

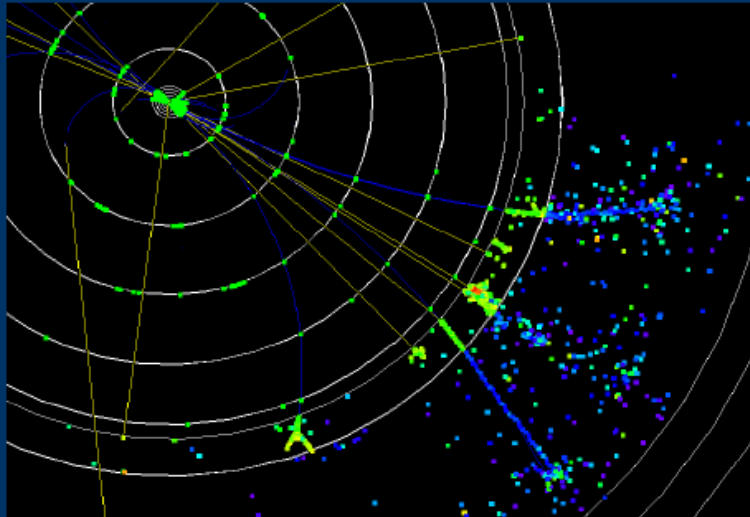
Software/Simulation Summary

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Full event reconstruction with PFA

$e+e- \rightarrow Z \rightarrow qq\bar{q}$ event

Calorimeters :
ECAL - W/Si
HCAL - W/Scintillator



Top, CW

66 MeV γ
6 GeV π^-
5 GeV π^-
131 MeV γ
12 GeV γ
12 GeV K_L^0
5 GeV π^+
2 GeV n
400 MeV γ
2 GeV π^+
40 MeV γ

This Talk:

- ★ Why, oh why ?
- ★ Frameworks/Tools
- ★ PFA where art thou ?
- ★ Outlook

① Why oh why ?

- ★ Working towards detector DCR by the end of 2006
- ★ Desire full simulation/full reconstruction detector performance studies

Perhaps more importantly:

- ★ 3 out of 4 detector concepts choose high granularity calorimetry (i.e. high cost) for particle flow
- ★ NEED to be convinced that Particle Flow paradigm is correct
- ★ For Detector DCR must try to demonstrate the PFA can be made to work for current concepts
- ★ Only(?) evidence that it can be made to work are “old” TESLA studies (LC-PHSM-2003-001)
- ★ For DCR repeating/validating these studies with current detectors **must be a very high priority**

So PFA Matters – what matters for PFA ?

Everything !

e.g. Perfect Particle Flow (see P. Krstonosic Vienna ECFA meeting)
e.g. $e^+e^- \rightarrow Z \rightarrow qq$ at 91.2 GeV

Effect	σ [GeV] separate	σ [GeV] not joined	σ [GeV] total (% / \sqrt{E})	σ % to total
$E_\nu > 0$	0.84	0.84	0.84 (8.80%)	12.28
$Cone < 5^\circ$	0.73	FORWARD REGION TRACKING		9.28
$P_t < 0.36$	1.36	TRACKING		32.20
σ_{HCAL}	1.40	HCAL RESOLUTION		34.12
σ_{ECAL}	0.57	1.51	2.32(24.27%)	5.66
$M_{neutral}$	0.53	1.60	2.38(24.90%)	4.89
$M_{charged}$	0.30	1.63	2.40(25.10%)	1.57

(assumed sub-detector resolutions: **ECAL 11%/√E**, **HCAL 50%/√E +4%**)

+ all mistakes made in PFA algorithm

**★ PFA is delicate - it needs realistic studies:
simulation + tracking + clustering**

2 Software Frameworks/Tools

So where are we as of LCWS06 ?

	Description	Detector	Language	IO-Format	Region
Simdet	fast Monte Carlo	TeslaTDR	Fortran	StdHep/LCIO	EU
SGV	fast Monte Carlo	simple Geometry, flexible	Fortran	None (LCIO)	EU
Lelaps	fast Monte Carlo	SiD, flexible	C++	SIO, LCIO	US
Mokka	full simulation – Geant4	TeslaTDR, LDC, flexible	C++	ASCI, LCIO	EU
Brahms-Sim	Geant3 – full simulation	TeslaTDR	Fortran	LCIO	EU
SLIC	full simulation – Geant4	SiD, flexible	C++	LCIO	US
LCDG4	full simulation – Geant4	SiD, flexible	C++	SIO, LCIO	US
Jupiter	full simulation – Geant4	JLD (GDL)	C++	Root (LCIO)	AS
Brahms-Reco	reconstruction framework (most complete)	TeslaTDR	Fortran	LCIO	EU
Marlin	reconstruction and analysis application framework	Flexible	C++	LCIO	EU
hep.lcd	reconstruction framework	SiD (flexible)	Java	SIO	US
org.lcsim	reconstruction framework (under development)	SiD (flexible)	Java	LCIO	US
Jupiter-Satellite	reconstruction and analysis	JLD (GDL)	C++	Root	AS
LCCD	Conditions Data Toolkit	All	C++	MySQL, LCIO	EU
GEAR	Geometry description	Flexible	C++ (Java?)	XML	EU
LCIO	Persistency and datamodel	All	Java, C++, Fortran	-	AS,EU,US
JAS3/WIRED	Analysis Tool / Event Display	All	Java	xml,stdhep, heprep,LCIO,	US,EU

