Improvements and Status of SiD-Iowa PFA

G. Halladjian

R. Zaidan, U. Mallik, R. Cassell, M. Charles

LCWS11, Granada, Spain

September 28th, 2011

Outline

- Setup of Iowa PFA
  - steps of the setup
  - modifications and improvements
- Baseline shower building algorithm
  - event energy resolutions
- New shower building algorithm (in progress)
  - steps of the algorithm
  - statues of the new shower building algorithm
- Conclusion

Data sample

qqbar events with 500 GeV at center mass (sid02)

Setup of the Iowa PFA

- Before hadron reconstruction
  - photon, electron & muon finding
- Pre-shower MIP finding
- DTree clustering
  - uses only hits not used so far
- Sub-structure finding
  - mips, clumps, blocks & leftover hits
- Track-seed matching
  - uses initial MIP finding
  - attempt to match unmatched tracks sequentially to MIPs, Clumps, blocks, and leftover hits
- Photon veto
  - attempt to recover hits from a hadron identified as a photon

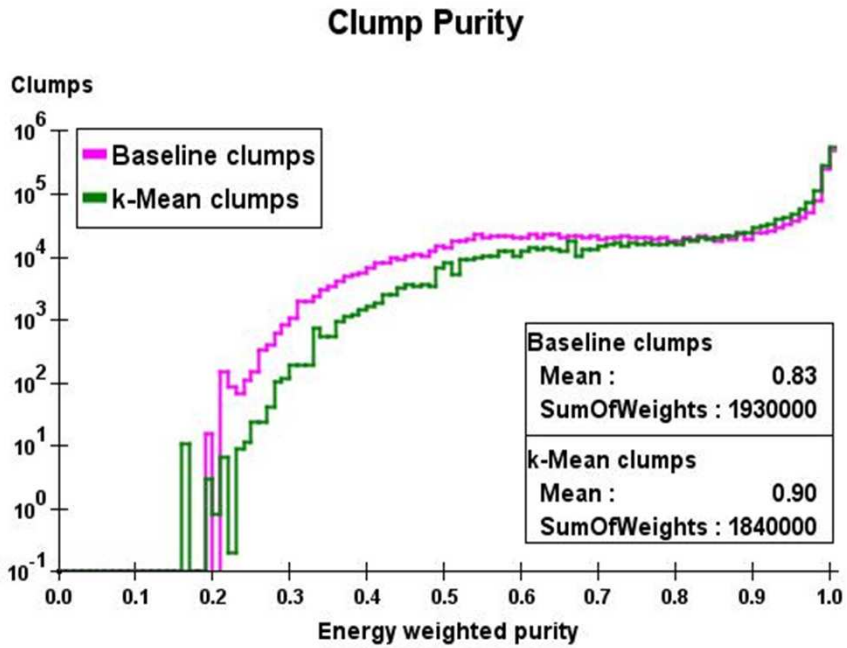
Modifications

- Modifications in the PFA setup
  - add new clump finding algorithm (k-mean clustering algorithm) complemented by a Nearest Neighbour algorithm
  - modify the photon veto
  - corrections to track-seed matching in special cases

- Modifications in the scoring
  - scoring is completely based on likelihood
  - add new variables to the likelihood
  - change definition of the good and bad links in the training
  - include correlations between the Probability Density Functions (PDF)
  - separate PDFs for different sub-detectors

Sub-cluster finding

- Add new sub-cluster finding (k-mean clustering)
- K-mean algorithm
  - find k-mean cores: initial set of clusters consisting of local density maxima
  - define a distance: a metric that tells how likely a hit belongs to a core
  - assign each hit to the “closest” core
- Purity based on energy
  - Nearest Neighbour : 83%
  - k-mean : 90%
- Ratio of the event total energy goes to clumps
  - Nearest Neighbour : 47.5%
  - k-mean : 45%

