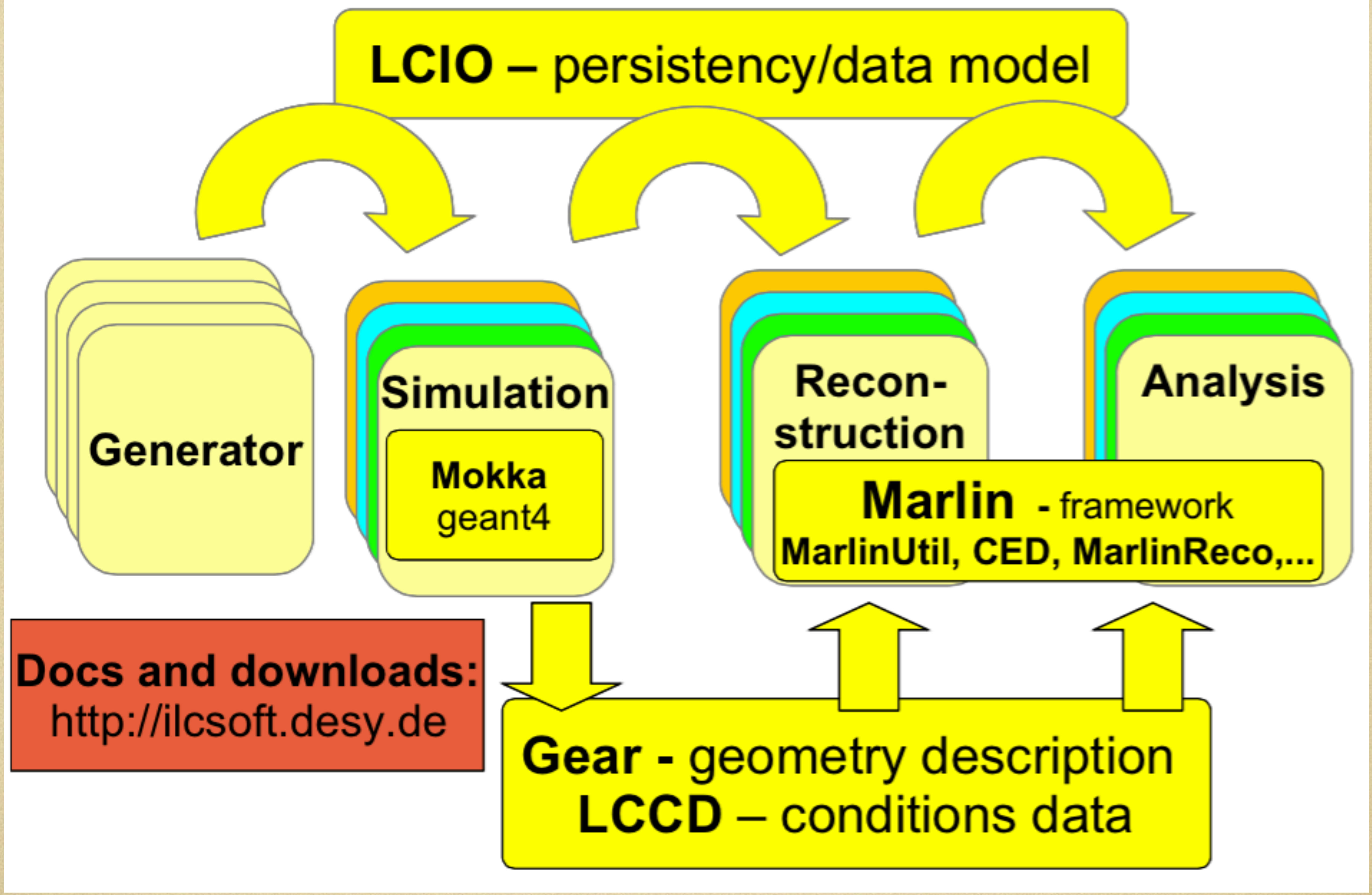
Nov. 28, 2014 @ TPC Optimization Discussion

outline

- framework: generator; detector simulation; reconstruction; analysis
- existing MC samples
- people involved in TPC ILD optimisation
- thoughts on next studies

framework overview — ILCSoft

F. Gaede @ LCWS13



latest release: v01-17-06

Generator

- Whizard (arXiv:0708.4233)
  - O'Mega (matrix element)
  - very robust (all the possible feynman diagrams can be generated automatically)
  - default generator for LoI and DBD (v1.x up to 6-fermion; v2.x 8-fermion; v1.95 for DBD)
- Physsim (http://www-jlc.kek.jp/subg/offl/physsim/)
  - HELAS (matrix element)
  - hand coded each feynman diagram
  - good for generating signal (well controlled)

Beam-Beam interaction: GuineaPig (TESLA-97-08)

Detector Simulation

- Mokka (LC-TOOL-2003-010)
  - based on Geant4, full detector simulation
  - ILD_o1 (AHcal); ILD_o2 (SDHcal); ILD_o3 (ScEcal)
  - changing geometry or sub-detector is not very trivial

- SGV 3.0 (arXiv:1203.0217v1)
  - sophisticated fast detector simulation
  - model ILD_00 available
  - convenient to change geometry and sub-detector
  - same interface to generator (stdhep) or analysis (dst)

DD4HEP being developed is going to replace Mokka

Reconstruction & Analysis

- Particle Flow (Nucl. Intrum. Meth. A611 (2009) 25-46)
  - tracking, clustering, matching
  - PandoraPFA, Arbor
- Flavor Tagging (T. Suehara @ LCWS12)
  - vertex finder, flavor tagging
  - LCFIPlus
- Isolated Lepton Finder
- Jet Clustering (arXiv:1111.6097)
  - Durham, kt algorithms
  - FastJet

many existing processors in MarlinReco, MarlinTrk, MarlinKinFit, etc. and from individual analyst

existing MC samples

available on grid (lfn:/grid/ilc/prod/ilc)

- generator samples
  - http://ilcsoft.desy.de/dbd/generated/
- fully simulated & reconstructed samples
  - https://ilcproddb.desy.de/admin/ild/gen/

    usually there are three types of samples: sim (just after detector simulation); rec (reconstructed, with hit level information saved); dst (only particle level information)

not on grid, also existing SGV samples for several ongoing studies, i.e. various TPC radii

DBD Samples

1TeV

- Four fermions
- Two fermions
- Beam-strahlung
- tth
- Six fermions
- Higgs
- gammagamma

500 GeV

- tt (6 ferm)
- Four fermions
- Two fermions
- Beam-strahlung
- gammagamma
- higgs

Other Samples

- 250, 350 GeV ...

proposals related to TPC optimization studies

(c.f. Jenny @ ILD opt meeting; Mikael @ LCWS14; etc.)