See talk of T.Behnke

Fast Simulation

Full GEANT Simulation

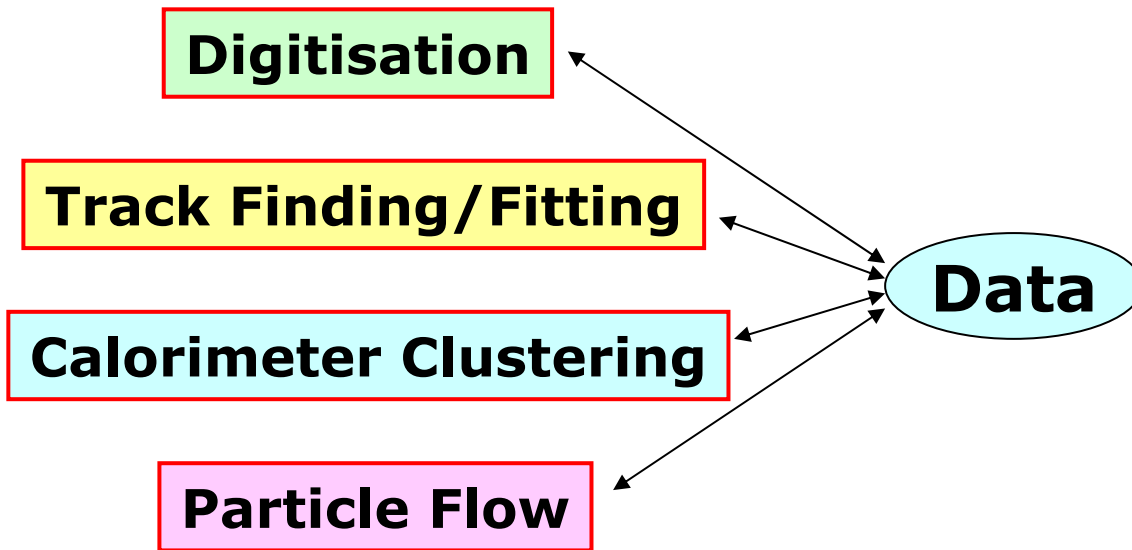
Reconstruction Framework

Geometry/Data Format+..

+reconstruction...

- ▲ Much duplication of work
- ▲ Currently Software highly tied to concepts/region
- ▲ Given the lack of resources, this is an unfortunate position
- ▲ Difficult to see change in short-term, but we should try....

Reconstruction Software

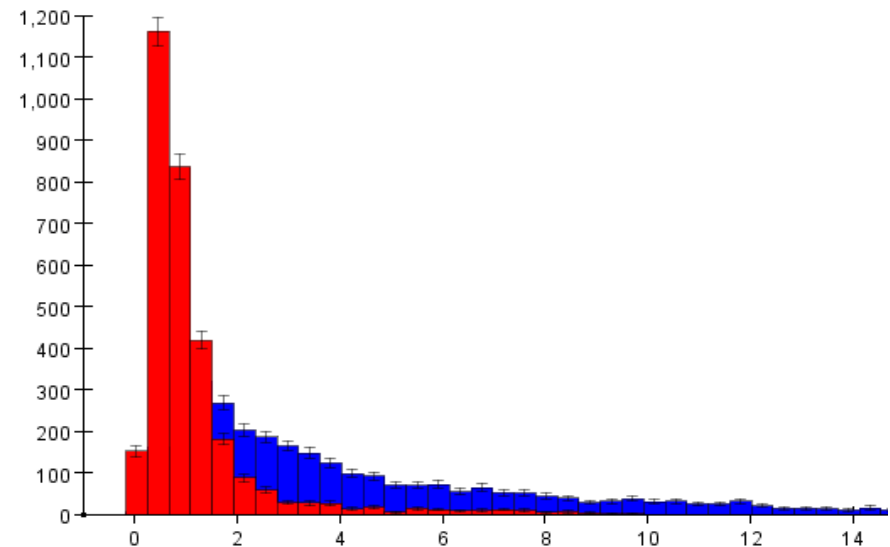


★ A lot already exists
★ These are serious reco. algorithms

e.g. N.Sinev's talk:

