High-Level Reconstruction: Overview and Workshop Goals

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DESY
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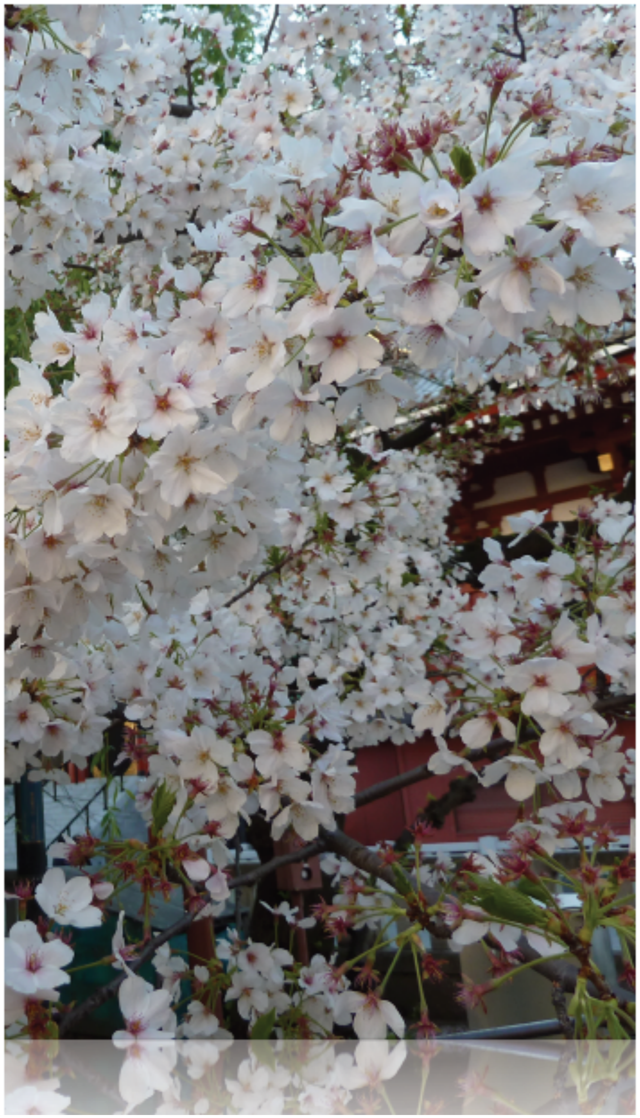
Outline



- Introduction:
  Why care now?
- DBD Status:
  What has been achieved?
- Beyond the DBD:
  What next?
- Example: Si Tracking
- Conclusions

Introduction

Why do we care now?

We have

- written CDRs, DBDs, Physics TDR
  & many individual publications
- using full, Geant4-based detector simulation and reconstruction
- backed-up by test beam performance

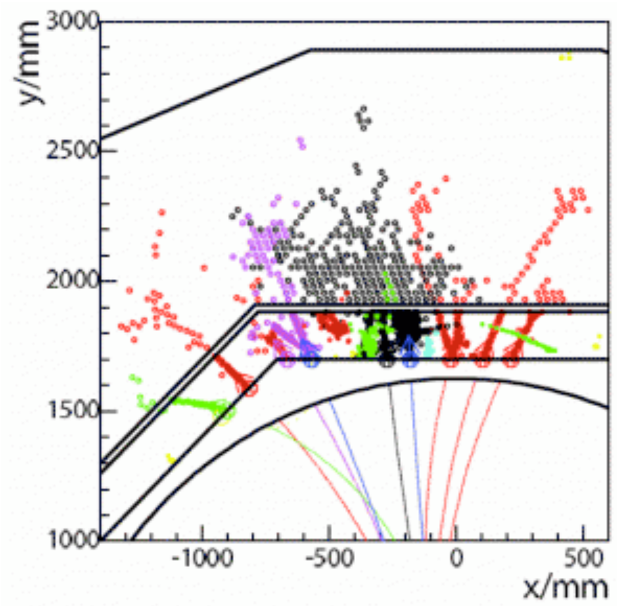
⇒ studied our detector concepts and their physics performance in more detail than ever before for a project at a comparable stage of its life-cycle!

So why do we have to push ever further than this?

Unprecendented Precision

Precision physics program requires LC detectors to be

- 2-10 x more precise than previous collider detectors
- highly granular to deal with 6, 8 and more jets in final state



⇒ Particle Flow Concept!