- first of all, not only **optimization**, but also **justification of TPC** (advantages)
- not only **detector performance**, but also **physics performance**
- impact of **high momentum tracking** (radius, SET, B-Field):
  - Higgs recoil mass again Z—>μμ (radius opt done by Tomohisa @ KEK using SGV, SET not yet)
  - branching ratio of H—>μμ (existing DBD analysis done by Tino @ KEK, not sure will work on TPC opt)
  - heavy gauge boson search, Z'—>μμ (no existing studies)
- impact of **low momentum tracking** (B-Field?):
  - how tracking efficiencies affect flavor tagging performance including γ^* and K_S reconstruction (no existing studies?)
  - degenerated higgsinos in natural SUSY, $M(X^+)$-$M(X^0)$ ~< 1 GeV, where only few low momentum particles can be detected (ongoing by Hale and Yorgos @ DESY)
  - efficiency as function of Pt, cosθ (partially done by Mikael using SGV)
  - new algorithm for low-pt PID, combine information from ECal, Yoke (partially being studied by Hale)

proposals related to TPC optimization studies

- impact of **dE/dx** (radius):
  - application to analysis is recently implemented in MarlinReco (by Masakazu @ Tokyo U')
  - use for vertex charge reconstruction, important for measurement of A_{FB} in tt-bar (being studied by Roman @ LAL, and Masakazu)
  - use for improving flavor tagging (by Masakazu)
  - many other physics cases which require PID for soft tracks
  - but all based on assumption of 3~5% dE/dx resolution, needs to be justified (by someone from TPC group; verify dE/dx calculation in Mokka simulation; include detector resolution; Astrid @ DESY was working on this, as well as Wenxin @ Saclay?)
- impact of **continuous tracking** (B-Field):
  - quasi stable stau in GMSB, large parameter space where stau decays in TPC (preliminary studied by Takuaki @ Tokyo U', but not decay in TPC)
  - track with kinks, need some quantitative study (no existing studies)
  - curling tracks are also crucial in degenerated Higgsinos (Hale and Yorgos)

proposals related to TPC optimization studies

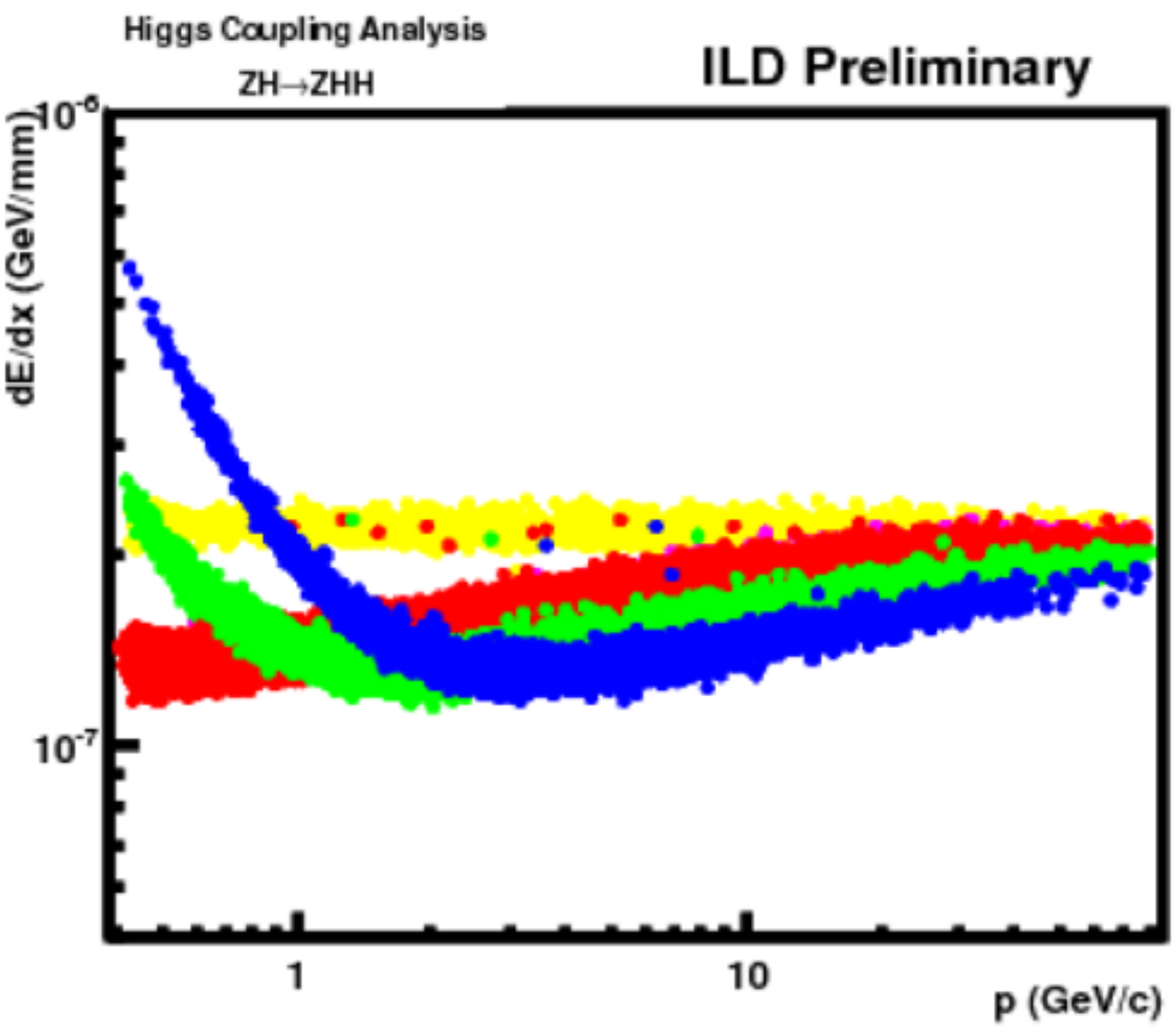
- **low material budget** in the tracking volume
  - mostly connect to efficiency of low momentum tracking
  - PID by different track mass assignment in secondary vertices D^0—>$K\pi$, Λ^0—>$p\pi$
  - another other impact?
- **two hit (track) separation**
  - 3-prong decay of highly boosted τ
  - reconstruction algorithm (not implemented)
- proper implementation of module boundaries
- improve tracking algorithm (Frank, etc. @ DESY)
- non-uniform B-field tracking (being studied by Bo Li @ Tsinghua U')