- ★ Ported SLD weight matrix fitter to JAS ILC framework
- ★ Although not quite finished it is a nice piece of work
- ★ BUT tied to US JAVA-based framework

Chi2 distributions for unfitted and fitted tracks

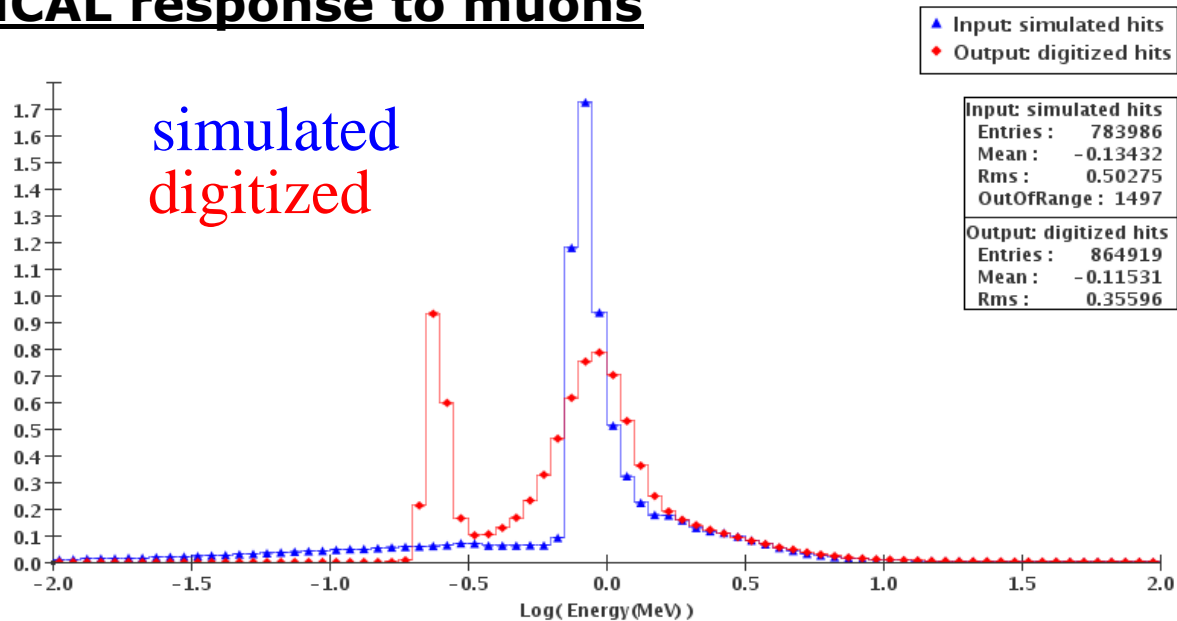


Another new example :DigiSim

See V.Zutshi's talk

- ★ Detailed and very general programme to turn raw MC hits into digitised hits including cross-talk/noise etc.
- ★ Both a **JAVA (JAS)** and **C++ (MARLIN)** version exist
- ★ **BUT** writing for 2 frameworks = **extra work**

e.g. HCAL response to muons



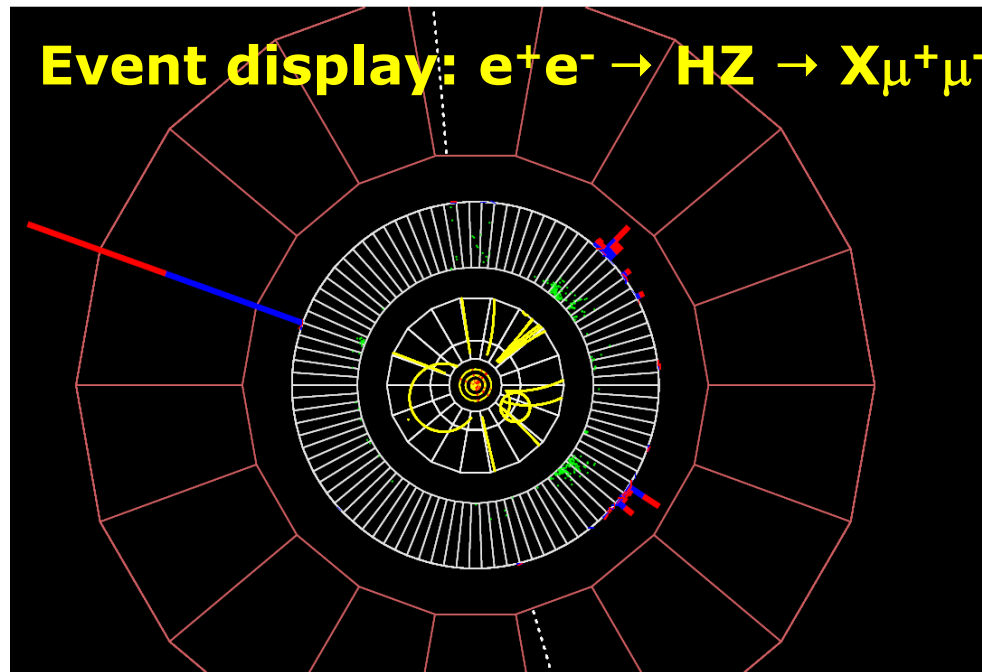
Overall : Real progress from Snowmass to LCWS06 !