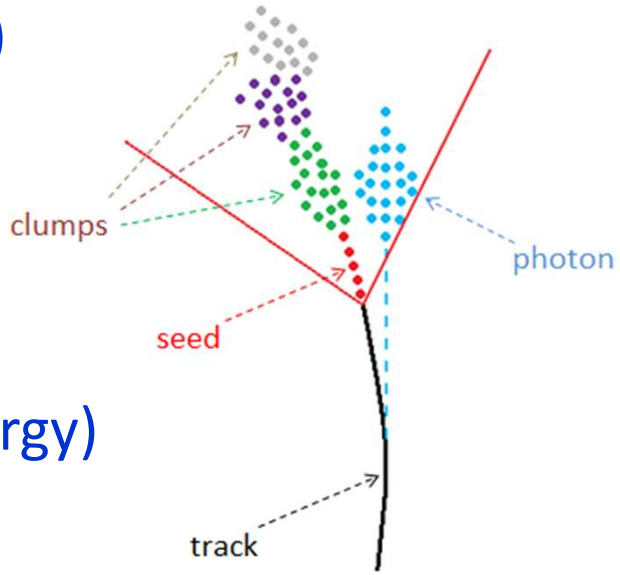


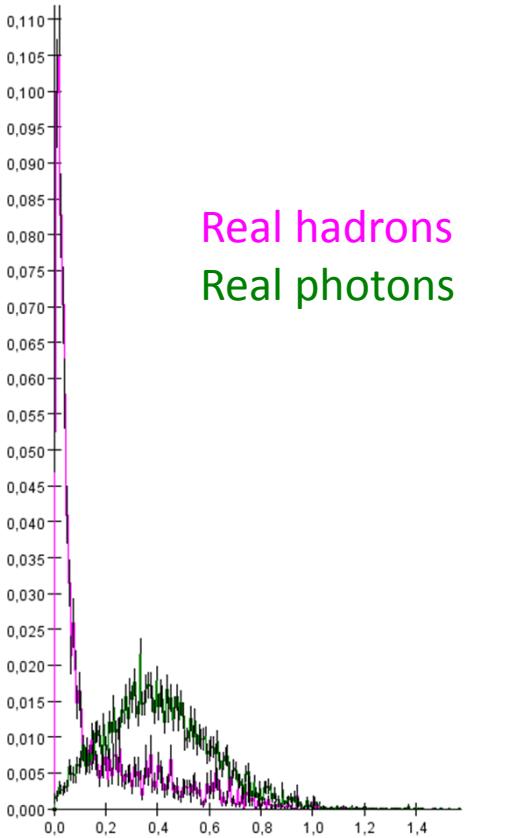
Photon veto

- New photon veto : hits identified as a photon are given a chance to be attributed to a hadron shower if the “photon” is within 3 degrees from a track