- design of LC detectors optimised for PFlow performance
- **detector design & final physics performance intimately intertwined with reconstruction**:

Since the DBD

- a lot of important software developments
- but no update of the standard recontruction
- all developments w.r.t. DBD StdReco
- non-trivial interplay
- our goal this week:
- a major update of the standard reconstruction
- make the developments available for all analyses and optimisation studies

DBD Reconstruction (ILD)

DBD Reconstruction - Overview

```
<marlin>
 <execute>
<!-- =========  overlay gamma gamma background  === -->
   <processor name="BgOverlay" />
<!-- ========== track digitization and tracking  === -->
  ......
   <!-- ========== the new C++ tracking ================ -->
   <processor name="MyClupatraProcessor" />
    <processor name="MySiliconTracking_MarlinTrk"/>
   <processor name="MyForwardTracking"/>
   <processor name="MyTrackSubsetProcessor" />
   <processor name="MyFullLDCTracking_MarlinTrk"/>

<!-- ========== the post tracking patrec   ================== →
   <processor name="MyV0Finder"/>
   <processor name="MyKinkFinder"/>
....
```

γγ->hadron overlay

TPC, Si, Fwd tracking, combined track fit in FullLDCTracking

V0 & Kink finding: input to Pandora

DBD Reconstruction - Overview

```
<!-- ===== calorimeter digitization and PFA ======= -->
  ....
<processor name="MyMarlinPandora"/>
<processor name="MyBCalReco"/>
```

PFO creation:
PandoraPFANew
BeamCal (pair bkg)

```
<!-- ========== particle ID =================== -->
<!--processor name="MyPFOID" / →
```

***NO* PARTICLE ID**

```
<!-- ========== full and DST output ============ -->
<processor name="MyRecoMCTruthLinker"/>
```

Link PFOs with MCTruth

```
<!-- ========== vertex finder ================== -->
<processor name="VertexFinder"/>
```

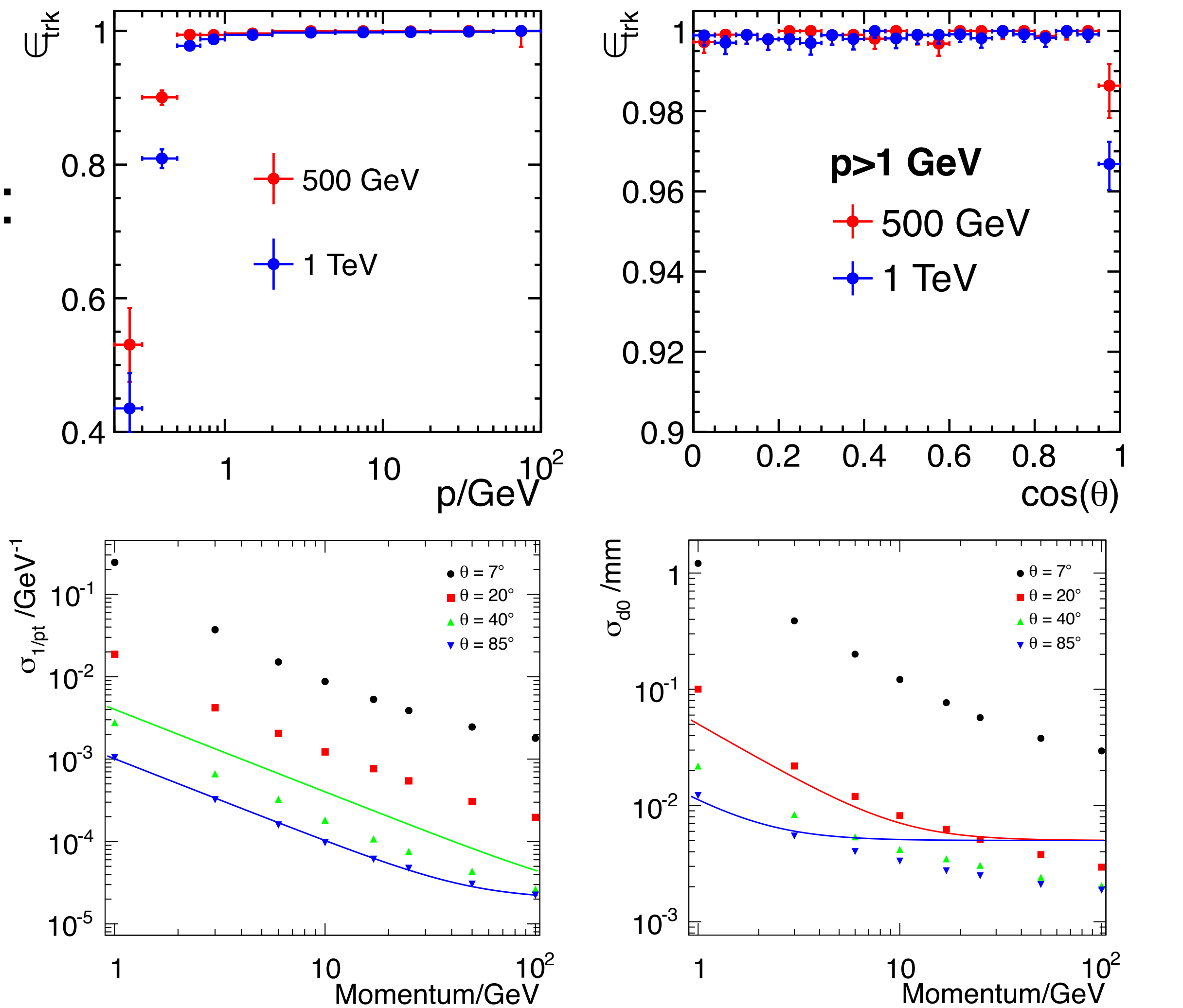
VertexFinder from LCFIPlus

```
<processor name="MyLCIOOutputProcessor"/>
<processor name="DSTOutput"/>
</execute>
```

