Summary of Calorimeter and Particle ID sessions

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Two parts to my report…

1) (Personal) overview of where we stand

   PFA, calorimetry, Muon systems…

2) Summary of progress reported at this workshop

   Calorimetry
   Muon systems/Particle ID
   PFAs (see Norman Graf’s talk later today)

Part I

Calorimeter/muon system overview

I) The ILC detector needs an unprecedented jet energy resolution

Previously $\sigma_{Jet} \sim 50\%/\sqrt{E_{Jet}}$(GeV) has been achieved
The aim is to be roughly a factor 2 better

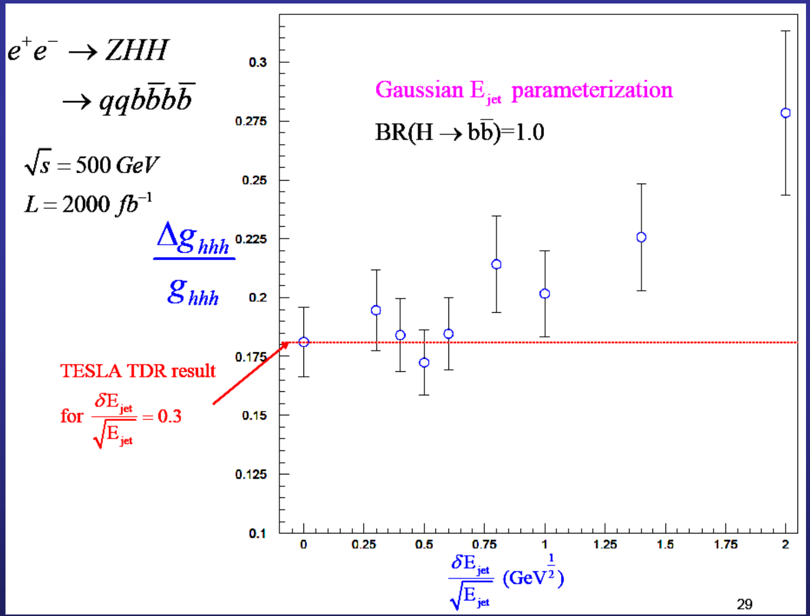
This need is substantiated by a number of studies

e.g. TESLA TDR

Triliniar Higgs coupling from $e^+e^- \to ZHH$
Separation of $e^+e^- \to \upsilon\upsilon WW$ and $\to \upsilon\upsilon ZZ$
….

Recently T. Barklow re-investigated $e^+e^- \to ZHH$
No benefit from $\sigma_{Jet} < 50\%/\sqrt{E_{Jet}}$(GeV)?

Absolutely need physics motivation for pushing for $\sigma_{jet} \sim 30\%/\sqrt{E_{jet}}$



II) The ILC calorimeter/muon system also needs to reconstruct/measure…

- photons with good energy resolution
- non-pointing photons (e.g. from the decay of long lived neutralinos)
- electrons (identification)
- muons
- taus (polarization), e.g. $\tau^+ \rightarrow \rho^+ \upsilon \rightarrow \pi^+ \pi^0 \upsilon$

Assuming we need it…

III) How do we go about achieving this fantastic σ_{Ejet}?

There are two camps…

The believers

The heretics

IV) Facts about the believers in PFAs

- About 95% of the ILC detector community
- Basis of SiD, LDC and GLD detector concepts
- The believers claim that

  - PFAs work (true)
  - No existing detector has been designed with PFAs in mind (true)
  - $\sigma_{jet} \sim 30\%/\sqrt{E_{jet}}$ is achievable (maybe)

However, we need a proof that this is possible
So far, we have mostly studied events at the Z^0 pole
Resolutions of 32 – 60 $\%/\sqrt{E_{jet}}$ have been achieved
(depending on what you do about the tails)

Need to look at physics events which are relevant for the ILC

We don't need a detector optimized for Z^0 – pole events

- In any case hardware which is in line with PFA applications needs to be developed NOW
- Finely segmented calorimeters also good for non-pointing γ, $\mu^\pm$, $\tau^\pm$,etc…

V) Facts about the heretics

- About 5% of the ILC detector community
- Basis of the 4th detector concept
- The heretics claim that

● PFAs need a good hadron energy resolution, since ‘this resolution will determine how well one can determine the contribution of the precisely measured charged jet fragments to the *total* calorimeter signal and, therefore, the precision of the neutral energy obtained after subtracting this contribution’ R.Wigmans, CALOR2002 (NO!)