- Purity (based on energy)
  - before the veto = 83%
  - after the veto = 90%

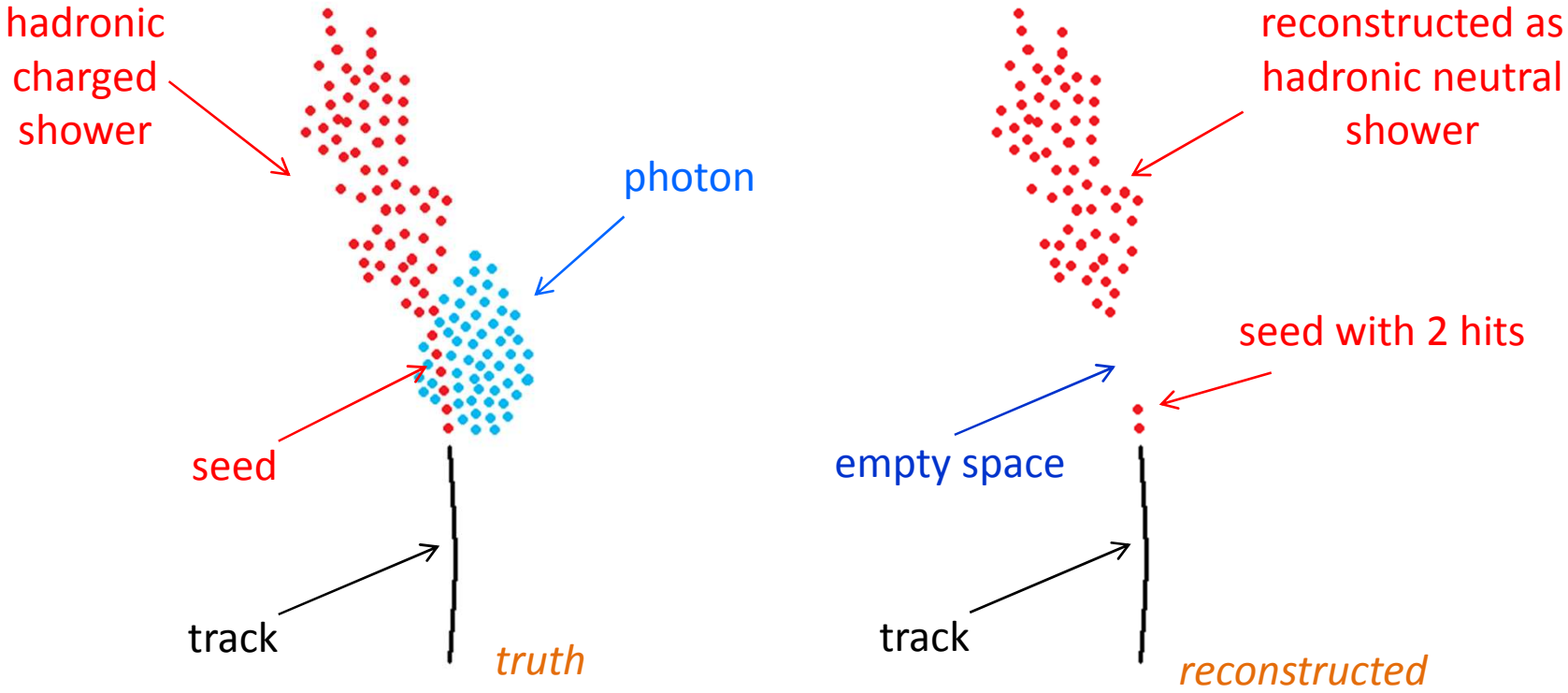
- Efficiency (based on energy)
  - before the veto = 92%
