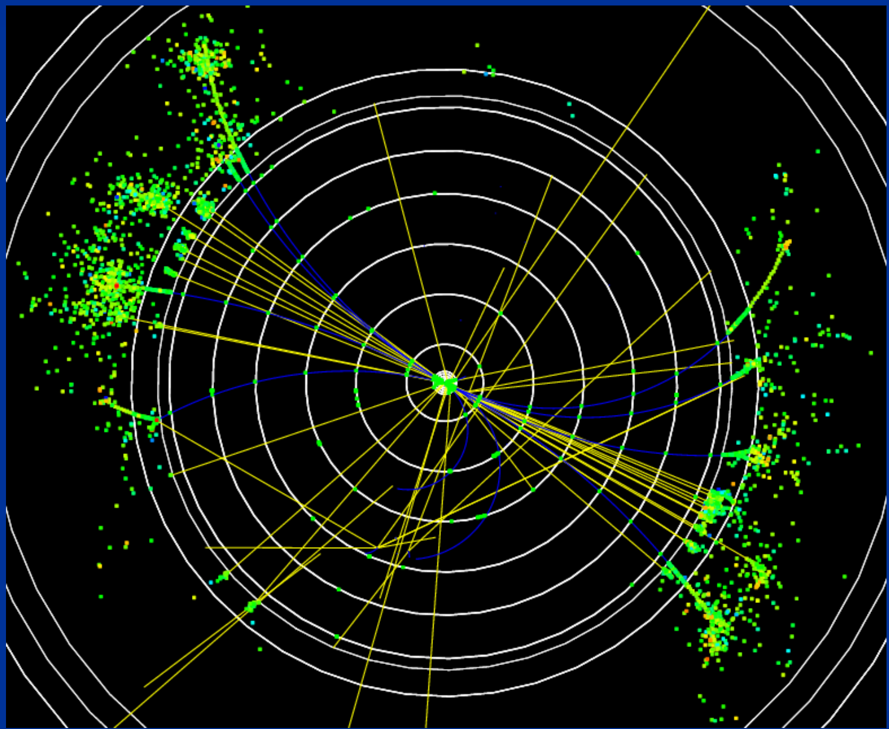
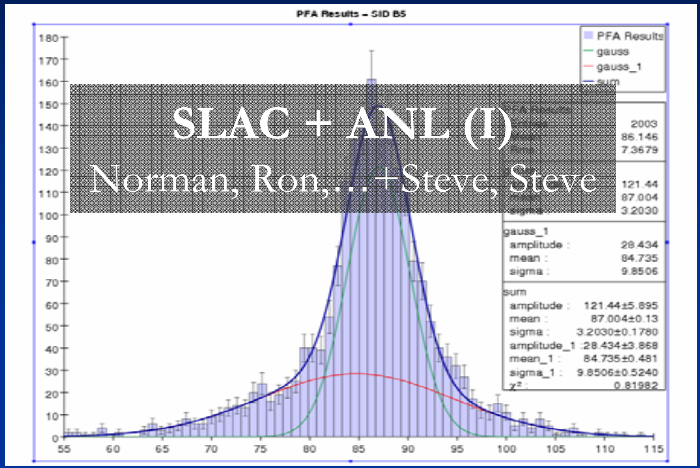
Status of SiD PFA Development

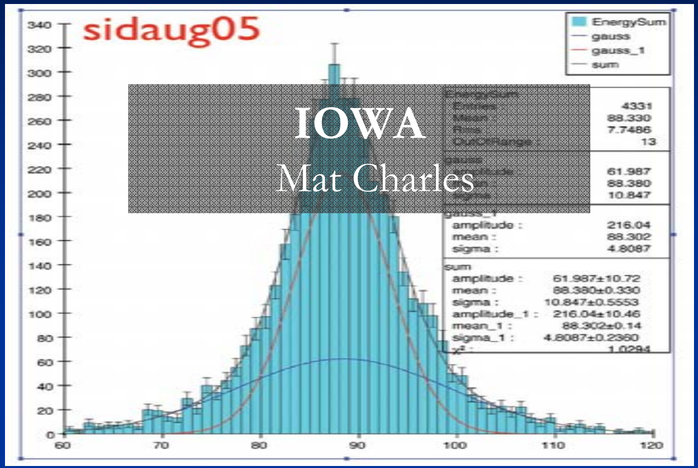
Lei Xia (ANL – HEP)