REC & DST output

DBD Performance – Tracking

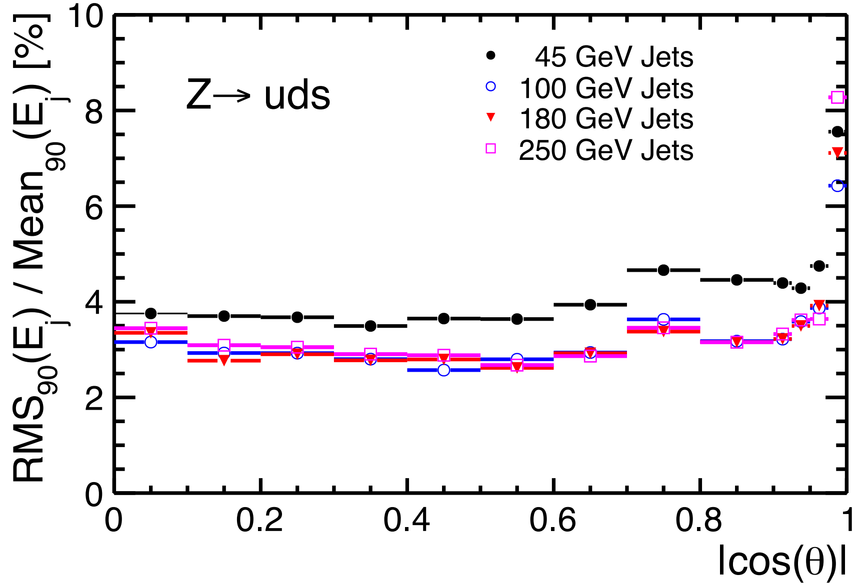
- tracking efficiency on tt->6jets with pair background overlaid: highly efficient for $p_t > 1$ GeV
- momentum and impact parameter resolution: meets or outperforms goals



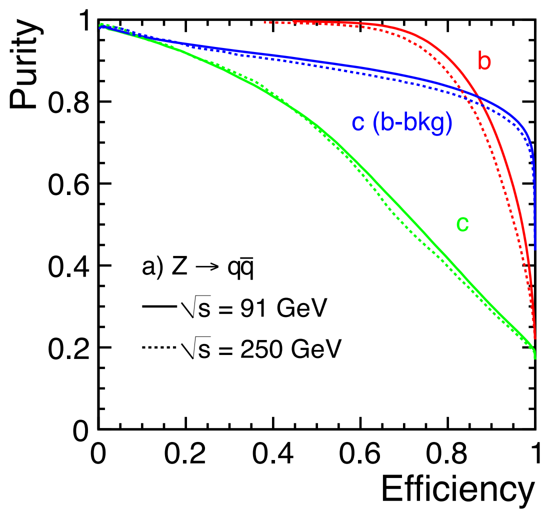
Caveats:
- **fake rate?**
- **prompt tracks**
- **p_t > 1 GeV**

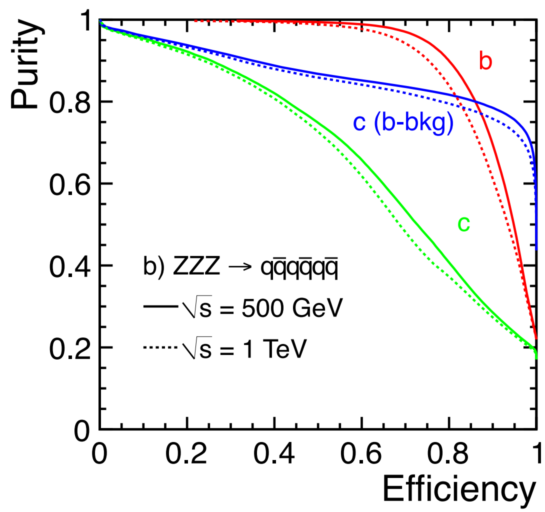
DBD Performance – PFlow & FlavourTag

- Jet energy resolution:
  - measured as $\mathrm{rms}_{90}(E_{vis} / 2)$ on dijet event without BS/ISR
- excellent b/c/light jet separation over a large range of energies



important for top physics:
- **JER in 6jet events?**
  => jet finding!
- **b-jet energy?**
- **A_{FB}: vertex charge?**





Since the DBD

Re-optimising the detectors

[F.Simon, ILD meeting Oshu City]

Are we looking at the right places?

Is there a "cliff" in a dimension we haven't been checking yet?

DBD reco did not consider:

- low momentum particles?
- particle ID?
- lepton ID in jets?
- reco of exclusive b/c decays?
- vertex charge?
- pi0 reconstruction?
- tau reconstruction?
- ....

And don't forget about systematic uncertainties!