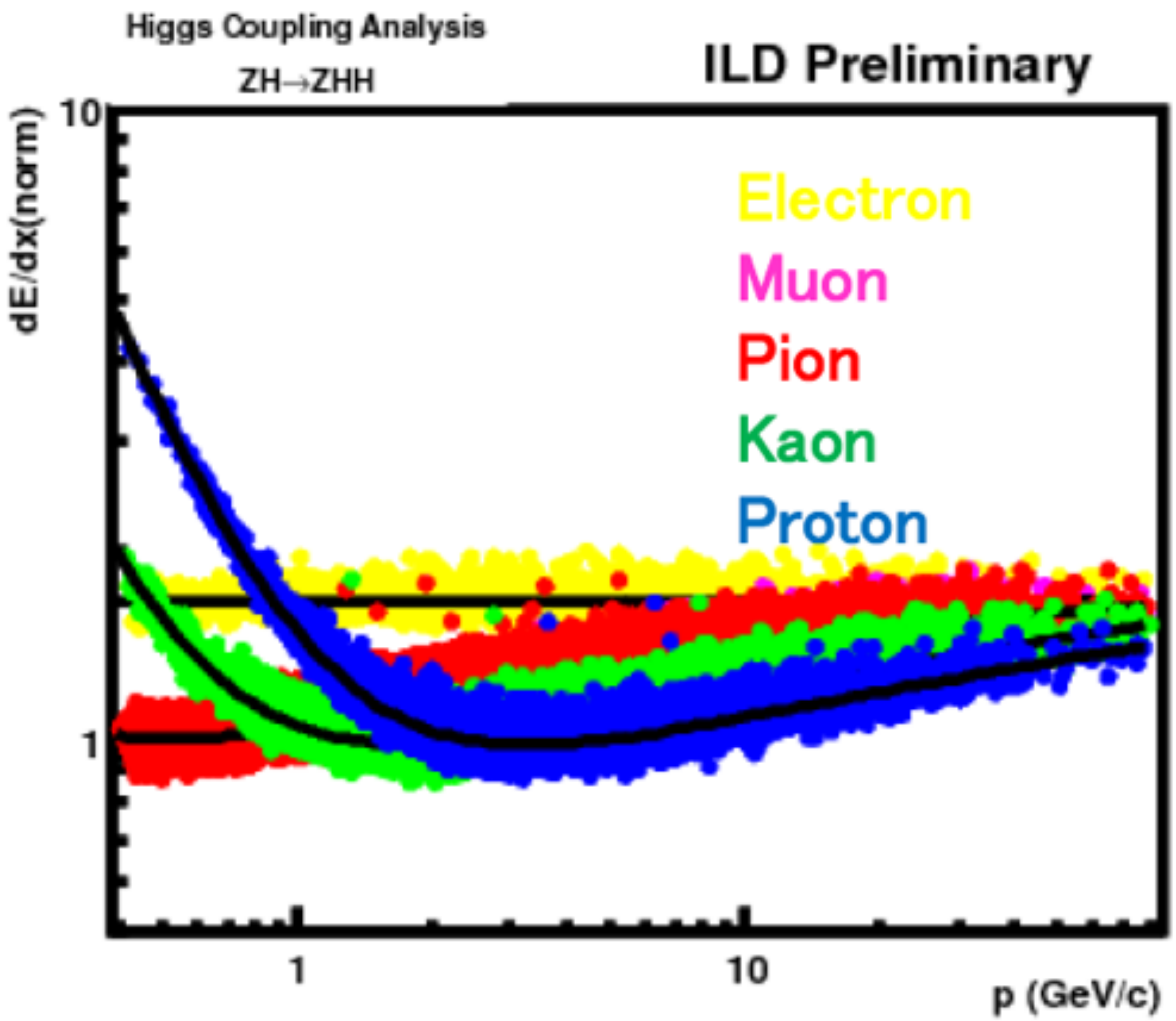
backup

dE/dx distribution

Masakazu @ ILD meeting 2014

- For each particle
  - Polar angle dependence corrected
  - Num. of Hits dependence corrected
  - Scale to $\left\langle \frac{dE}{dx} \right\rangle = 1.0$ for MIP pion