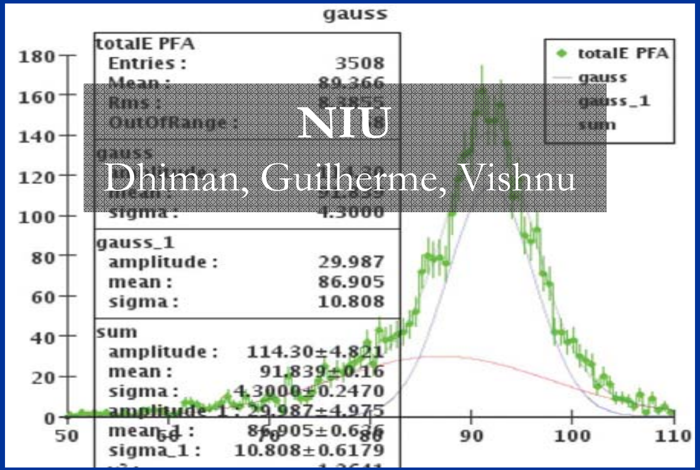


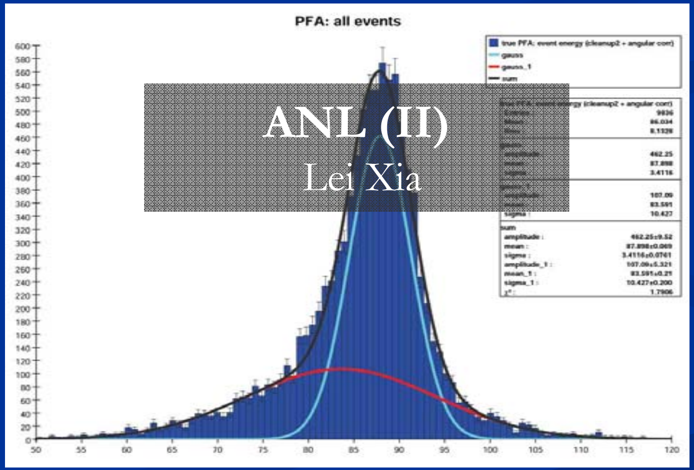
- What tools do we need
- Where are we now
- Future plan