IVth Concept Reconstruction C.Gatto

- ★ IVth concept often criticised for lack of full simulation demonstration of concept

LCWS06:

- ★ Huge amount of progress on IVth detector concept reconstruction and simulation
- ★ Based on existing, well supported tools : e.g. ROOT



★ Impressive progress : expect first performance results soon

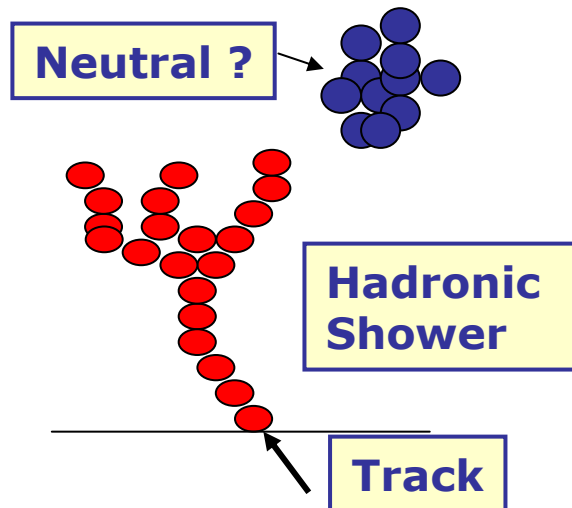
③ PFA where art thou ?

★ PFA paradigm central to GLD, LDC, SiD, concepts

- **NOT THERE YET !**
- **BUT:** Real progress being made with PFA :
63.63 % of talks in **LCWS06** software session related to **PFA**
- **Progress**, but some way to go.... 6 months ? 1 year ? Longer ?

PFA challenges: (Para)

- ★ Many challenges (Adam Para gave an interesting summary)
- ★ **HARDEST (?)** : separation of neutral and charged hadrons



- ▲ Irreducible problem ?
- ▲ Gets worse with higher particle density
i.e. higher jet energy/boost
- ▲ So far PFA mainly tested on Z
- ▲ **NOT A GOOD TEST**

Para Challenge: Case of bottles of (moderately good) wine for a demonstration of $0.3/\sqrt{E}$ resolution for ZH events at $\sqrt{s}=500$ GeV

Break even point

★ PFA is **extremely** complex

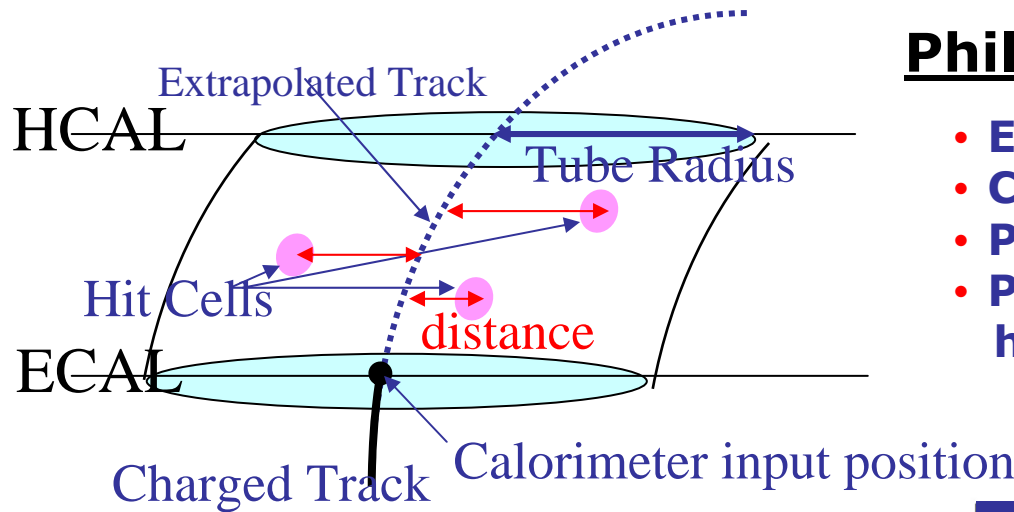
★ Can “achieve” worse performance c.f. pure calorimetric measurement