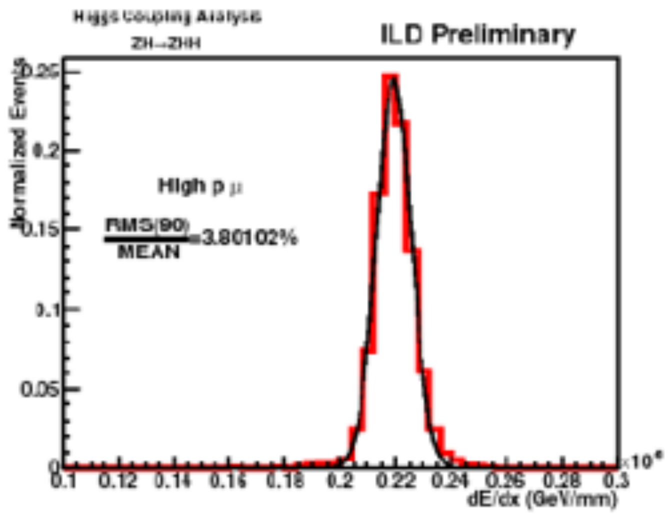


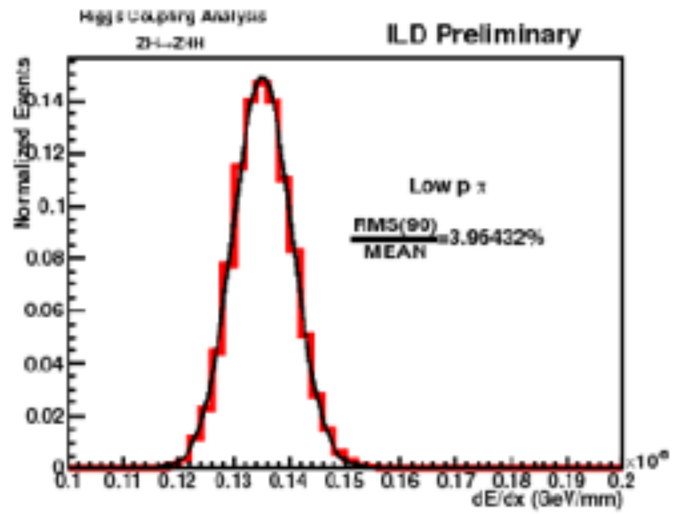


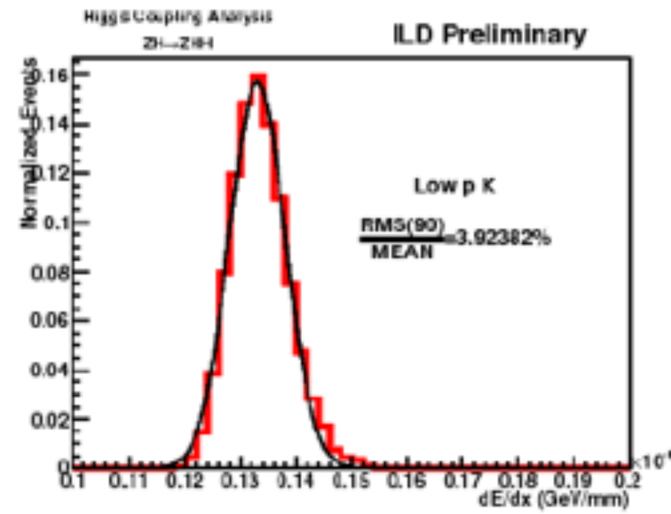
dE/dx FLUCTUATION

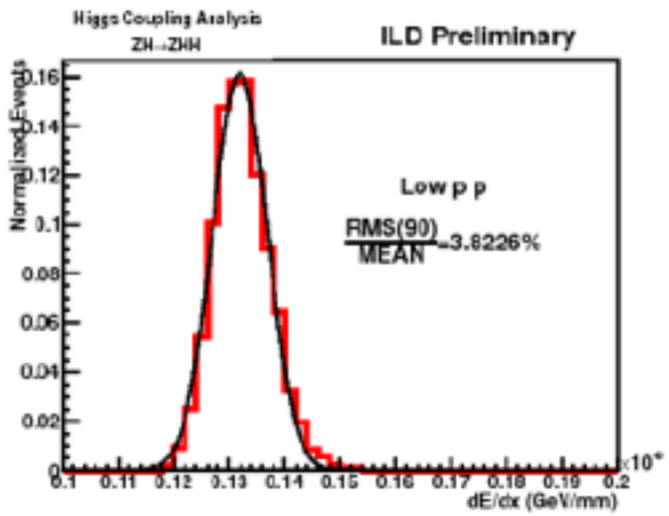
Masakazu @ ILD meeting 2014

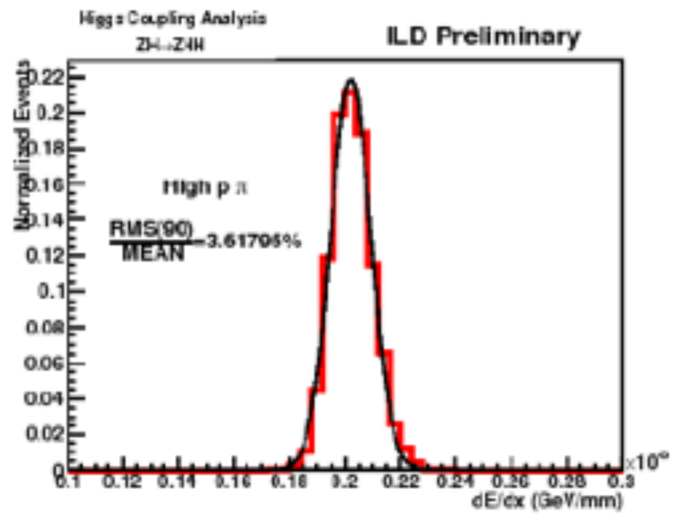
- Fluctuation of dE/dx using various type of tracks
  - Estimation of RMS(90)/MEAN

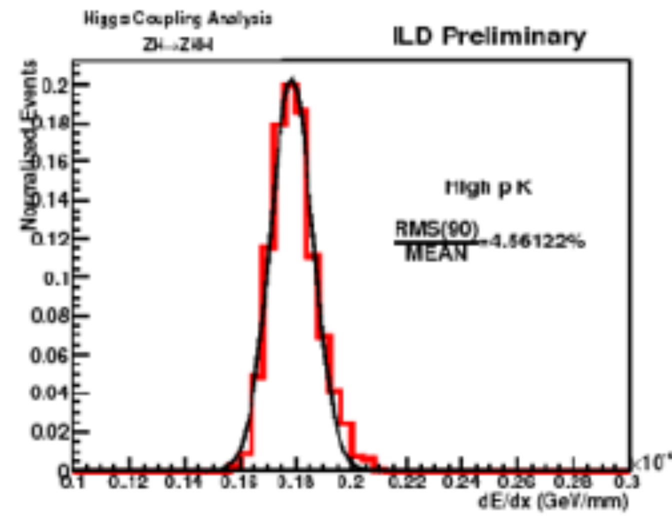


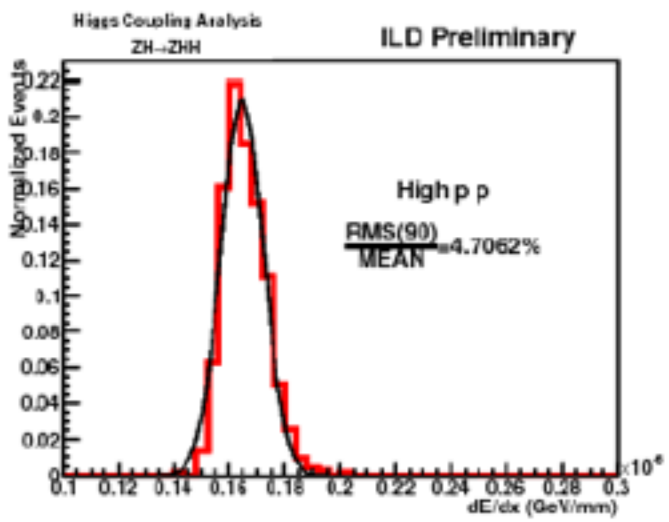












High: p >20GeV/c

Low: π 0.3GeV/c<p<0.6GeV/c

K 1.0GeV/c <p<3.0GeV/c

p 2.0GeV/c<p<4.0GeV/c

- Fluctuations of each particle/each momentum rage

3 – (<5)%!!