Groups contributing to SiD PFA development



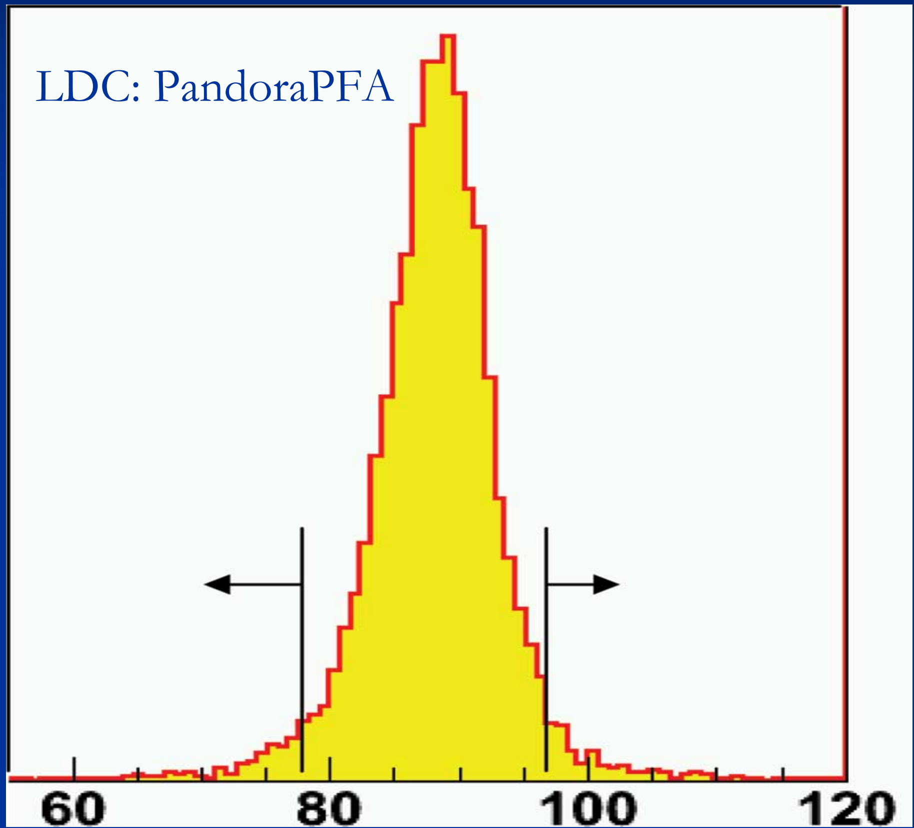






And many other groups (Fermilab, Colorado, Kansas, Tracking groups, …)

As a reference point: PandoraPFA



- PandoraPFA is an European effort on PFA development
- Results are based on LDC concept
- Currently, it gives the best Z-pole performance

Mark Thomson
University of Cambridge

'Current' performance of PandoraPFA
(as of 06/15/2006)

Tools needed for detector optimization: I

- Goal:
  - 30%/sqrt(E) jet energy resolution ← PFA
    - We need this jet energy resolution for ZH, ttbar, ZHH… @ 500 – 1000 GeV
    - In other words, need 30%/sqrt(E) resolution for jet energy range: 45 – 250 GeV / jet
  - PFA → Detector optimization

- Tools (I): Particle Flow Algorithm
  - A complete PFA, with all algorithms implemented
    - Calibration, Track finding, Clustering algorithm, Photon identification
    - Charged hadron id (track-cluster matching), neutral hadron id/fragment id
  - Good performance for Z-pole → di-jet events
    - Demonstrate 30%/sqrt(E) jet energy resolution at E = 91 GeV
    - Have good understanding of all algorithms, source of the 'confusion term', etc.
  - Understand PFA performance for jet energy range 45 – 250 GeV / jet
    - Can use di-jet events at higher E_{cm} to do this study
    - For PFA at high energy, may need quite different approach from what we have at Z-pole

PandoraPFA: LDC00
e+e− → uds pair
using PFA optimized at Z-pole

(Taken from Mark Thomson's talk)

E_{JET}	$\sigma_E/E = \alpha\sqrt{(E/GeV)}$	
	All angles	$\lvert\cos\theta\rvert<0.7$
45 GeV	33.4±0.3%	29.2±0.4 %
100 GeV	42.0±0.3 %	38.4±0.5 %
180 GeV	71.7±0.3 %	63.8±0.4 %
250 GeV	90.7±2.0 %	87.2±2.5 %

Tools needed for detector optimization: I

- Tools (I): Particle Flow Algorithm (continue…)
  - Understand PFA performance for multi-jet/complicated final states
    - Demonstrate jet energy resolution for these final states
    - Understand the effect from jet algorithm, neutrinos, energy leaks, etc.

Tools needed for detector optimization: II

- Tools (II): Optimization Procedure of PFA
  - PFA must come with the capability to be optimized for different final states and detector configurations
  - We need to assess the performance of different detector configurations with their optimal PFA – We want to compare the difference of detectors, not PFAs

A 'bad' example: again, from PendoraPFA/ LDC

Detector Model	$\sigma_{Evis}/E = \alpha\sqrt{(E/GeV)}$		
	Z @91 GeV	tt@500 GeV	Z@500GeV
LDC00Sc 1cm x 1cm	31.4 ± 0.3 %	42 ± 1 %	81 ± 2 %
LDC00Sc 3cm x 3cm	30.6 ± 0.3 %	45 ± 1 %	88 ± 2 %
LDC00Sc 5cm x 5cm	31.3 ± 0.3 %	48 ± 1 %	94 ± 2 %
LDC00Sc 10cm x 10cm	33.7 ± 0.3 %	56 ± 1 %	114 ± 2 %

★ Finer granularity helps somewhat at higher energies – why ?