● Overlaps will make the PFAs of limited use at higher energies (maybe)

● Optimizing the hadron energy resolution only way to improve σ_{jet} (maybe)

● Dual – readout calorimetry is the way to improve σ_{Ejet} (maybe)

↳ Measurement of em fraction of jets

Needs a demonstration of the method

- without using beam constraints in analysis
- which can be applied to a 4π detector

VI a) PFA ECAL Projects (worldwide)

Lead institutions	Active element	Absorber	Granularity	Status	Reported at VLCW06
Oregon/SLAC	Silicon	Tungsten	$0.16 cm^2$	Wafers in hand, readout with 64 channels	yes
CALICE (Ecole Polytechnique)	Silicon	Tungsten	$1.0\ cm^2$	Prototype in test beam	**no**
CALICE (Birmingham)	MAPS	Tungsten	$50 \times 50\ \mu m^2$	R&D initiated	**no**
CALICE (Japan)	Scintillator	?	Effective	R&D initiated	yes
Colorado	Scintillator	Tungsten		R&D initiated	yes

VI b) PFA HCALs (worldwide)

Lead institutions	Active element	Absorber	Granularity	Status	Reported at VLCW06
CALICE (DESY)	Scintillator	Steel	3 x 3 cm^2	Prototype in test beam	**no**
CALICE (ANL)	RPCs	Steel	1 x 1 cm^2	Ready for prototype construction	**yes**
CALICE (UTA)	GEMs	Steel	1 x 1 m^2	R&D initiated	**yes**

VII) Dual – readout calorimeters

Lead institutions	Active element	Absorber	Granularity	Status	Reported at VLCW06
DREAM (Texas A&M)	Quarz/scintillating fibers	Steel	?	First results from test beams	yes
Washington	Lead glass/scintillator	Lead glass (+ Heavy metal)	?	R&D initiated	**no**

Part II

Progress reported at VLCW06

Photodetectors for scintillator

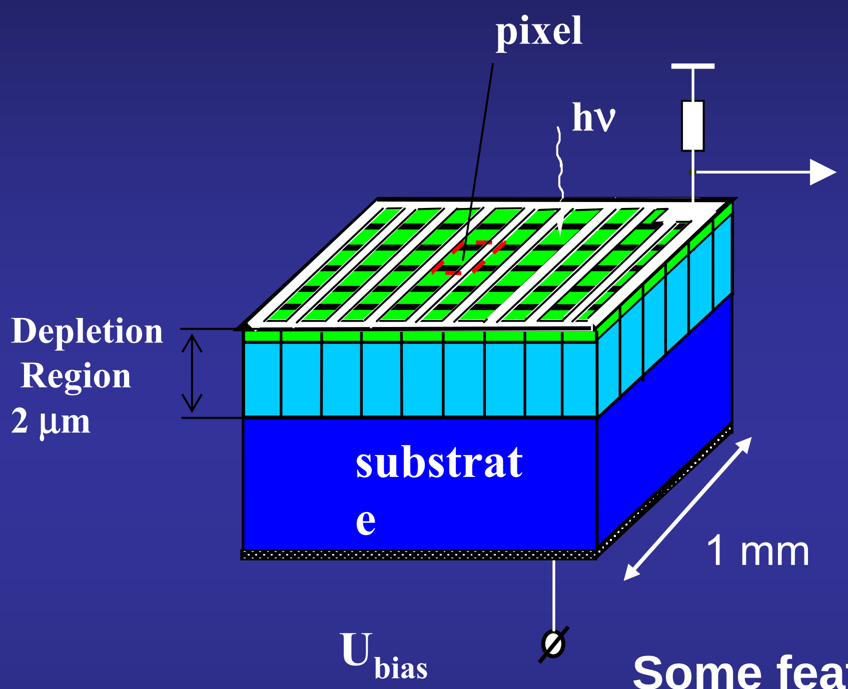
Development of SiPMs has become a worldwide enterprise