Systematic uncertainties

- many studies quote statistical uncertainties only
- in particular, the “benchmarks”, both for LoIs and DBDs
- useful rule of thumb based on LEP experience:
  ~1%-level is readily achievable at e^+e^- collider

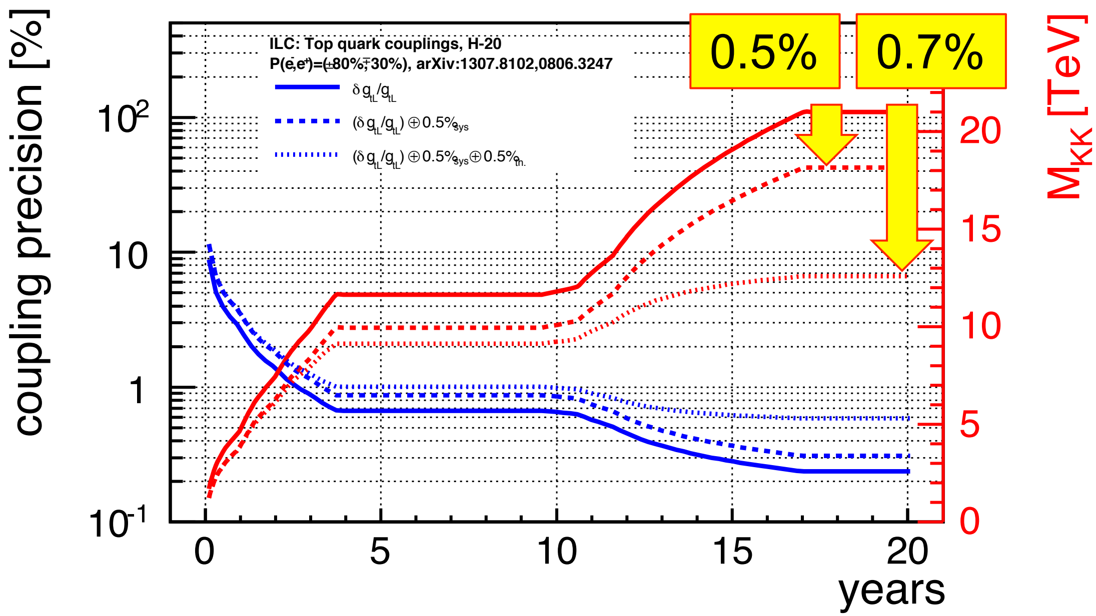
but we claim better precision in many places:

- **Higgs**: H->bb, m_H. g_{ZZH}, ...
- **Top**: mass, EW couplings, ...

Are there specific detector requirements to control eg:

- **Jet energy scale / resolution**
- **b-fragmentation**
- **..... ?**

=> do we need a more detailed reconstruction?



High-Level Reconstruction

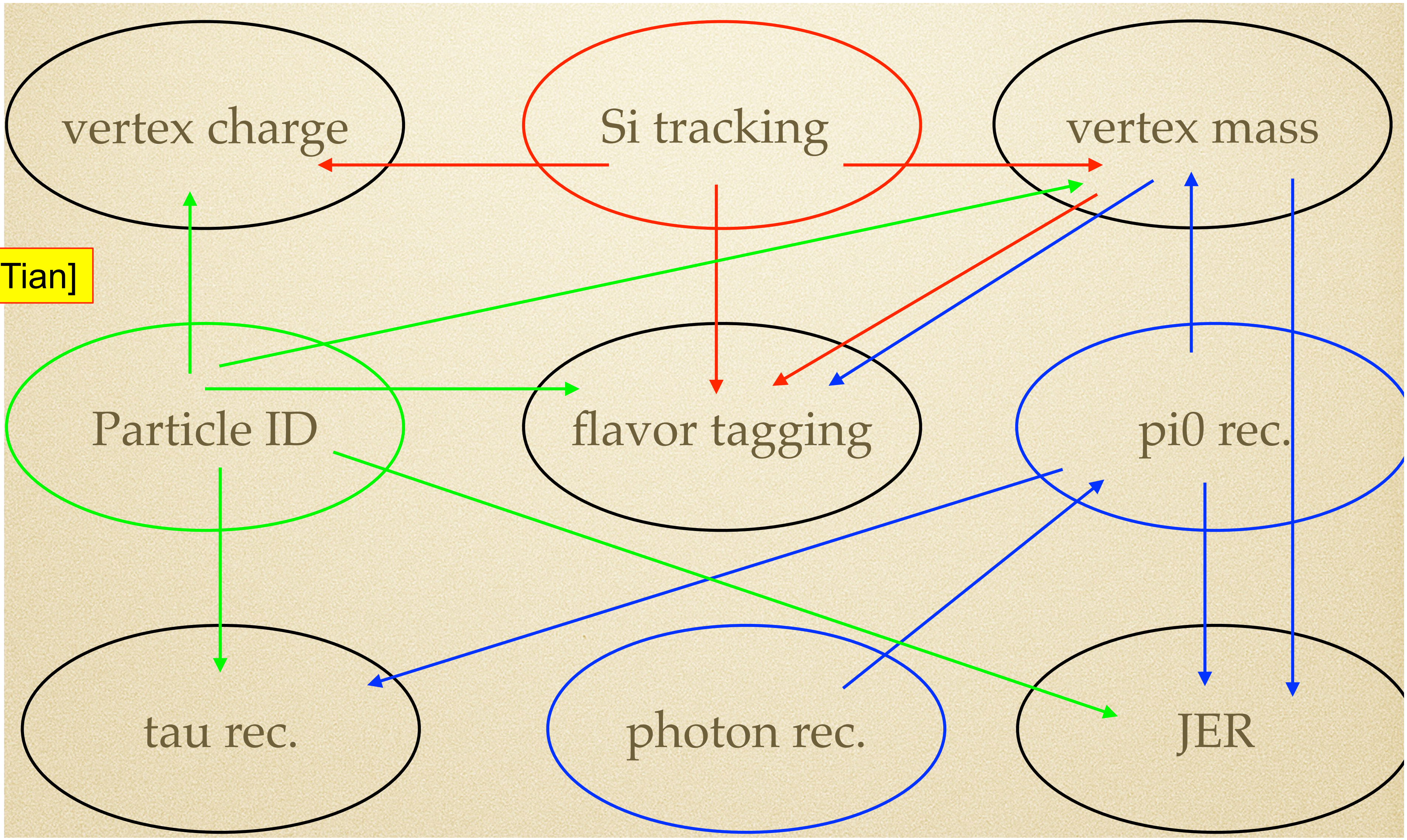
- **Particle ID**
  - photon reco
  - pi0 reco
  - tau reco
  - **dE/dx**
  - **cluster shape**
  - isolated leptons
  - **V0s**
- **FlavourTag**
  - life time
  - **leptons in jets**
  - **vertex charge**
  - vertex mass
- MarlinKinfit
  - **b jet treatment**
  - vertex fitting