V.Morgunov

LDC00	Whole calorimeter sum		Check plots	
	Mean [GeV]	Sigma [GeV]	Mean [GeV]	Estimated energy resolution [GeV]
e+ e- into , at energy				
t tbar, 1000 GeV	982.3	24.6	0.19	18.7
W+ W-, 1000 GeV	992.6	25.5	2.7	17.4
t tbar, 500 GeV	488.8	16.9	1.8	12.6
W+ W-, 500 GeV	496.6	14.5	1.6	10.9
heavy quarks, 500 GeV	495.0	14.8	-0.5	12.8
light quarks, 500 GeV	497.9	14.9	-1.1	14.3
t tbar, 360 GeV	356.4	14.0	5.5	10.0
Z pole, 91.2 GeV	90.4	4.67	-0.06	4.25

- IF PFA performance worse than these **values** – it is making things worse
- **VERY** useful sanity check

PFA in GLD T.Yoshioka



Philisophy:

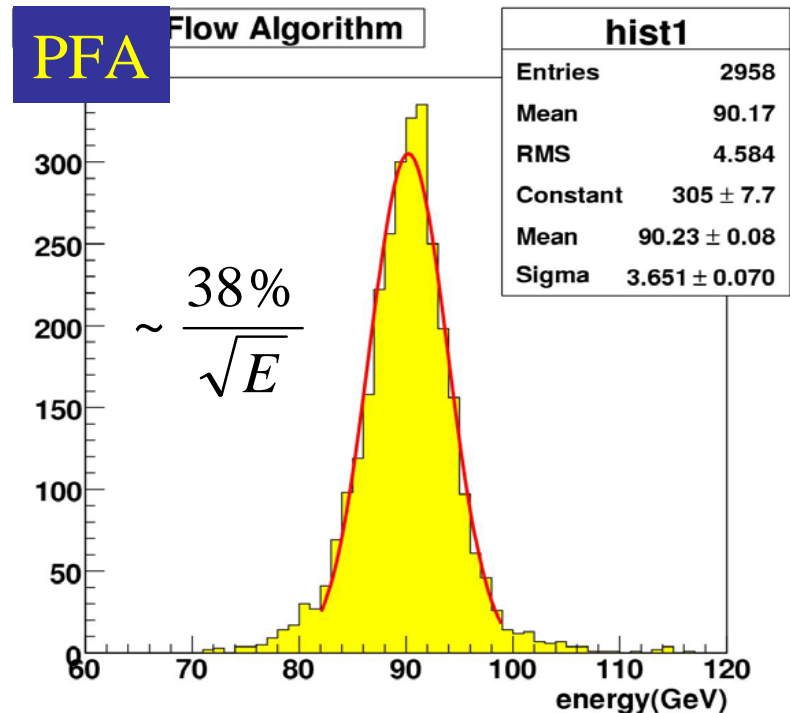
- Extrapolate track into CALO
- Construct tube
- Pick up hits
- Photon ID : classify remaining hits as from hadrons/photons

Performance:

- $Z \rightarrow uds$ (91.2 GeV)
- "Barrel region"
- add in missing energy from ν
 - centres peak at 91.2 GeV
- Decent performance:

$$38\% / \sqrt{E(\text{GeV})}$$

BUT doesn't yet work well for higher energies



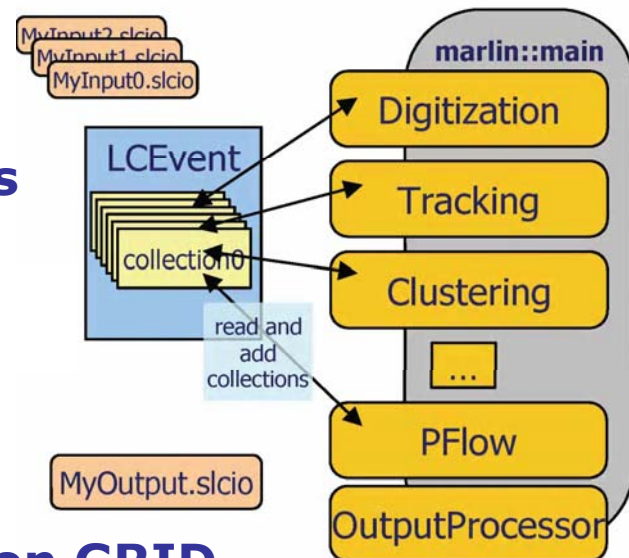
PFA in LDC

Two reasonably well developed algorithms:

- ★ **WOLFPFA [default]** (Rasparezza et al)
- ★ **PandroroPFA** (Thomson)

Both Using MARLIN C++ framework O.Wendt

- **Flexible framework**
- **Plug in reconstruction modules**
- **Almost complete reco chain exists**
- **Steering files drive analysis:**
i.e. swap different modules
+ change algorithm parameters



Simulated Events

- **Large events samples generated on GRID**
- **0.5 M events**
 - different processes
 - different detectors
- **Basis to test LDC PFA performance**