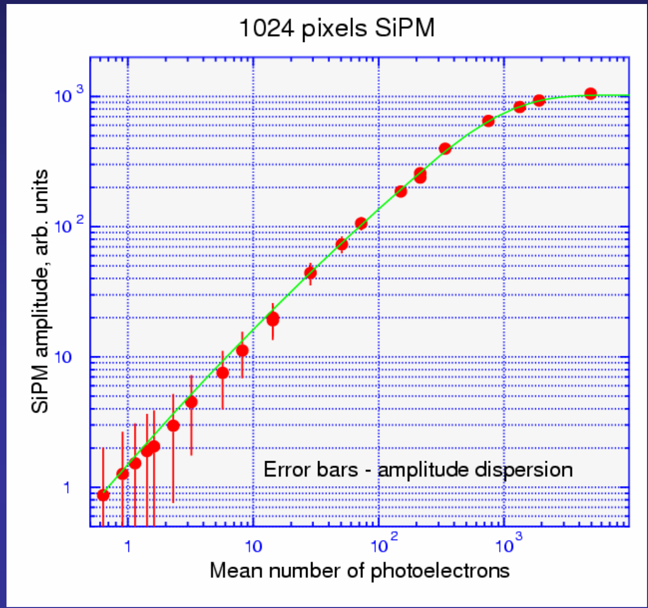
Name	Company	Location	Status	Reported at VLCW06
SiPM (Silicon PhotoMultiplier)	MEPHI, Pulsar	Russia	O(5000) produced, extensively tested	**no**
MRS (Metal Resistor Silicon APD)	INR, Moscow	Russia	O(few 100), tested by several groups	**no**
MPPD (Mulit-pixel photon counters)	Hamamatsu	Japan	O(10), tests initiated	**yes**
SiPM	ITC-irst	Italy	O(100), tests initiated	**yes**
SiPM	Photonis	?	?	**yes**
GPD (Geiger-mode avalanche PhotoDiodes)	A-Peak	USA	O(few), test initiated	**yes**

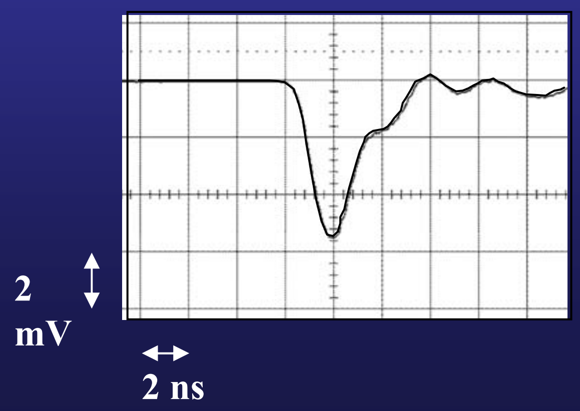
Adapted from R. Wilson (Colorado State)

Silicon – PMs

R&D at MEPHI (Moscow)
together with PULSAR (Russian industry)







Some features

Sensitive area 1 x 1 mm^2
Gain $2 \cdot 10^6$ U_{bias}~ 50 V
Recovery time ~ 100 ns/pixel
Number of pixels: 1000/mm^2
Dynamic range > 200

Comparison of Photodetectors

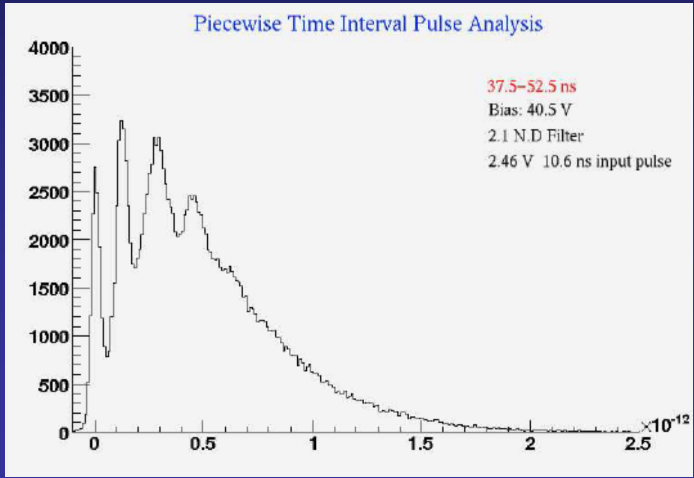
	PMT	MPPC/SiPM
Gain	~10^6	10^5~10^6
Photon Detection Eff.	0.1 ~ 0.2	0.1~ 0.4
Response	fast	fast
Photon counting	Yes	Great
Bias voltage	~ 1000 V	30 ~ 70 V
Size	Small	Compact
B field	Sensitive	Insensitive
Cost	Expensive	Low ($1~10?)
Dynamic range	Good	Determined by # of pixels
Long-term Stability	Good	Unknown
Robustness	decent	Unknown, maybe good
Noise (fake signal by thermions)	Quiet	Noisy (order of MHz)