  - after the veto = 90%





Track-seed matching

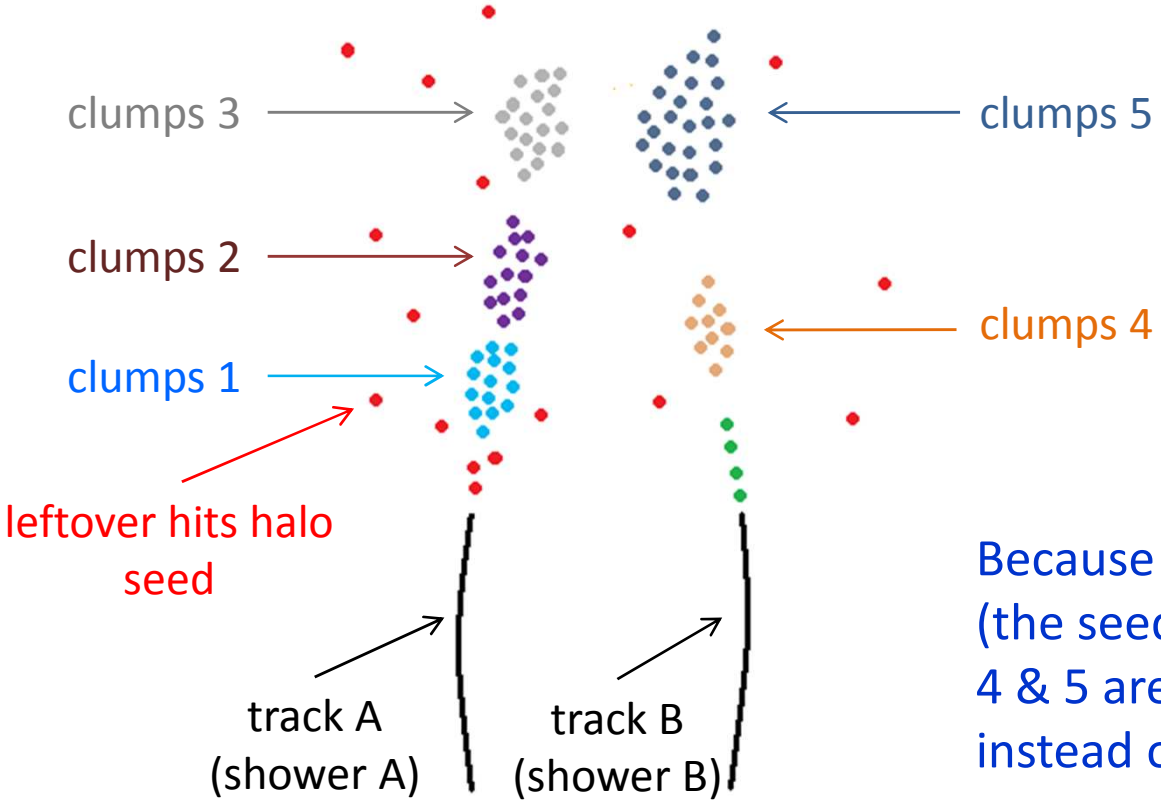
- Two problematic cases are identified
  - case 1 : photon close to a track (8% of the tracks)