A lot has happened since the DBD – but mostly in the context of individual analyses!

- JetFinding
  - Marcel’s JetFinder
  - vertex-based jetfinding
  - **ColorSingletJetFinder?**
- BeamCalReco
  - new parametrisation?
- **PFO uncertainties**
  - **p covariance matrix**
  - **jet by jet energy uncertainty**
- Truth information
  - RecoMCTruthLink
  - TruthVertexFinder
  - TruthColorSingletFinder
- MatrixElements
  - interface Helas / Omega

Interplay in High-Level Reconstruction

[J.Tian]



Towards a new reconstruction

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Fix average number

$\gamma\gamma$->hadron overlay

Minivector VTX tracking

TPC, Si, Fwd tracking, combined track fit in FullLDCTracking

?????
Status?

V0 & Kink finding: input to Pandora

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PFO creation: PandoraPFANew BeamCal (pair bkg)

NO PARTICLE ID

Link PFOs with MCTruth

VertexFinder from LCFIPlus

REC & DST output

PFO covariance matrix

Update Pandora & Calib Garlic?

New BeamCalReco

PARTICLE ID!

Updated version, truth vertices

track recovery, updates

are we happy with DBD DST format?

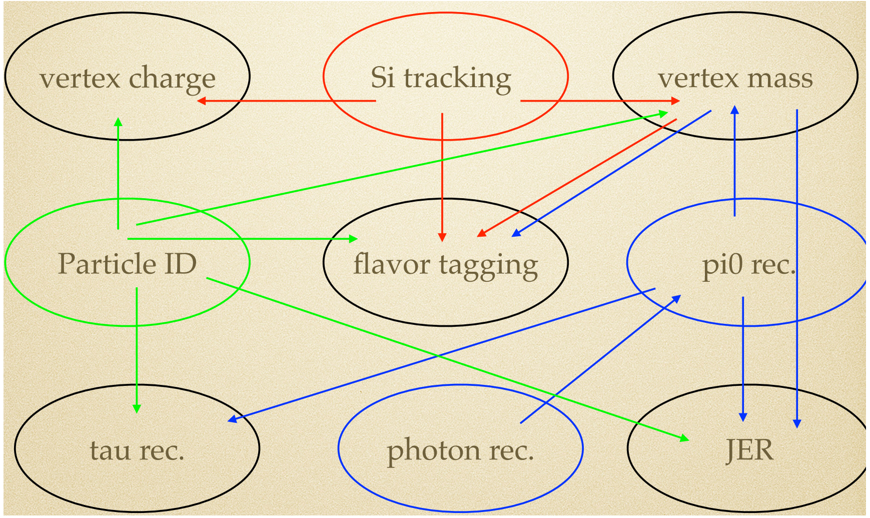
Post-DST

Should / can any of these be included in standard reconstruction?

- isolated lepton finding
- pi0 finding/ fitting
- tau finding
- flavour tag
- jet finding
- kinematic fitting
- matrix elements
- .....

Conclusions

Conclusions



- LC detectors have been designed and benchmarked to an unprecedented level
- LoI, DBD studies demonstrated the basic capabilities of particle flow detectors
- now, it is time to exploit *all* the details our highly granular and performaning detectors offer
- expect significant impact on physics performance and on detector (re-)optimisation
- this serious work, but let's start the effort!