S Uozumi (Tsukuba)

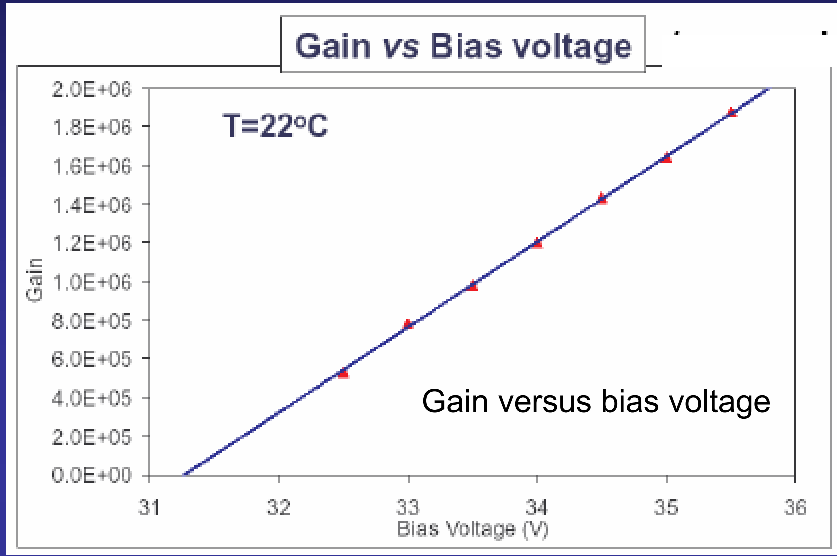
Selection of the Results Reported

Single photoelectron peaks in different time bins

J Proulx (Colorado)