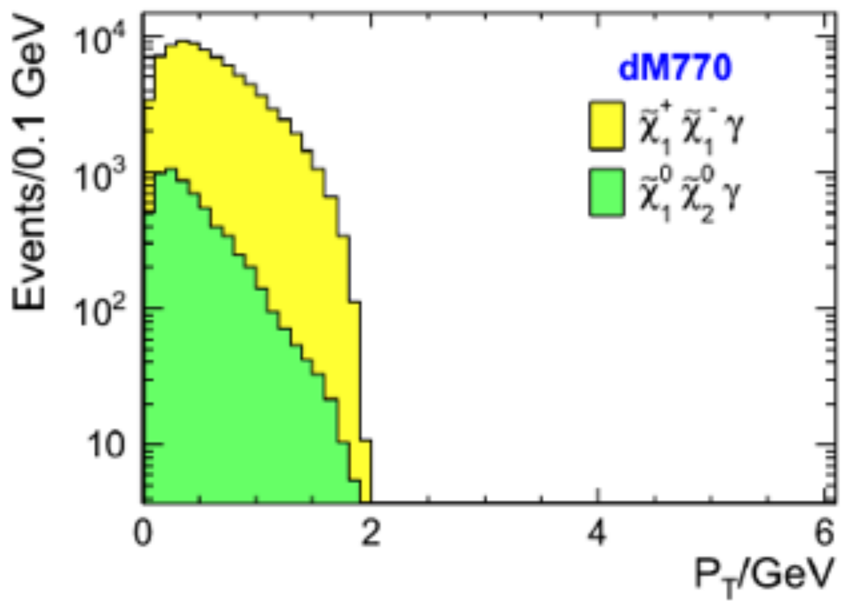
Production Processes & Decay Modes

Production Processes

- $e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_1^-$
- $e^+e^- \to \tilde{\chi}_1^0\tilde{\chi}_2^0$

Decay Modes

- $\tilde{\chi}_1^\pm \to \tilde{\chi}_1^0 W^{\pm *}$
- $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 Z^{0*}$
- $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \gamma$



P_T dist. of final state particles at generator level

- Muons & Pions are very soft!

Separation of Signal Processes

Exclusive decay modes:

- $\tilde{\chi}_1^+\tilde{\chi}_1^+ \to 2\tilde{\chi}_1^0\ W^{+*}\ W^{-*}$
  - semileptonic final state (35%)
- $\tilde{\chi}_1^0\tilde{\chi}_2^0 \to 2\tilde{\chi}_1^0\ Z^{0*}/\gamma$
  - photonic final state (74%)

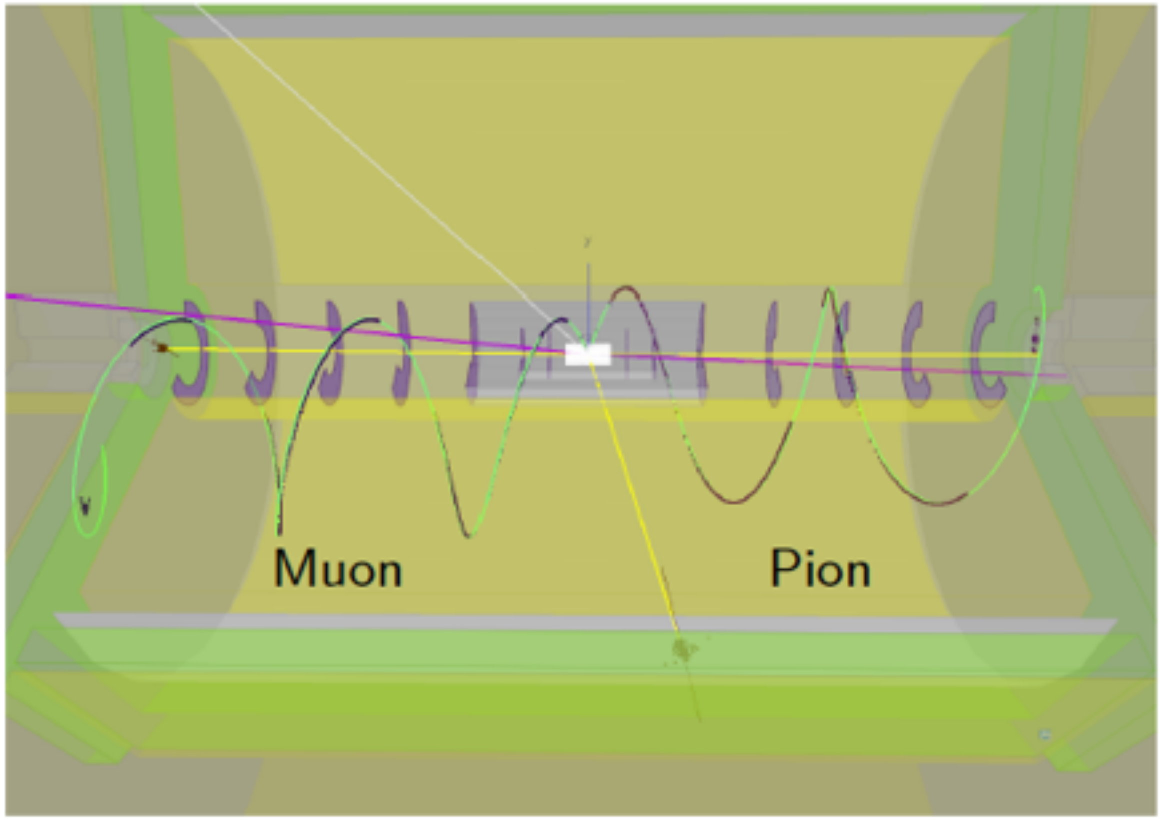
In semileptonic decays

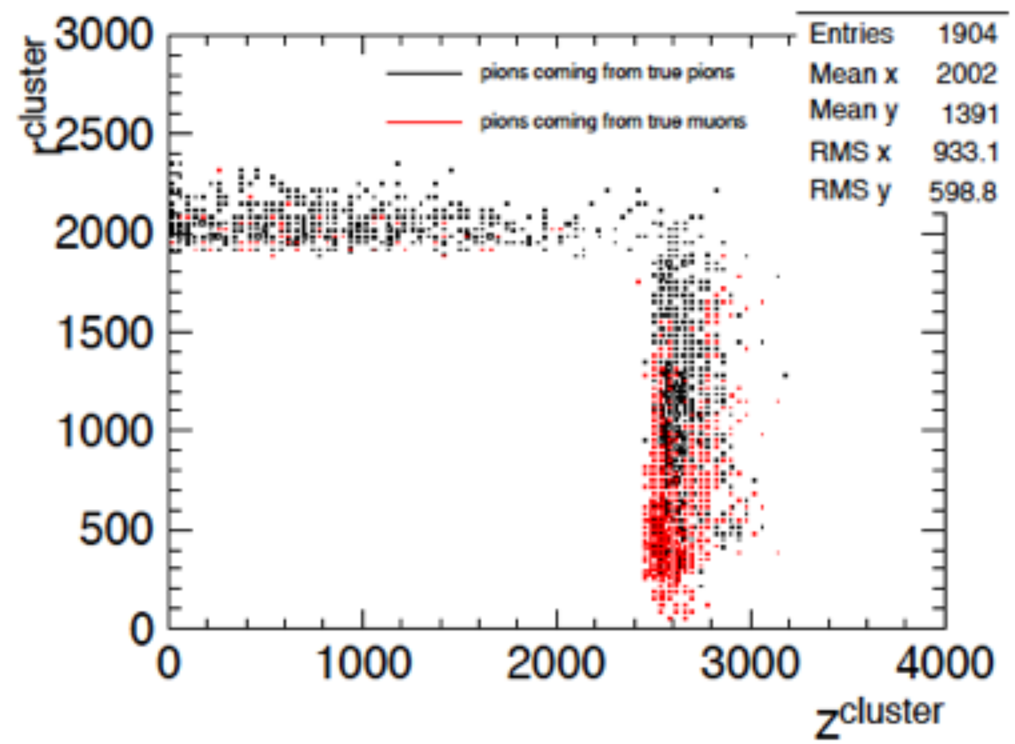
- $BR(\tilde{\chi}_1^\pm \to \tilde{\chi}_1^0\ \pi) \approx 60\ \%$
- $BR(\tilde{\chi}_1^\pm \to \tilde{\chi}_1^0\ \mu^-\nu_\mu) \approx 13\ \%$