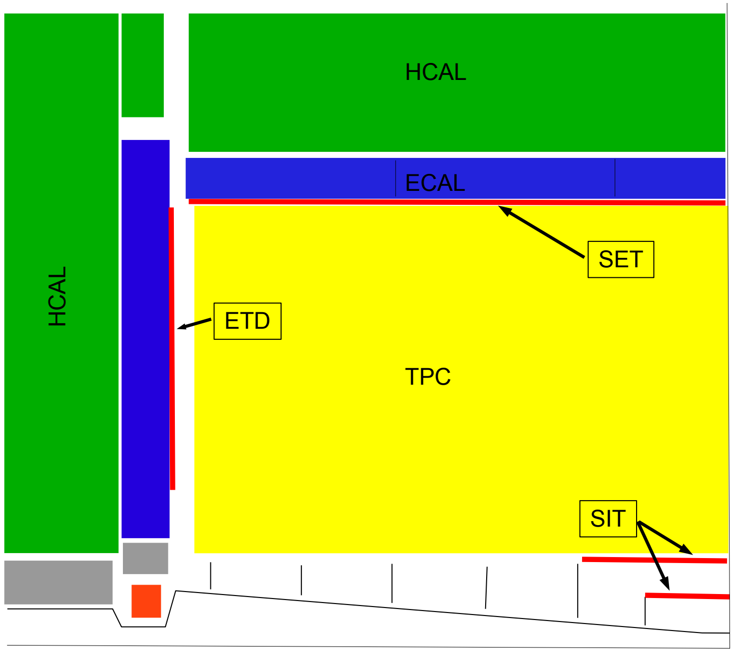
Backup

Silicon Tracking

Silicon Tracking in ILD

- forward silicon (FTD):
  - stand-alone tracking (R. Glatthauer, http://www.hephy.at/fileadmin/user_upload/Publikationen/DiplomaThesis.pdf)
- central silicon:
  - based on TPC pat rec
  - pick-up of SIT / VTX hits

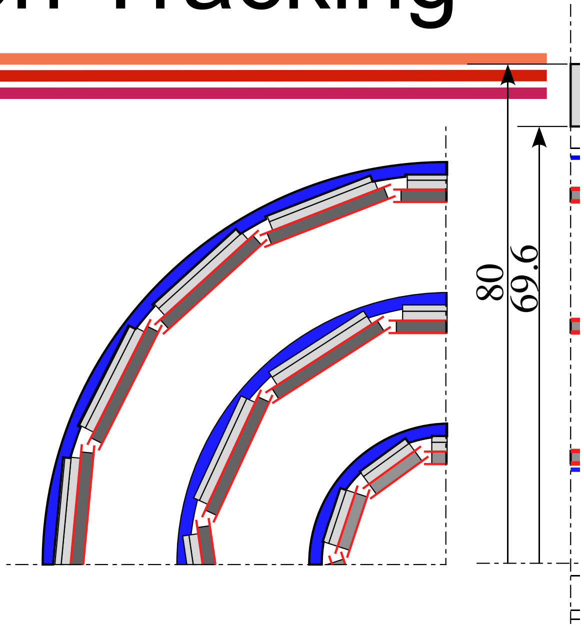
$\Rightarrow$ limited at lower p_t by TPC acceptance!



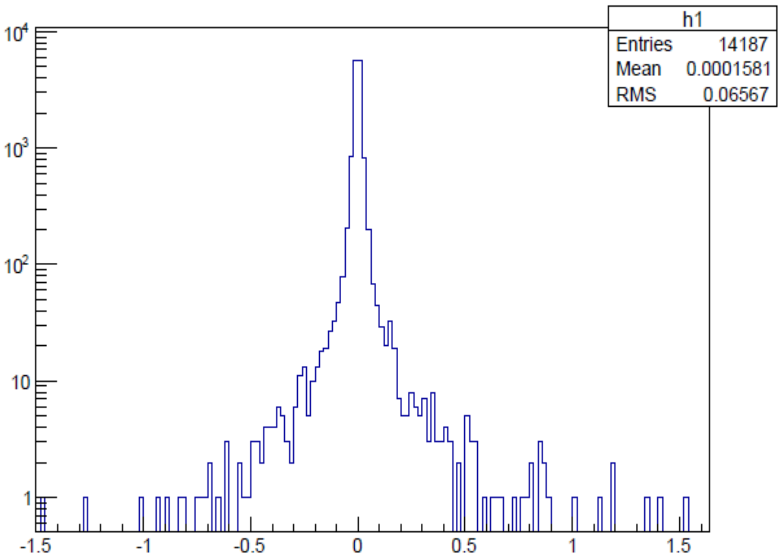
- std-alone track reconstruction in VTX?
  - problem: pair background!
  - up to 5-10 hits / cm^2 / BX
  - ILD baseline VTX integrates over 30-300 BX

	R (mm)	$\|z\|$ (mm)	$\|\cos\theta\|$	σ (μm)	Readout time (μs)
Layer 1	16	62.5	0.97	2.8	50
Layer 2	18	62.5	0.96	6	10
Layer 3	37	125	0.96	4	100
Layer 4	39	125	0.95	4	100
Layer 5	58	125	0.91	4	100
Layer 6	60	125	0.9	4	100