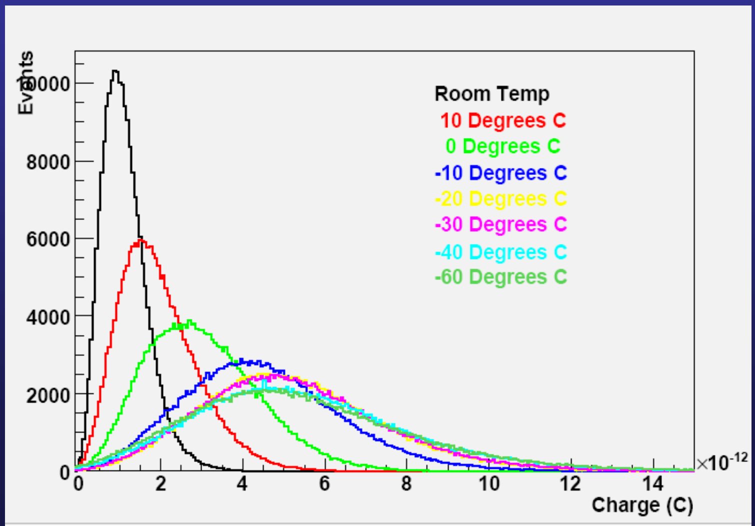


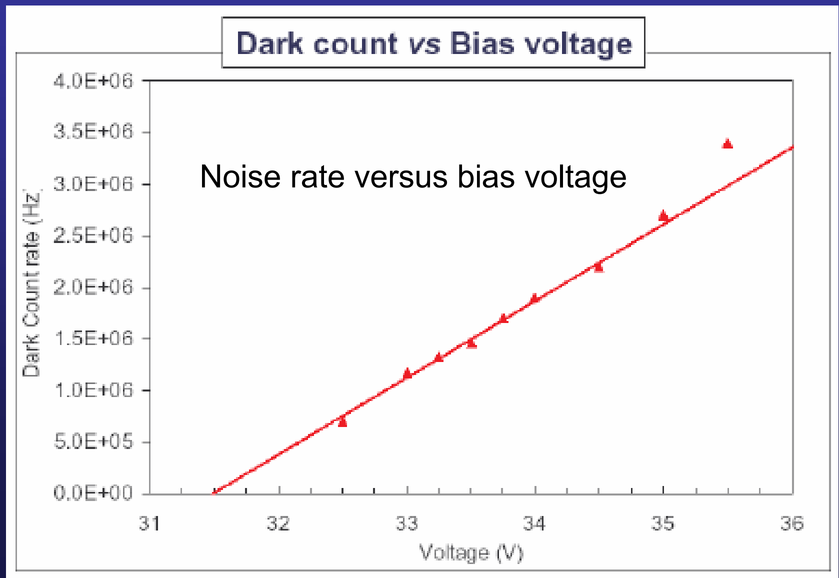
G Pauletta (Udine)



Signal charge at different Temperatures

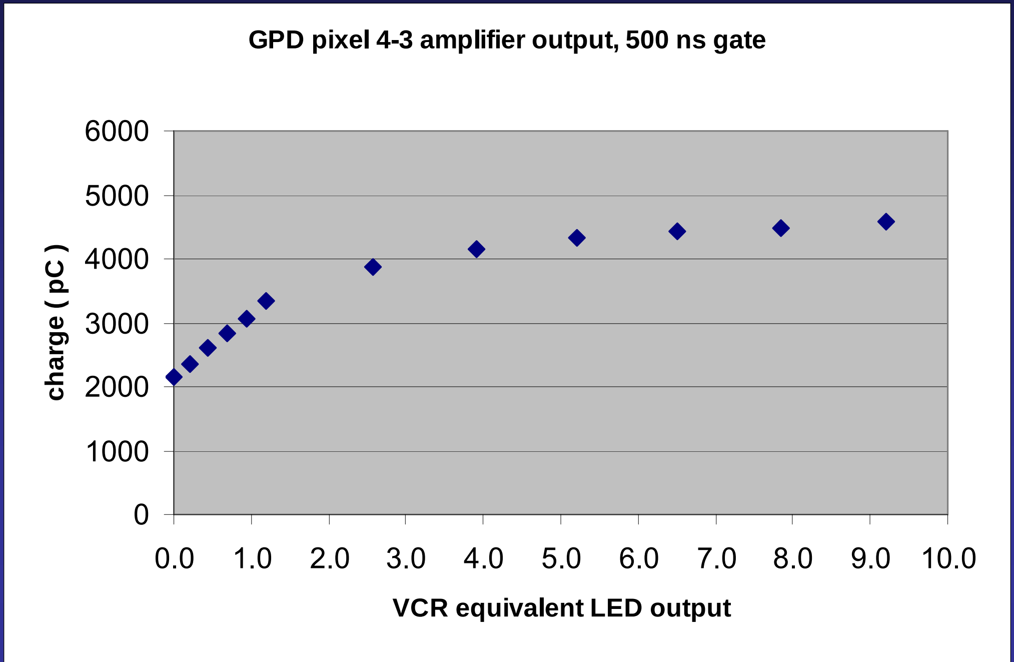
J Proulx (Colorado)





Saturation curve

R Wilson (Colorado State)