Wolf Results O.Wendt

NOTE: $Z \rightarrow qq$ and $Z \rightarrow l+l^-$

LDC

Tesla

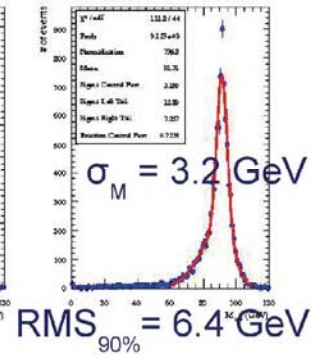
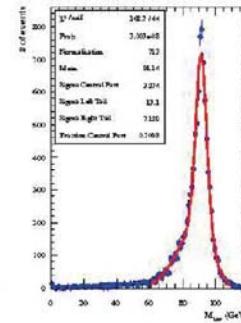
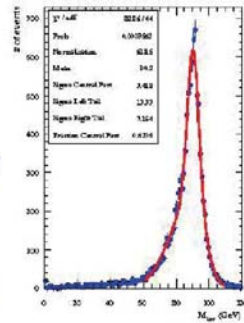
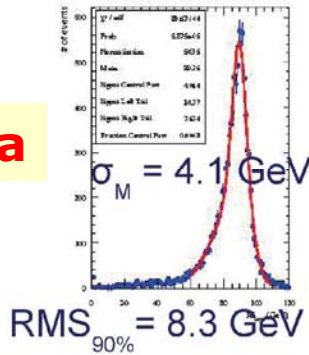
R=1380

R=1580

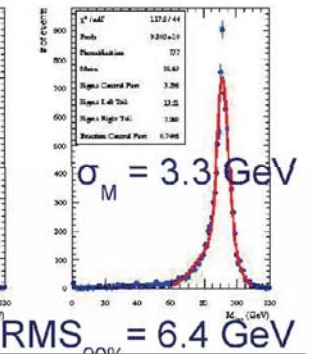
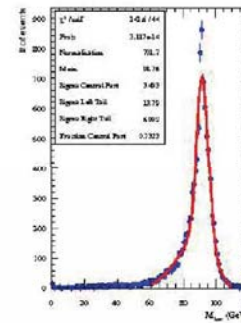
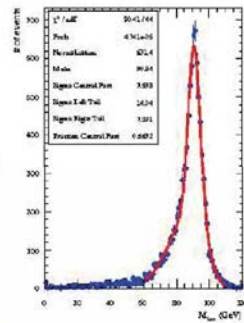
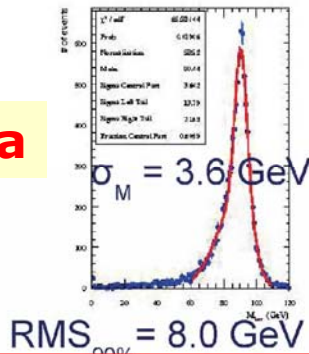
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R=1890

B=3 Tesla



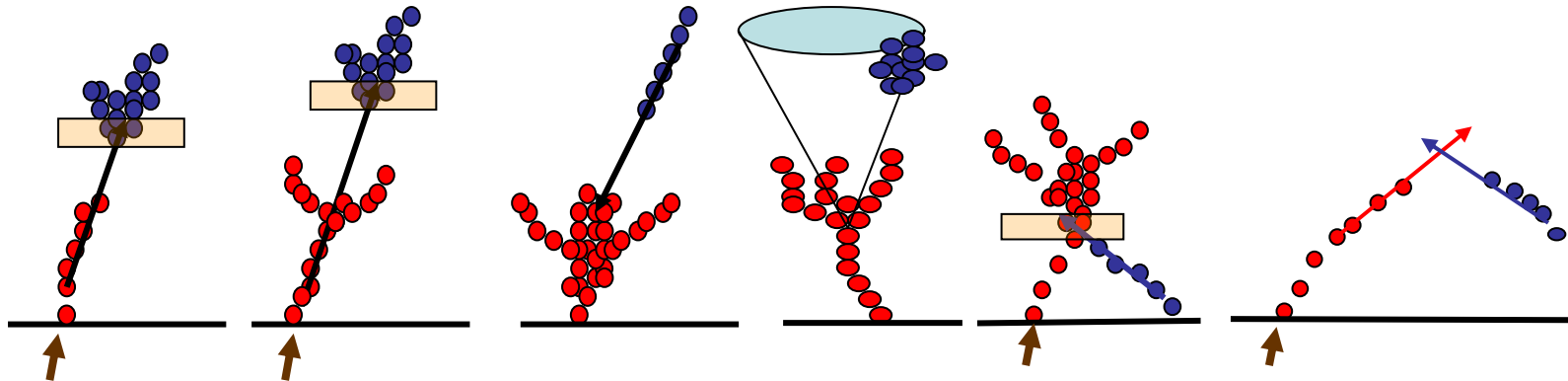
B=3 Tesla



- ★ First attempt at performance vs detector size
- ★ No significant dependence of jet energy resolution
- ★ BUT, DON'T YET TAKE TOO SERIOUSLY: Zs + could be just the algorithm