photons are taking off part of the hadronic shower hits and creating an empty space.
This space will prevent the shower from developing

Track-seed matching

- Two problematic cases are identified
  - case 1 : photon close to a track (8% of the tracks)
  - case 2 : track seed is made from left-over hits (7% of the tracks)



Because of the leftover hits halo (the seed of the track A), the clumps 4 & 5 are included in shower A instead of shower B

Track-seed matching

THE UNIVERSITY OF IOWA

- Two problems shown on previous slides:

1. Photon steals most early hits, hard to extrapolate to main part of shower (8% of tracks)
   - Fix: helix extrapolation of the track to the closest sub-cluster

2. Seed is a sparse “leftover” cluster with poor geometrical information (7% of tracks)
   - Fix: helix extrapolation of the track to the closest sub-cluster

- Performance : ~ 80% of the 15% are fixed

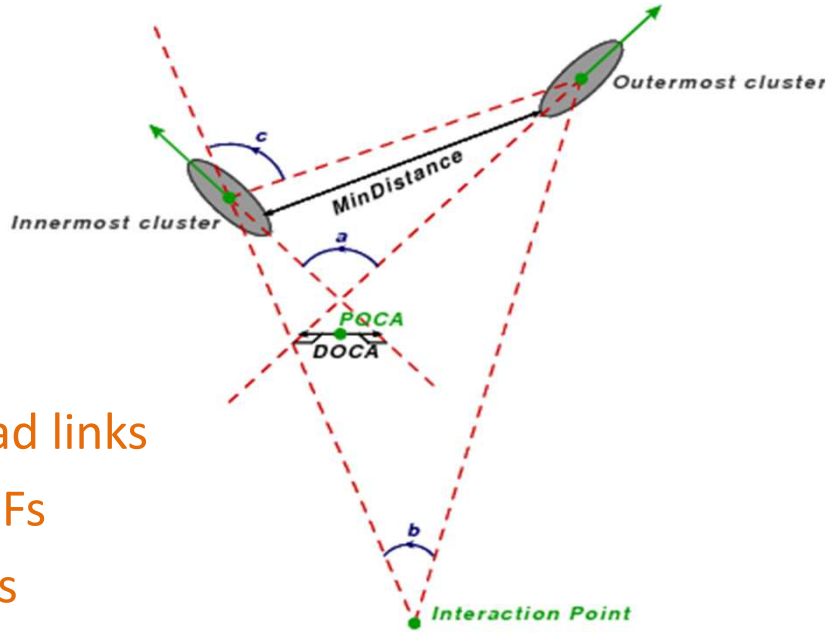
Modifications

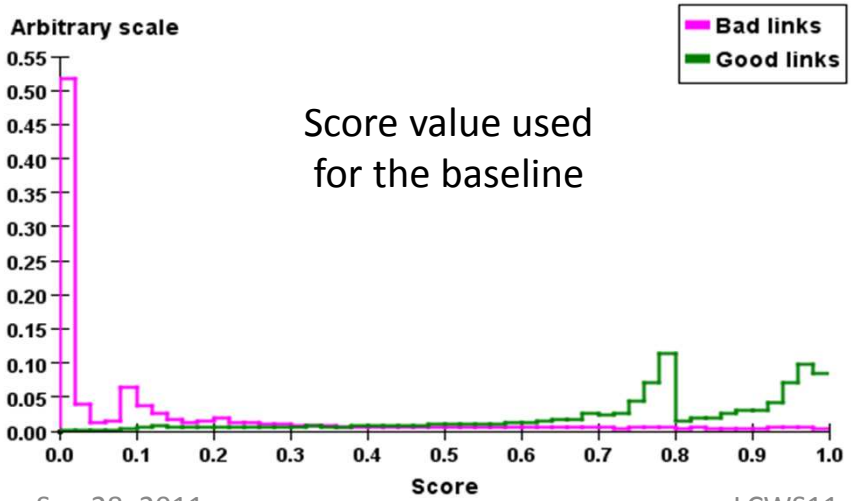
- Modifications in the PFA setup
  - add new clump finding algorithm (k-mean clustering algorithm) complemented by a Nearest Neighbour algorithm
  - modify the photon veto (as described)
  - corrections to track-seed matching in special cases

- Modifications in the scoring
  - scoring is completely based on likelihood
  - add new variables to the likelihood
  - change definition of the good and bad links in the training
  - include correlations between the Probability Density Functions (PDF)
  - separate PDFs for different sub-detectors

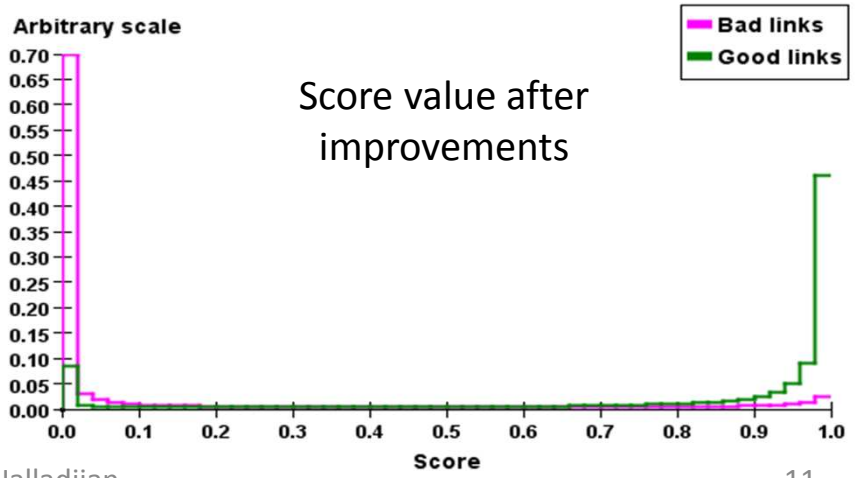
Scoring

- Scoring is improved
  - completely based on likelihood
  - add new variables
    - angle of sub-clusters (a)
    - kink angle (c)
  - change the definition of the good and bad links
  - include the correlations between the PDFs
  - separate PDFs for different sub-detectors