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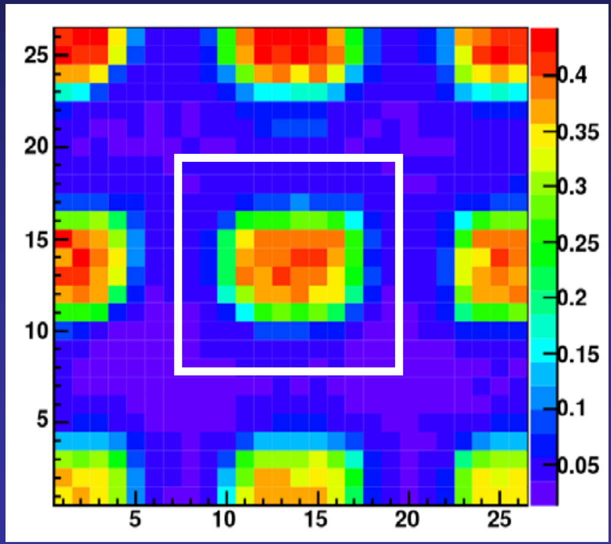
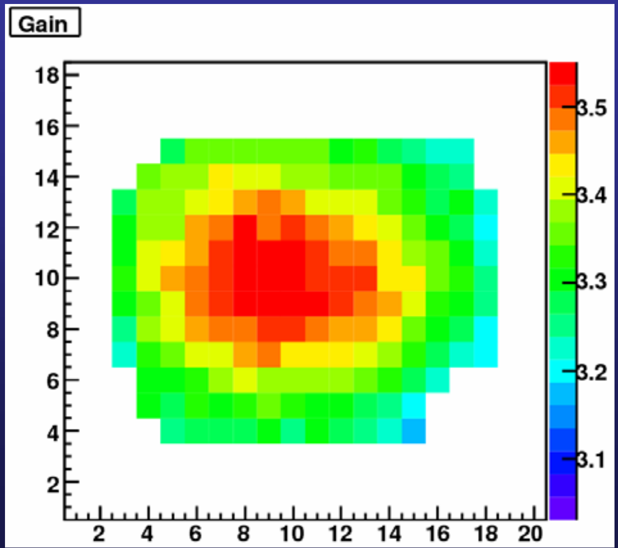


Scans with laser (1 μm spot size)
→ Geometrical acceptance ~20%
→ Variation within active area 7 – 13%



→ Gain variations inside active area 2 – 3%

Tail – Catcher/Muon Tracker

Question I

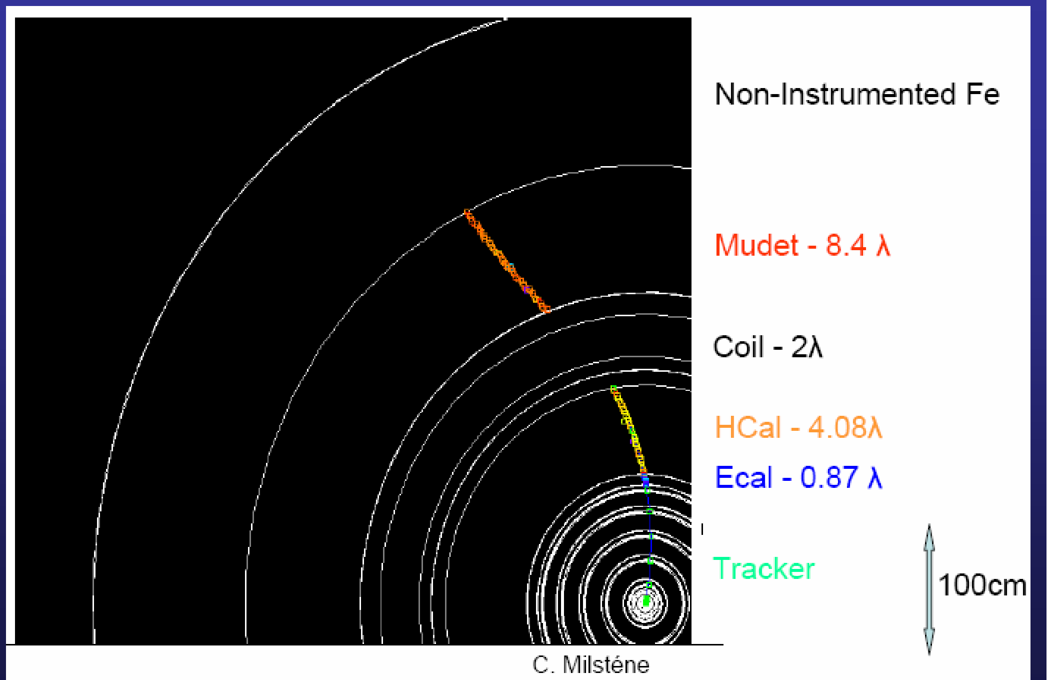
- PFA calorimeters excellent at tracking MIPs
- High magnetic field means muons need $p_T \sim 3$ GeV/c to reach back of coil

Do we need a muon system?