Mini-Vector Cellular Automaton Tracking



- exploit double-layer structure of VTX
  - for real track, hits in both parts of double layer should be close by and point in same direction
- applied in various CMOS VXD configurations
  - Mini – vector formation
  - Hits in adjacent layers (dist 2mm) with max distance 5mm
  - Or δθ between hits in adjacent layers (cut can go up to 0.1^0)
  - Divide VXD into θ, φ sectors
  - Try to connect mini–vectors in neighbouring sectors using a cellular automaton algorithm



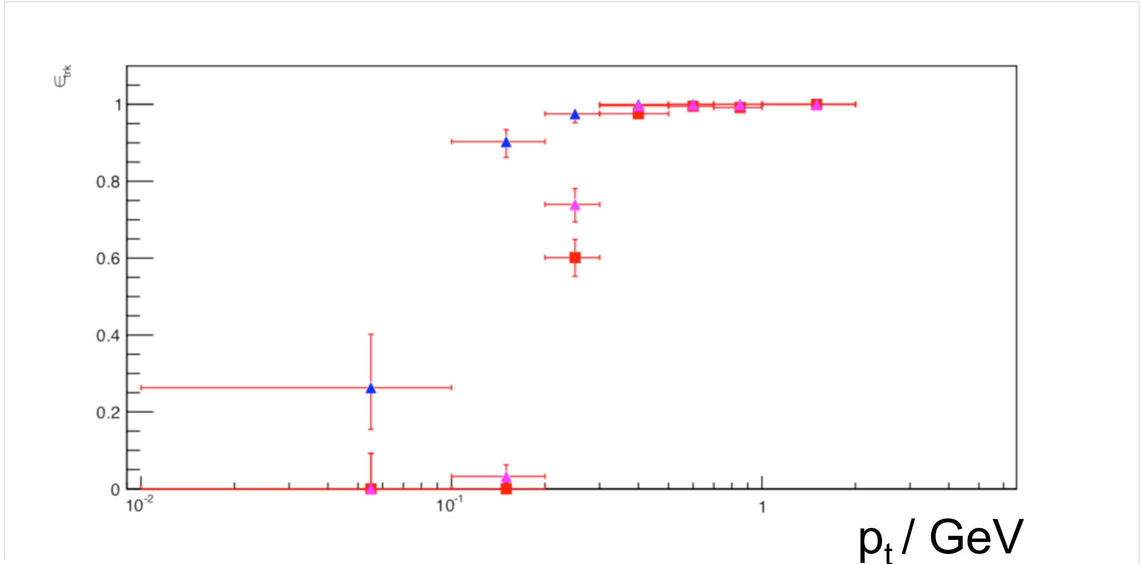
tt, δθ of hits belonging to a MV based on MC info