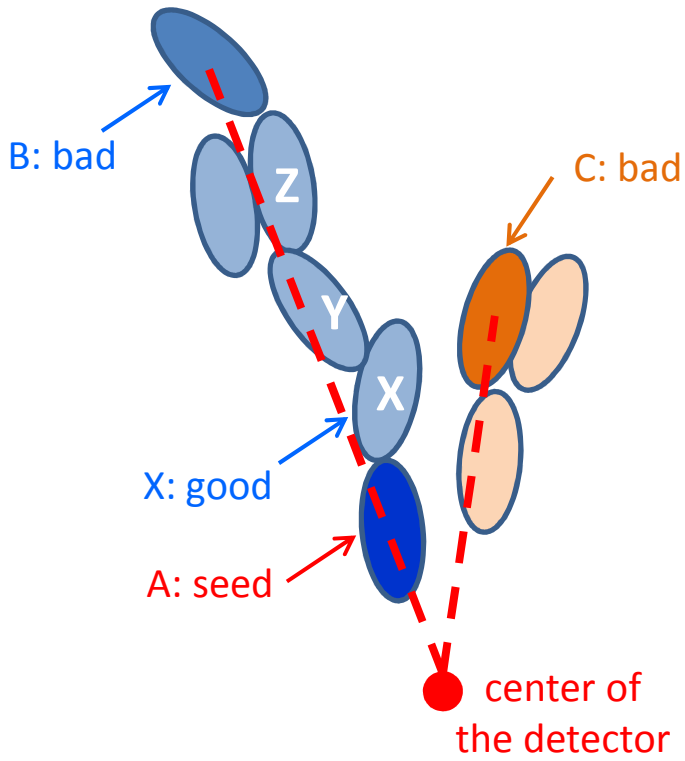
Score value used for the baseline



Score value after improvements

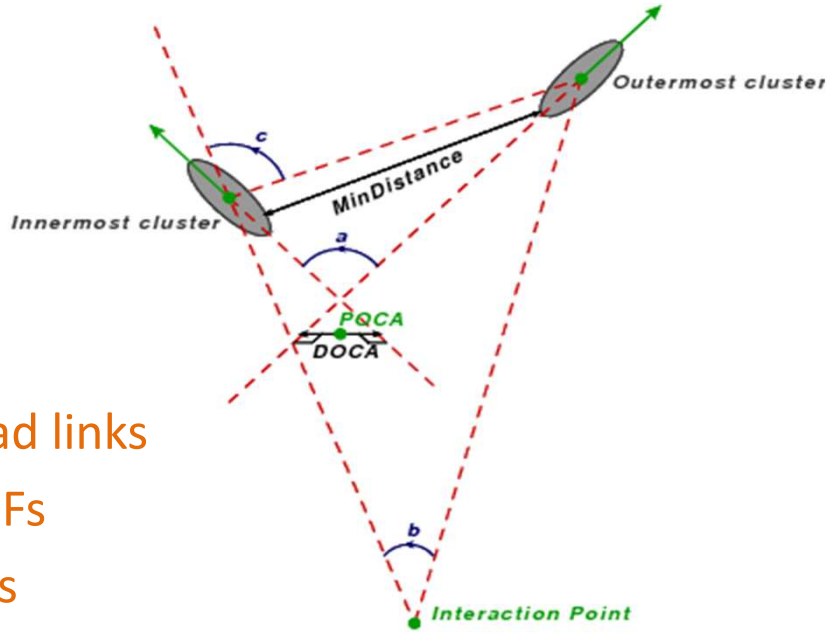
Scoring

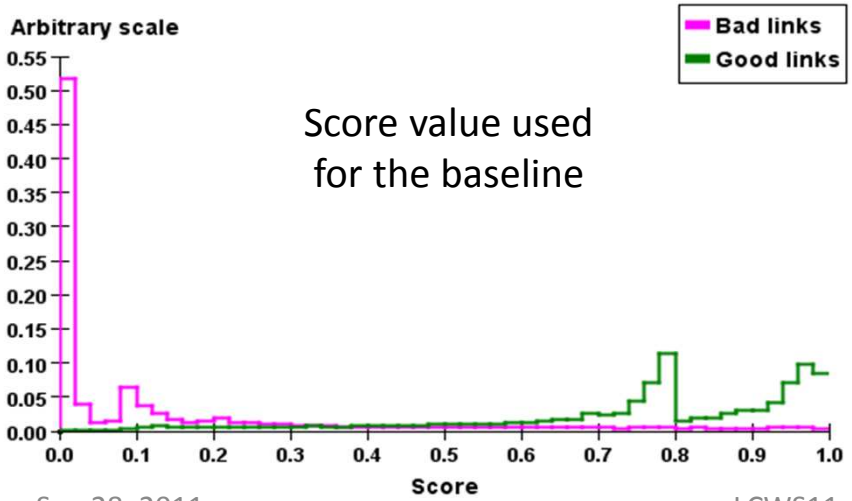
- New linking definitions
  - Bad link: A-B , A-C
  - Good link : A-X , X-Y , Y-Z , Z-B
- A-B is an indirect good link