C Milstene: Study of bbar-b events

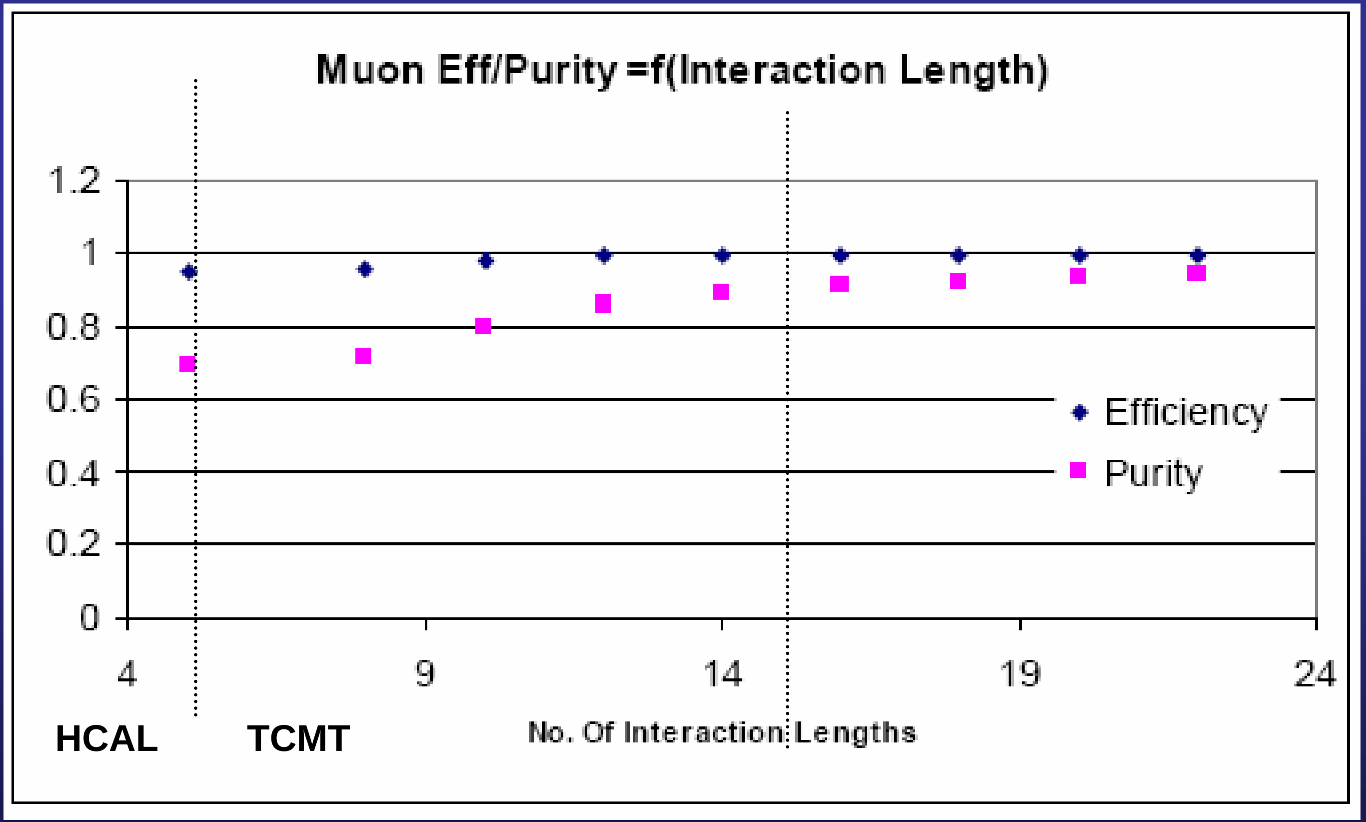
- Study in context of SiD detector
- 10,000 events generated with GEANT4

- Polar angle cut to select events in barrel
- Transverse momentum > 3 GeV/c



Filter to remove hadrons

- Cut tracks with large energy deposits (above 2 hits/layer)
  Either in HCAL (first point) or in TCMT (other points)
- Cut tracks with voids in 2 – 3 consecutive layers
- Require 1 – 4 hits in the last 4 HCAL layers
- Require hits in the TCMT