Topological approach to PFA M.Thomson

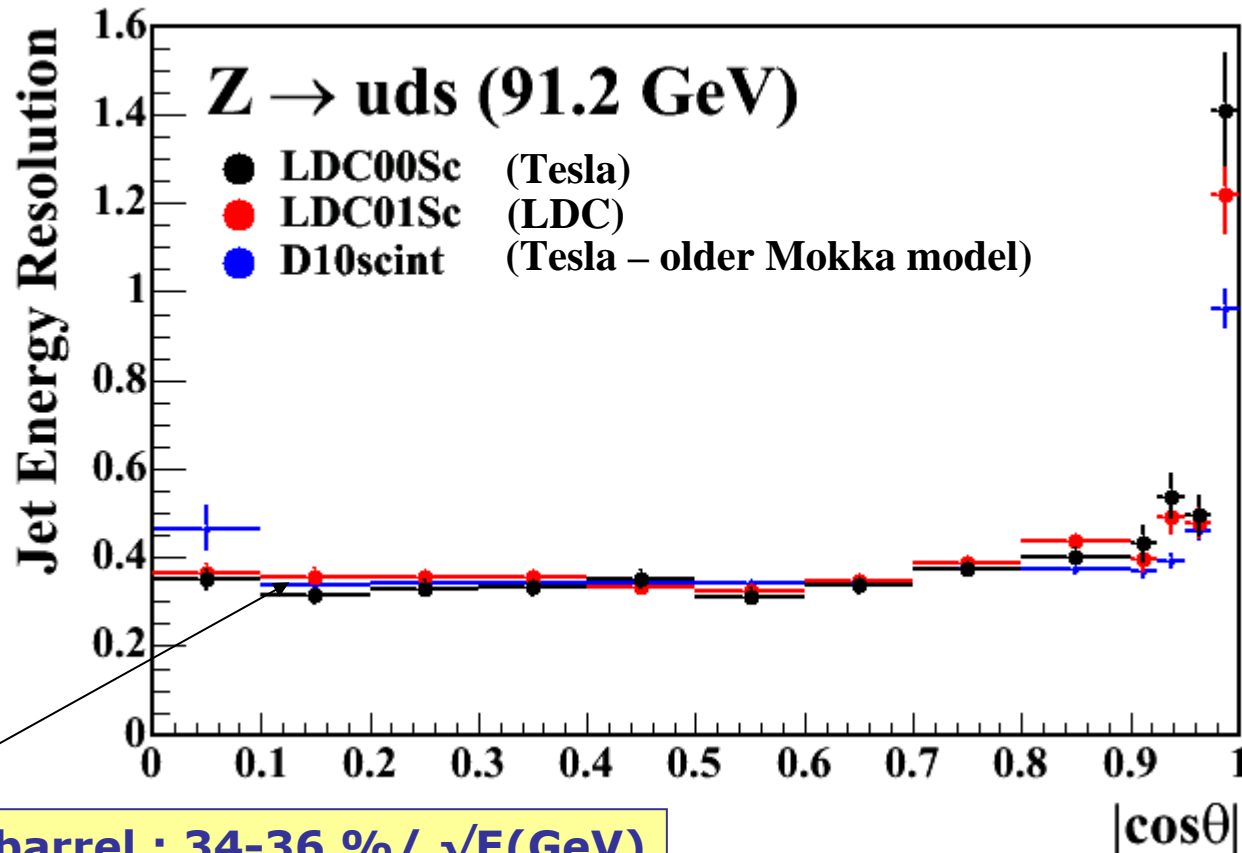
- ★ Work from the premise that PFA is not a pure ECAL/HCAL clustering problem
- ★ PFA and calorimeter clustering performed together
- ★ Start by applying loose clustering
- ★ Then join clusters using topology



- ★ Algorithm defined by loose cluster finding + topological rules to join clusters

Results : Z uds events Angular dependence

★ Plot resolution vs generated polar angle of qq system



★ In barrel : 34-36 %/ $\sqrt{E(\text{GeV})}$

BUT doesn't yet work well
for higher energies

SiD : PFA studies in US

U.Mallik + V.Zutshi



A lot of activity in US
Work on 4+ distinct algorithms
Still work in progress....