Scoring

- Scoring is improved
  - completely based on likelihood
  - add new variables
    - angle of sub-clusters (a)
    - kink angle (c)
  - change the definition of the good and bad links
  - include the correlations between the PDFs
  - separate PDFs for different sub-detectors



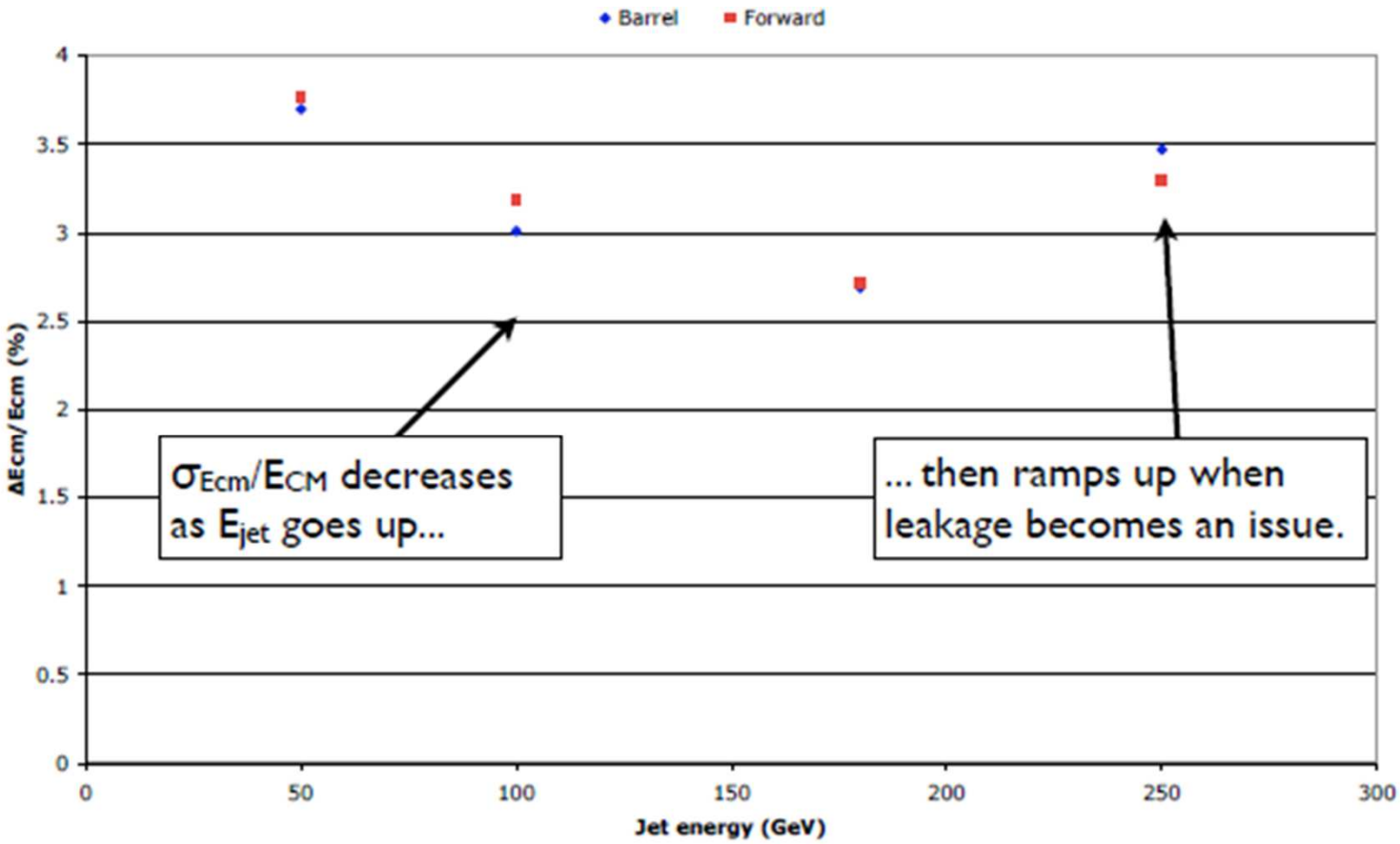


Score value used for the baseline

Score value after improvements

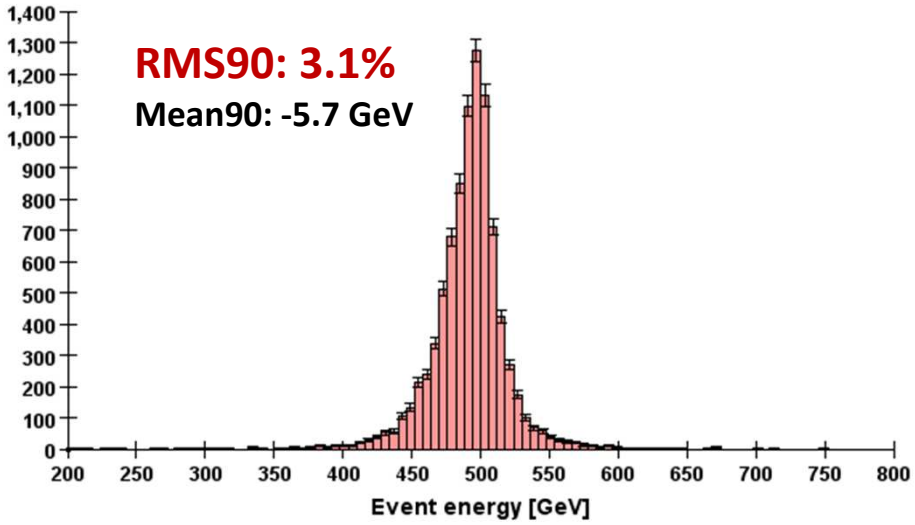
Performance at LOI (sid02)

- Last significant event energy resolution result used for the LOI