- Muon & Pion separation plays an important role in this analysis

Muon and Pion Separation in Calorimetry

Checked the behaviours of muon and pion using event display

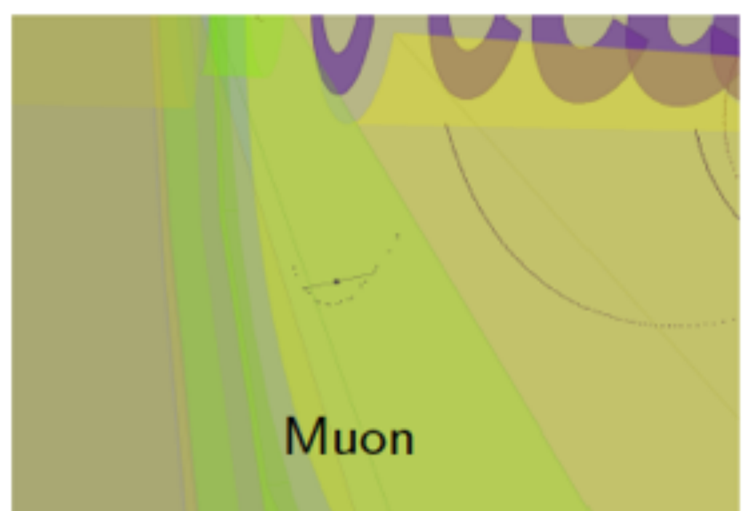




- The particles curl and travel along the magnetic field lines, and hit the endcap calorimeters

Cluster properties are studied

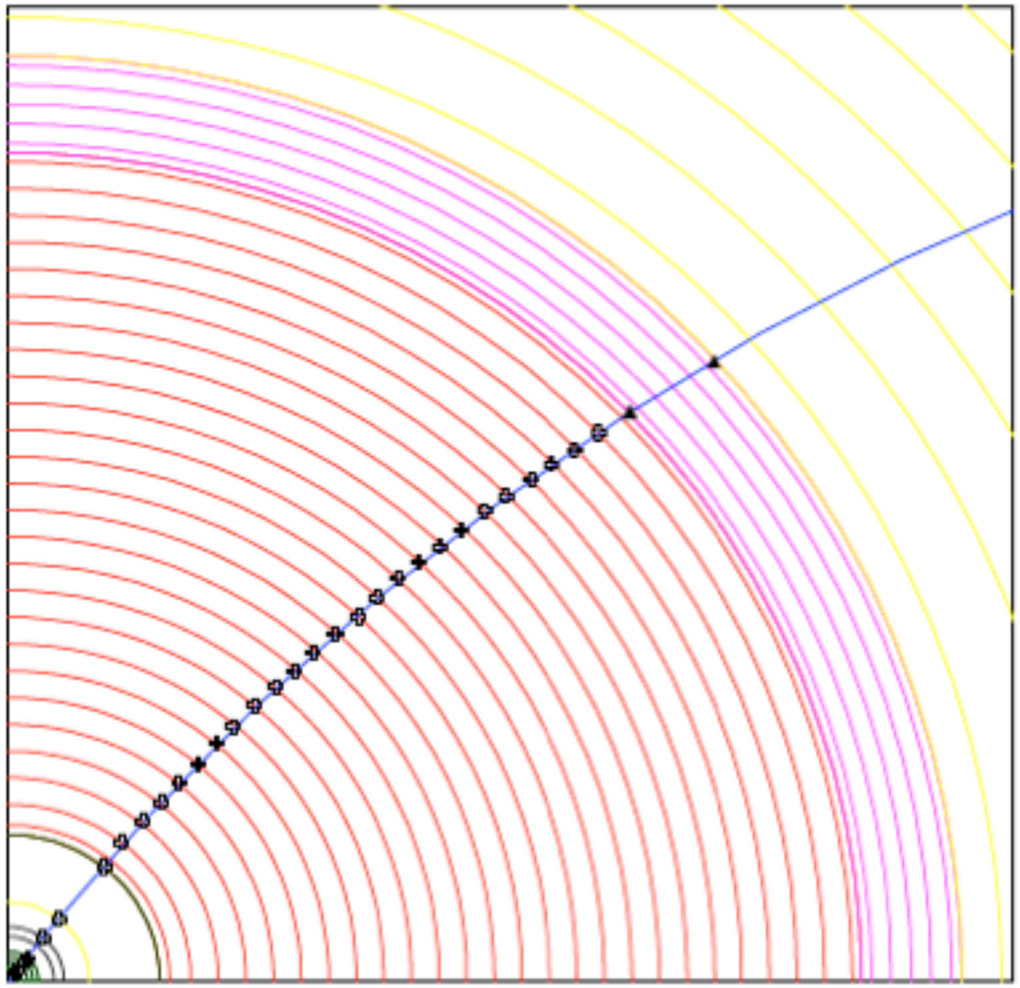
- Observed that the cluster shape of muon and pion is different