Related to non-optimal PFA?

(Taken from Mark Thomson's talk)

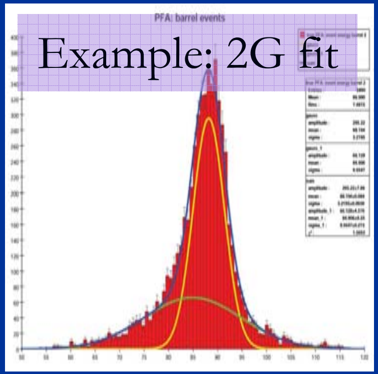
Tools needed for detector optimization: III

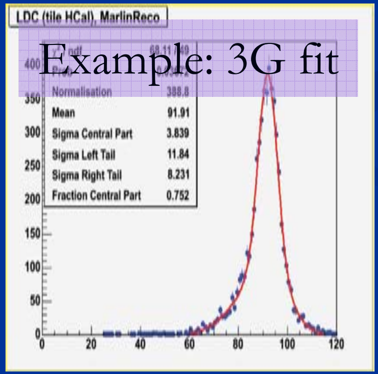
- Tools (III): PFA performance bench mark
  - A lot of 'figure of merit' has been used, we can hardly compare one with another
    - Same result can look very different under different 'figure of merit'
    - These 'figure of merit' have very different 'tolerance' on tails of distributions
  - Commonly used 'figure of merit'
    - 2-Gaussian fit (North America)
      - (narrow, fraction), (broad, fraction)
    - 3-Gaussian fit (Europe)
      - (central, fraction), (L, fraction), (R, fraction)
    - RMS of the smallest region containing 90% of events (Europe)
    - Equivalent pure Gaussian, which gives same physics performance as your PFA
      - For example: W and Z separation (the famous blue plot!)
    - Or just RMS ?

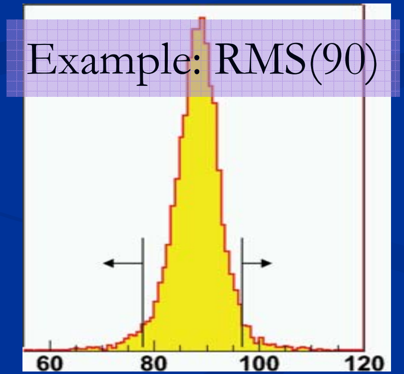
σ (narrow) ~ σ (central)
frac(2G) $\neq$ frac(3G)

σ (narrow) ~ RMS(75)
(fraction ~60%)

→ RMS(90)