TCMT improves

- Efficiency

ε = 95.0 → 99.6%

- Purity

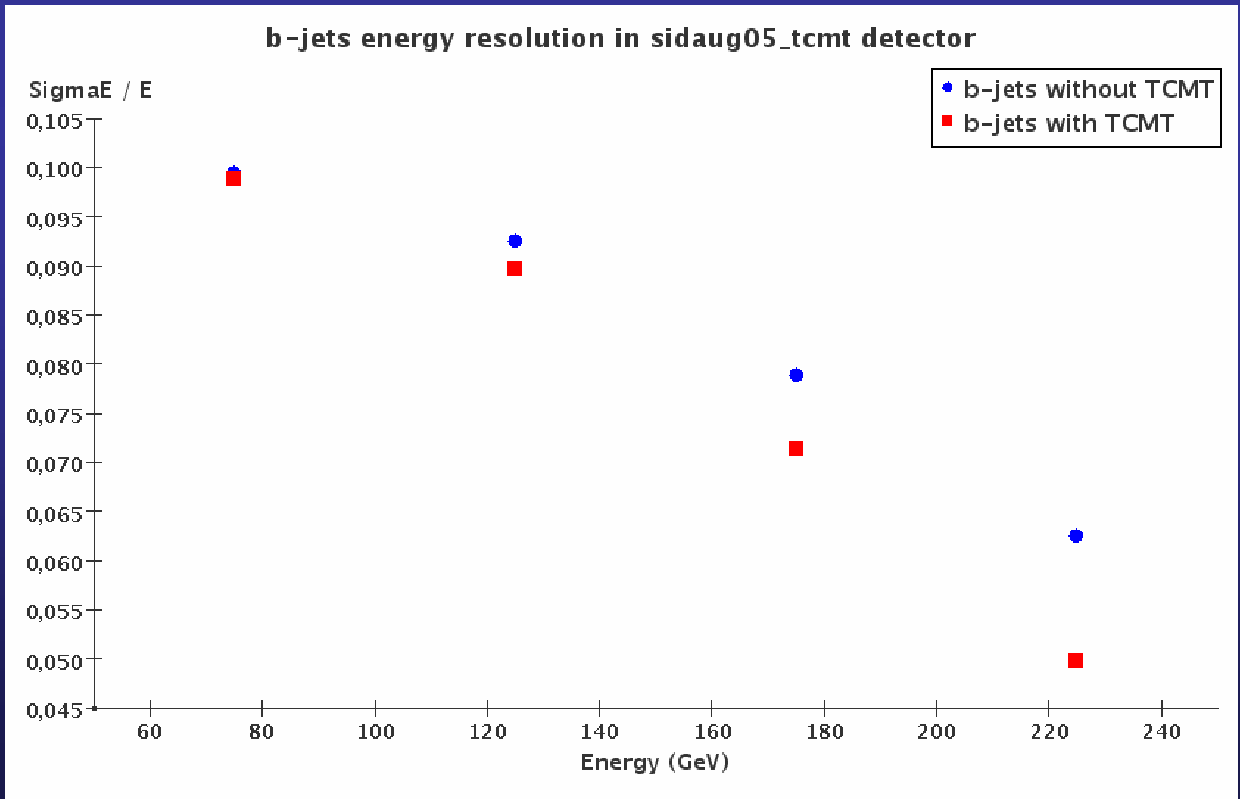
P = 69 → 94 %

Question II

- System will be located outside coil (approximately 1 λ_I)

Can a tail catcher improve σ_{Ejet}?

in PFAs through improving $\sigma(h^0)$



Calorimeter only

- Improved resolution
- Energy dependence?

→ Needs to be studied in the context of PFAs

Muon systems: Hardware R&D

Lead institutions	Active element	Readout	Status	Reported at VLCW06
FNAL	Scintillator	MAPMT	First results from test beams	**yes**
NICADD/NIU	Scintillator	Si-PM	First results from test beams	**yes**
Frascati	RPC		First results from test beams	**yes**
Wisconsin	RPC		R&D initiated	**yes**

M. Piccolo: ‘Performance not critically dependent on the operational details of the active detector’

More important to use the same technology as the HCAL?

Hardware: Scintillator

Hardware: Resistive Plate Chambers