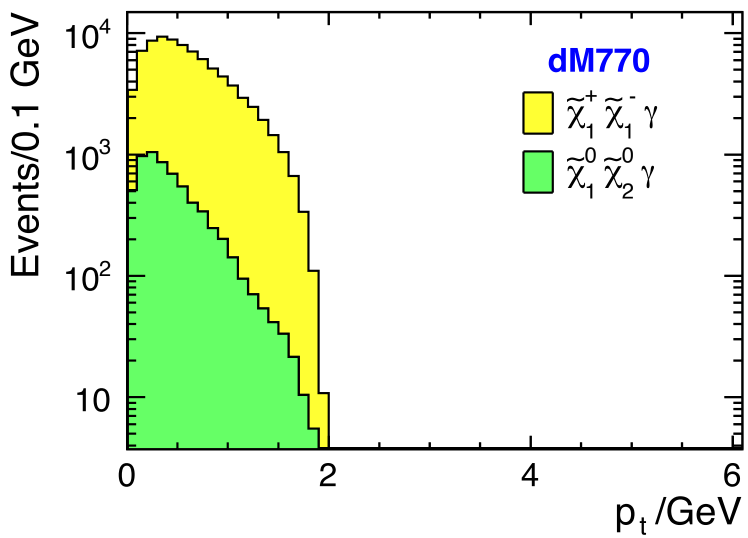
Performance of new VXD tracking tools

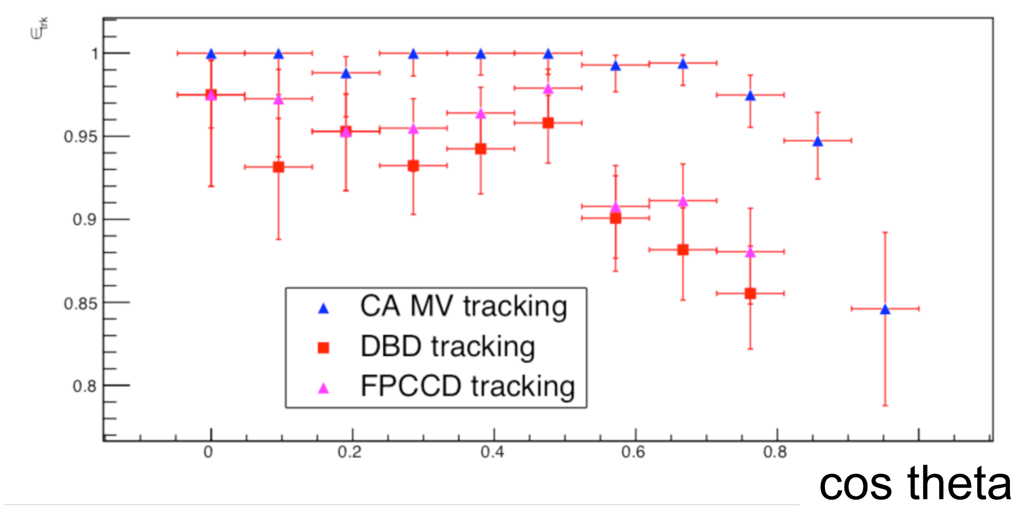
Fast CMOS VXD

layer	$\sigma_{spatial}$(μm)	σ_{time}(μs)
L1	3 / 6	50 / 2
L2	4 / 10	100 / 7
L3	4 / 10	100 / 7

Sample: higgsinos, $\sqrt{s}$ = 500 GeV, pair bkg overlayed







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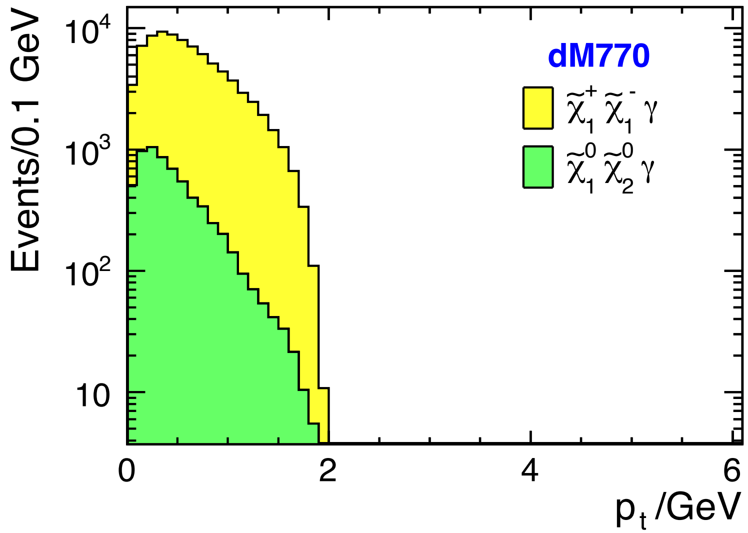

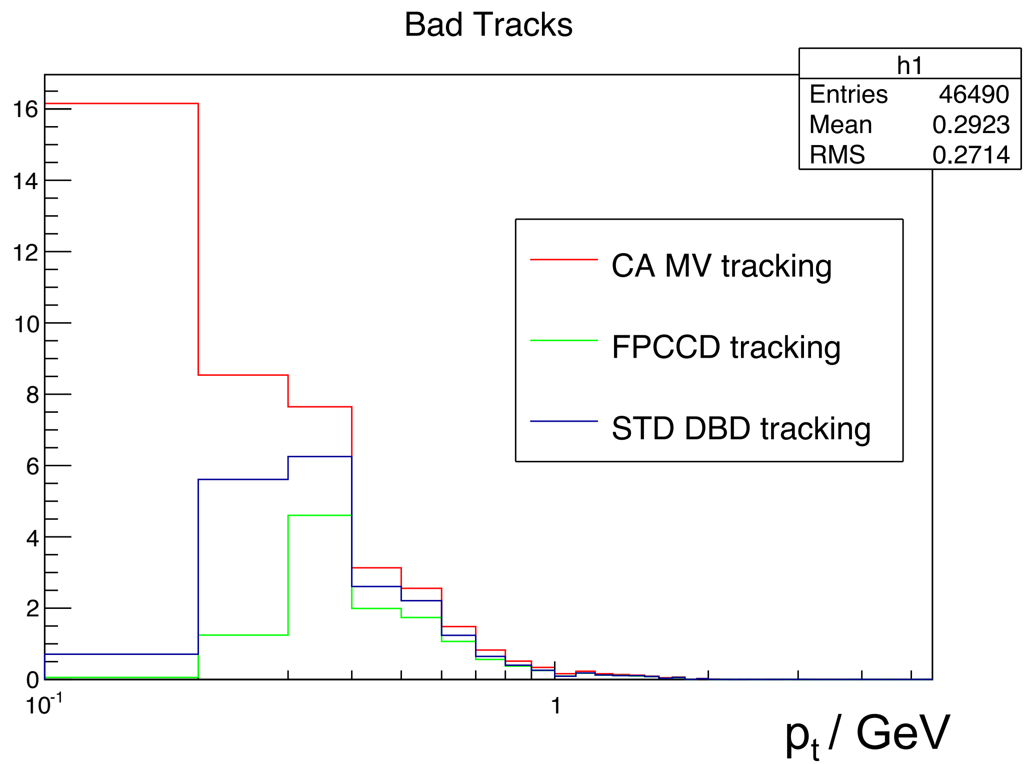

bad track rate needs work for ***any*** of the tracking algorithms!
=> will be analysis specific, eg primary / displaced vertices