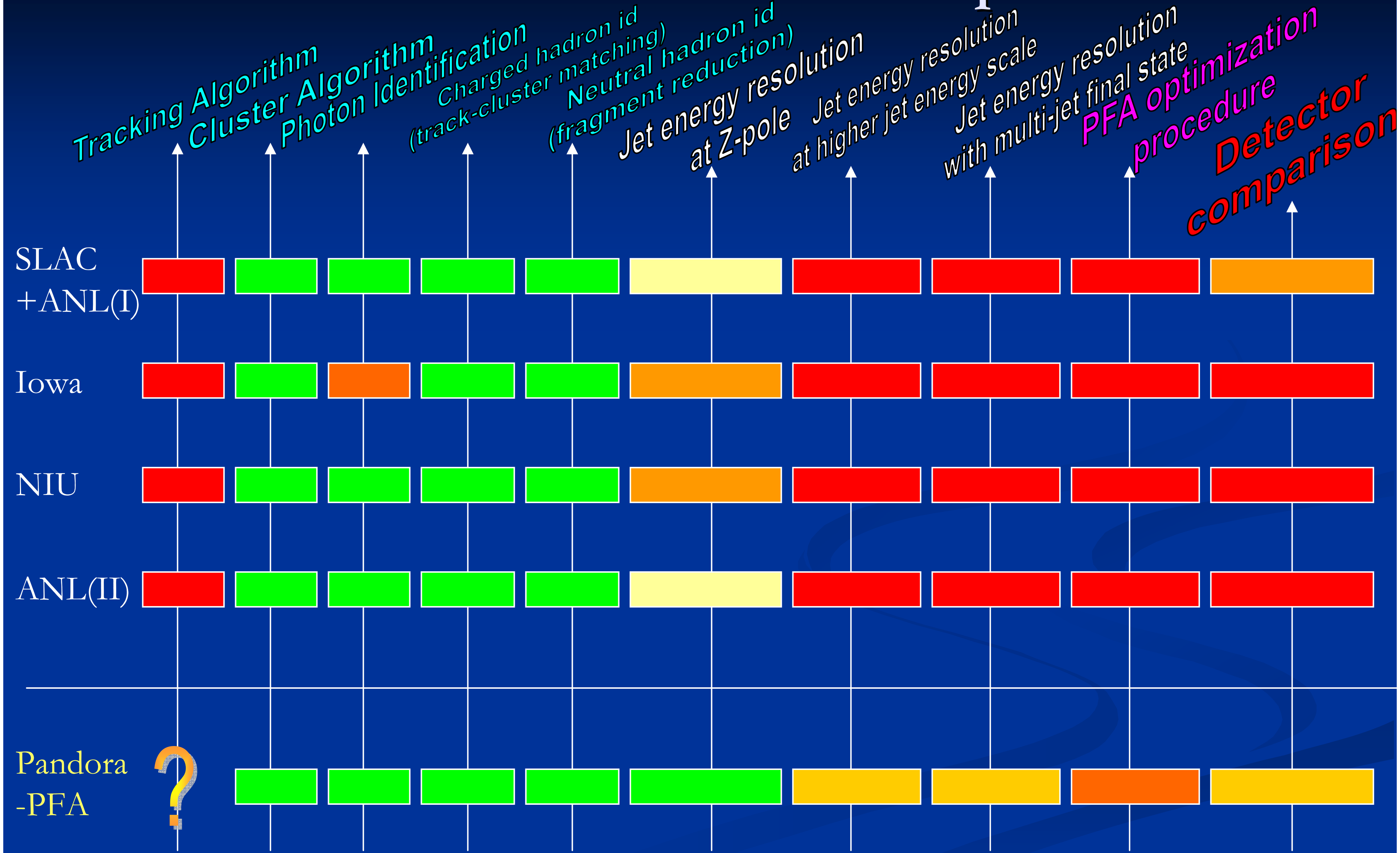






- Which PFA performance bench mark can reflect our physics need?
  - If we don't require pure Gaussian or RMS, then 30%/sqrt(E) is not a complete measure yet
    - How much 'tail component' can we tolerate?
    - What is the impact of the 'tail component' on the physics results we are interested in?
  - This is a question that can not / should not be answered by PFA guys alone

Current status of PFA development



We are (more than?) half way there…

Color code: Done Not touched In progress

Current PFA performance at Z-pole (uds)

(GeV)	SiD model	2 Gaussian All events		2 Gaussian Barrel events*		RMS(90)		Equivalent** Pure Gaussian	RMS	
		Narrow	Broad	Narrow	Broad	All	Barrel		All	Barrel
SLAC+ ANL(I)	sidaug05			3.2 (59%)	9.9 (41%)					7.4
Iowa	sidaug05			4.8 (61%)	10.8 (39%)					7.7
NIU	sidaug05 _tcmt			3.9 (59%)	10.6 (41%)					8.1
ANL(II)	sidaug05 _np	3.4 (59%)	10.4 (41%)	3.2 (59%)	10.0 (41%)	4.9	4.5	~ 6.0	8.1	7.5
Pandora PFA	LDC					3.2	2.8		5.2	
GLD PFA	GLD						2.9			5.3

* Different groups give slightly different definitions for 'barrel events'

** Pure Gaussian that gives equivalent W, Z separation

1. 'Tail' of distribution is very important
2. Z-pole performance of our PFAs is not good enough yet

Future plan (I)