SGV: How tracking works

SGV is a machine to calculate covariance matrices

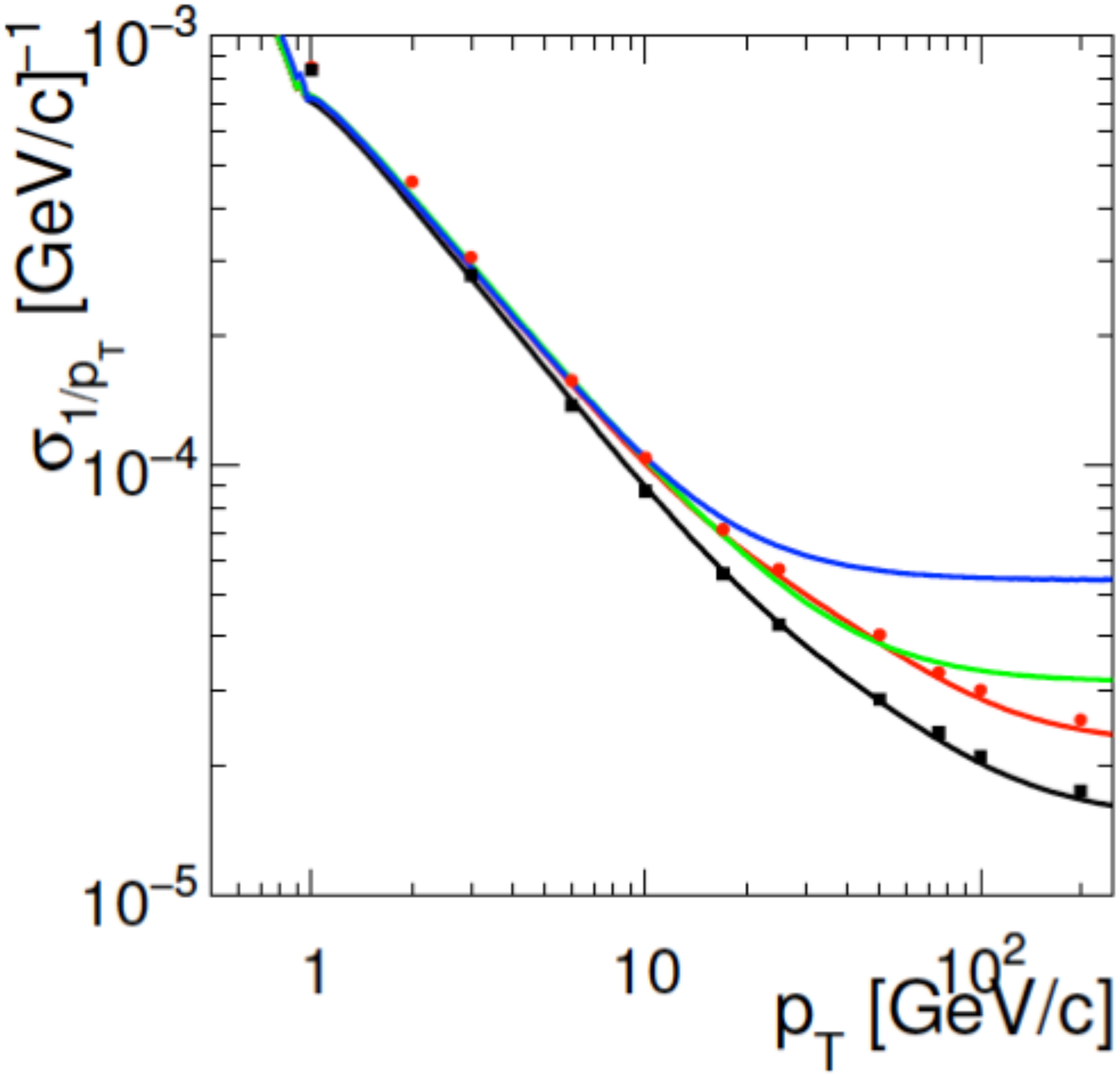
Follow track-helix through the detector-layers