But many interesting ideas currently being investigated

- ★ Nearest neighbor clustering
- ★ MST clustering
- ★ Directed tree clustering
- ★ Density Weighted cluster algorithm
- ★ Fixed Cone cluster algorithm

CLUSTERING

-
- ★ Calorimeter track-segment finder
 - ★ Track-MIP match

CALO TRACKING

-
- ★ H-matrix (& others) for photon id
 - ★ Neural networks

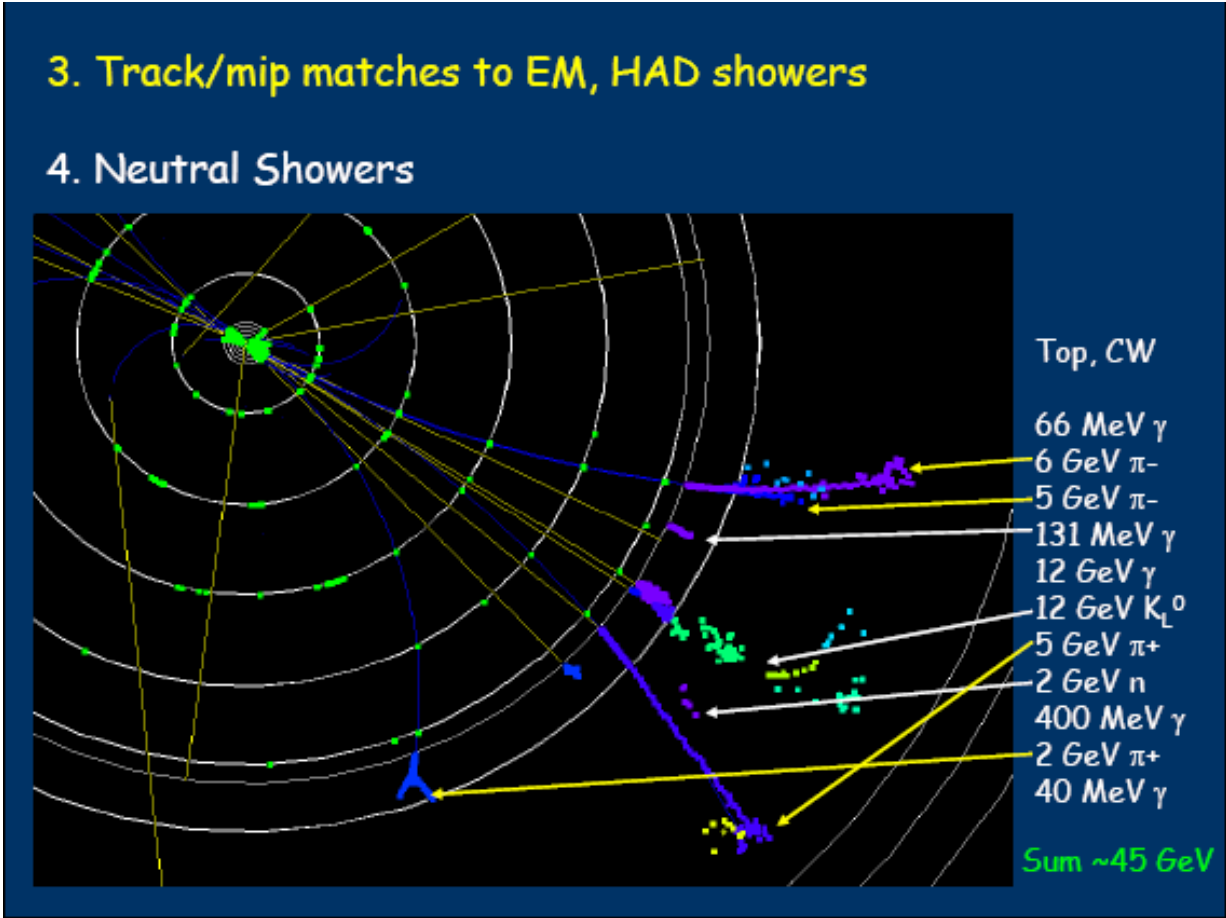
CLUSTER IDENTIFICATION

-
- ★ Neutral fragment identification and matching
 - ★ and many others.....

e.g. Work at ANL:

3. Track/mip matches to EM, HAD showers

4. Neutral Showers



Currently achieve: $\sim 40\% / \sqrt{E(\text{GeV})}$

4 Conclusions and Outlook

Why ?

- ★ Sophisticated Reconstruction vital to prove ILC detector concept paradigms (PFA or IV)

Software Frameworks/Tools

- ★ Lots of progress worldwide
- ★ Both on frameworks and reconstruction tools
- ★ BUT... lack of shared software/frameworks isn't helping
- ★ Lots of duplicated work !

PFA where art thou ?

- ★ Lots of activity worldwide
- ★ But not there yet (goal 30%/√E)

$$\sigma_E/E = 34-40 \% / \sqrt{E}(\text{GeV})$$

- ★ Not bad, but this is **only** for Z at 91.2 GeV
- ★ But, don't give up on PFA... good performance was achieved for Tesla TDR

Where next (personal view)?

- ★ Full detector studies by end 2006 → **VERY CHALLENGING !**
- ★ Not impossible... not helped by lack of shared effort
- ★ Detector concepts need to collaborate more effectively

Event display: $e+e \rightarrow H^0 Z^0 \rightarrow X \mu^+ \mu^-$