- SLAC + ANL(I)
  - Finish/optimize PFA performance at Z-pole
  - Once understood Z-pole, start true detector optimization + multi-jet event at higher E_{cm}
  - Construct detector optimization grid, try to isolate and vary a single variable at a time
- Iowa, NIU, ANL(II)
  - Continue to optimize PFA performance at Z-pole, make sure it delivers required jet energy resolution
  - Study PFA performance with complicate final states (multi-jet) at high E_{cm}, and make sure PFA works and gets good jet energy resolution
  - Make sure the PFA is flexible enough to be tuned to deliver optimal resolution for different detector designs
  - Start detector optimization after all the above is achieved

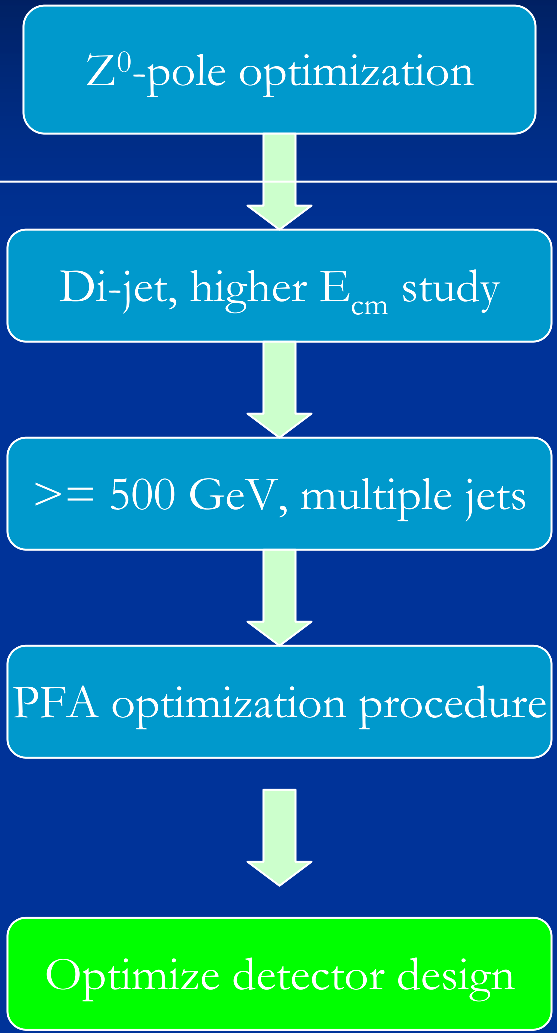
Future plan (II)

- ALL
  - All efforts will adapt the PFA template to make PFA components interchangeable
    - PFA template is a set of conventions that defines the general structure and interface of a particle flow algorithm, which makes PFA components as interchangeable as possible
  - Encourage sharing code, algorithm and design ideas
    - Source code should be publicly available for all efforts
  - Need closer collaboration to avoid multiple parallel implementation of everything
  - Need to implement more realistic tracking, digitization and tail catcher/muon system algorithm at some point

- PFA template: any new effort should start from here!
  - https://confluence.slac.stanford.edu/display/ilc/lcsim+PFA+guide
  - A trivial worked example in CVS at
    - org.lcsim.plugin.web.examples.TrivialPFA

Timeline

PFA development



Should be able to finish in a few months

Hard to tell at this moment

- If PFA at high energy is just an extrapolation of Z-pole, then it should be done rather soon (but not likely…)
- Otherwise, may have to take quite different approach and need a lot of effort
    - for example, clustering, instead of building up clusters, we may need to think hard on how to divide clusters into smaller pieces

- In the past , we might have underestimated the amount of effort needed to develop a good PFA
- Now we still need to do a lot to get PFA ready for detector optimization

Summary

- We made a lot of progress on PFA development, since last SiD meeting
  - All algorithms are implemented (except track finding)
  - Combined PFA performance at Z-pole kept improving
  - PFA template in place
- We still need to do a lot to get PFA ready for detector optimization
  - Optimize Z-pole performance in the near future and achieve jet energy resolution goal at this energy
  - Study more complicated final states at higher E_{cm} and show their optimal jet energy resolution
  - Find an optimization procedure for PFA, in order to get the optimal performance for different detector designs

- Special thanks to Mat Charles, Guilherme Lima and Steve Magill, for their valuable input and comments