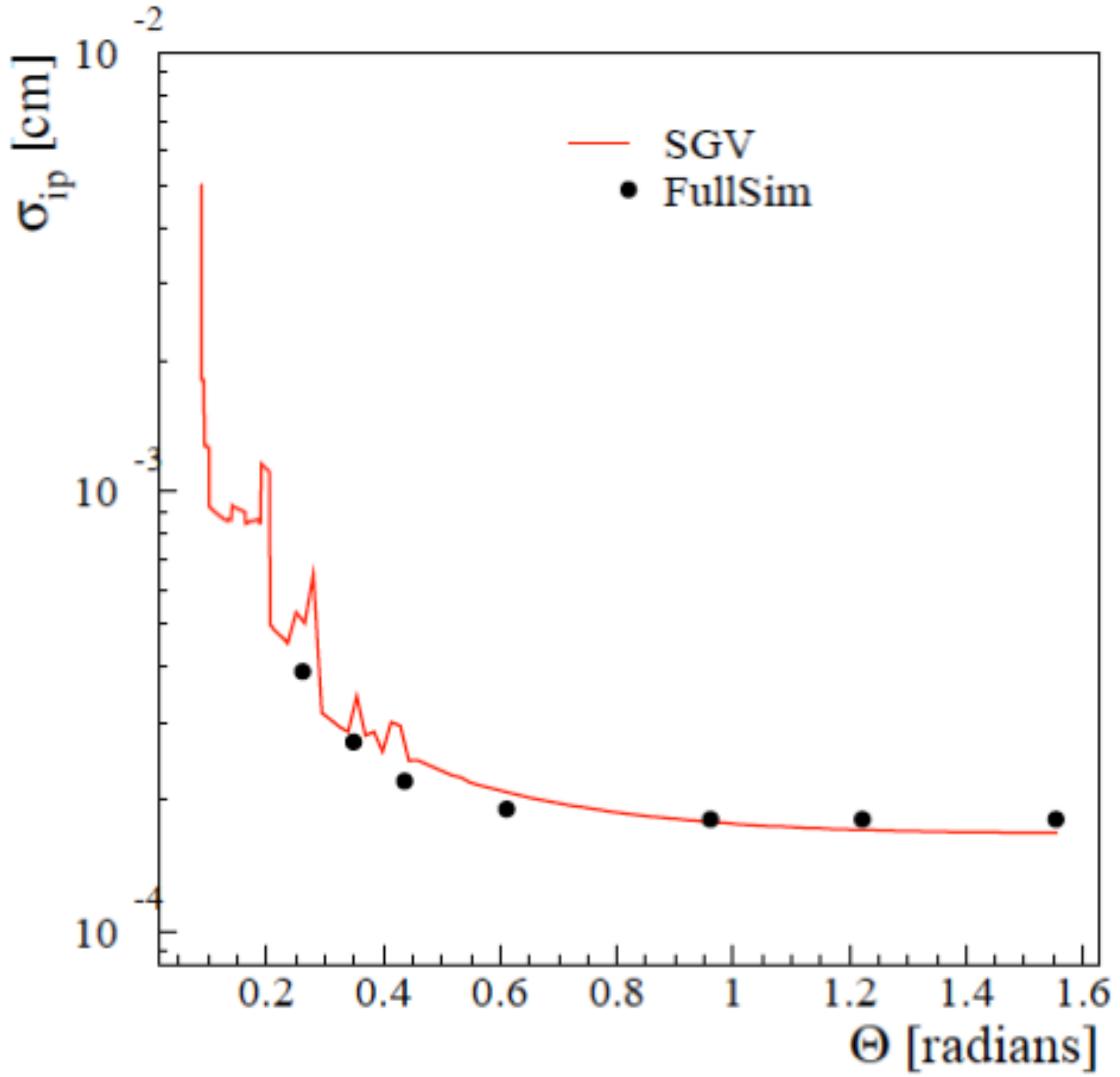


(Fringe benefit of stepping: EM-interactions in detector layers simulated)

- Calculate cov. mat. at perigee, including material, measurement errors and extrapolation.
- Smear perigee parameters (Choleski decomposition: takes all correlations into account)
- Helix *parameters* exactly calculated, *errors* with one approximation: helix moved to (0,0,0) for this.
- Other stuff:
  - Plug-ins for particle identification, track-finding efficiencies,...
  - Information on hits accessible to analysis.

SGV and FullSim: P_T and D_0 resolution





Lines: SGV, dots: Mokka+Marlin

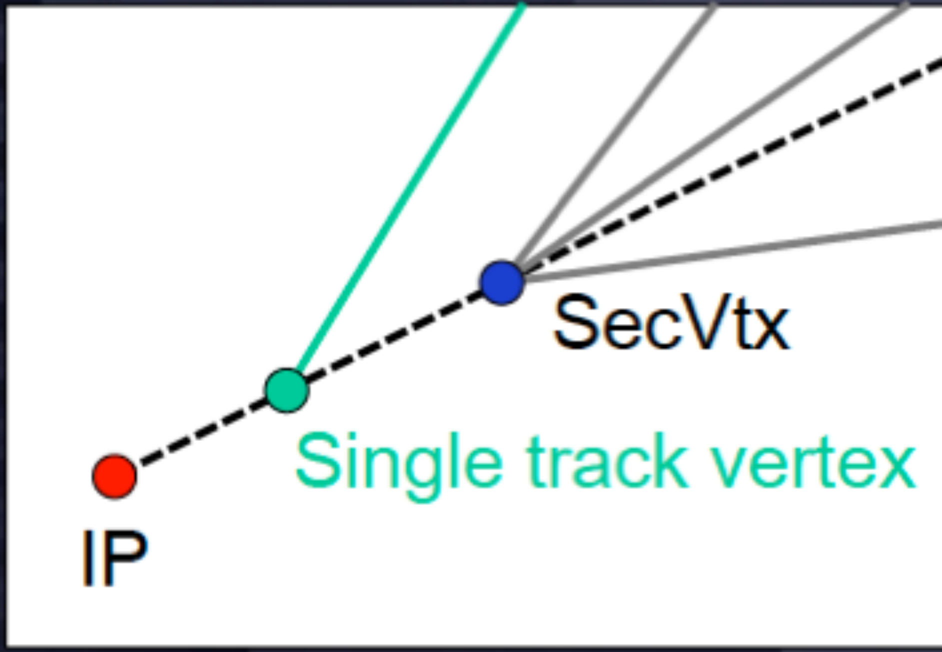
Calorimeter simulation

The issues:

- Clearly: Random E, shower position, shower shape. Controlled by the geometry-file.
- But also association errors:
  - Clusters might merge.
  - Clusters might split.
  - Clusters might get wrongly associated to tracks.
- Will depend on Energy, on distance to neighbour, on EM or hadronic, on Barrel or forward, ...
- Consequences:
  - If a (part of) a neutral cluster associated to track → Energy is lost.
  - If a (part of) a charged cluster not associated to any track → Energy is double-counted.
  - Other errors (split neutral cluster, charged cluster associated with wrong track ....) are of less importance.

LCFIPlus achievements

1. Vertex finder (primary & secondary)
   - Do not use jet direction
   - Optimized! (critical)
2. Jet clustering
   - Using vertex information in some ways
3. Vertex Refiner
   - Single track vertices (critical)
   - Optimization again using jets



4. Flavor tagging
   - Imported to TMVA (more general)
   - Adding some variables

WHIZARD in a Nutshell

WHIZARD is a universal event generator for elementary processes at colliders:

- e^+e^-: LEP and TESLA/NLC $\Rightarrow$ ILC, CLIC, ...
- pp: Tevatron $\Rightarrow$ LHC, ...

It contains

1. O'Mega: Automatic matrix elements for arbitrary elementary processes, supports SM and many BSM extensions
2. Phase-space parameterization module
3. VAMP: Generic adaptive integration and (unweighted) event generation
4. Intrinsic support or external interfaces for: Feynman rules, beam properties, cascade decays, shower, hadronization, analysis, event file formats, etc., etc.
5. Free-format steering language SINDARIN

The WHIZARD Event Generator – Release 2.1

- Multi-Channel Monte-Carlo integration
- Efficient phase space and event generation (weighted & unweighted)
- Optimized tree-level matrix elements (O'Mega)
  - $e^+e^- \to t\bar{t}H \to b\bar{b}b\bar{b}jj\ell\nu$ (110,000 diagrams)
  - $e^+e^- \to ZHH \to ZWWWW \to bb + 8j$ (12,000,000 diagrams)
  - $pp \to \ell\ell + nj, n = 0, 1, 2, 3, 4, \ldots$ (2,100,000 diagrams with 4 jets + flavors)
  - $pp \to \tilde{\chi}_1^0\tilde{\chi}_1^0 bbbb$ (32,000 diagrams, 22 color flows, $\sim 10,000$ PS channels)
  - $pp \to VVjj \to jj\ell\ell\nu\nu$ incl. anomalous TGC/QGC
  - Test case $gg \to 9g$ (224,000,000 diagrams)

WHIZARD 2.1.1 release: Sep. 18, 2012

Old series: WHIZARD 1.97 (development stopped with 1.94)

The WHIZARD team: F. Bach, B. Chokoufé, W. Kilian, T. Ohl, JRR, M. Sekulla, F. Staub, C. Weiss,

Web address: `http://projects.hepforge.org/whizard`

Standard Reference: Kilian/Ohl/JRR, EPJC 71 (2011) 1742, arXive:0708.4233