  - In 2009 for validation of the SiD concept



Event energy resolution

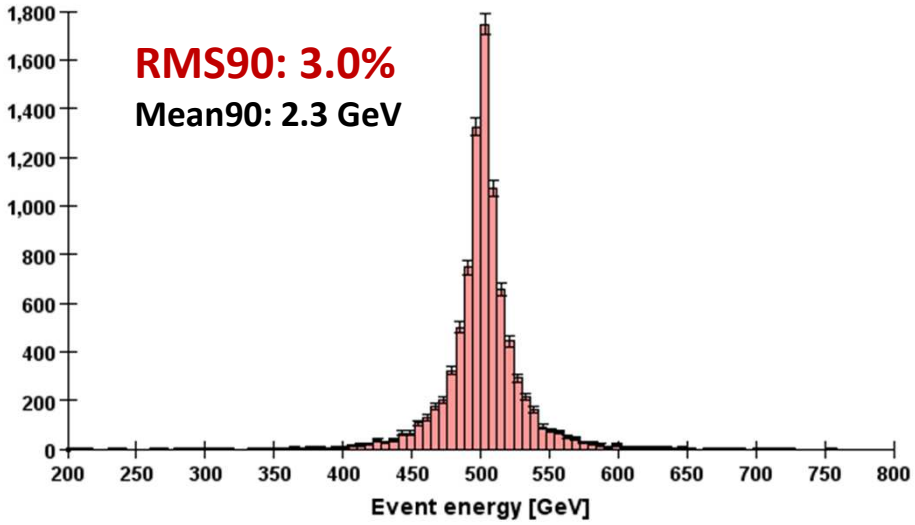
- Event energy resolution of Iowa PFA with the modifications described = 3.1 %
- Confusion between the charged and neutral sub-clusters is correlated



	Charged	Neutral	Photon	Purity
Reco as Charged	51.56	3.97	1.59	0.90
Reco as Neutral	6.69	7.81	1.55	0.49
Reco as Photons	3.12	0.79	22.91	0.85
Efficiency	0.84	0.62	0.88	

Event energy resolution : perfect shower building

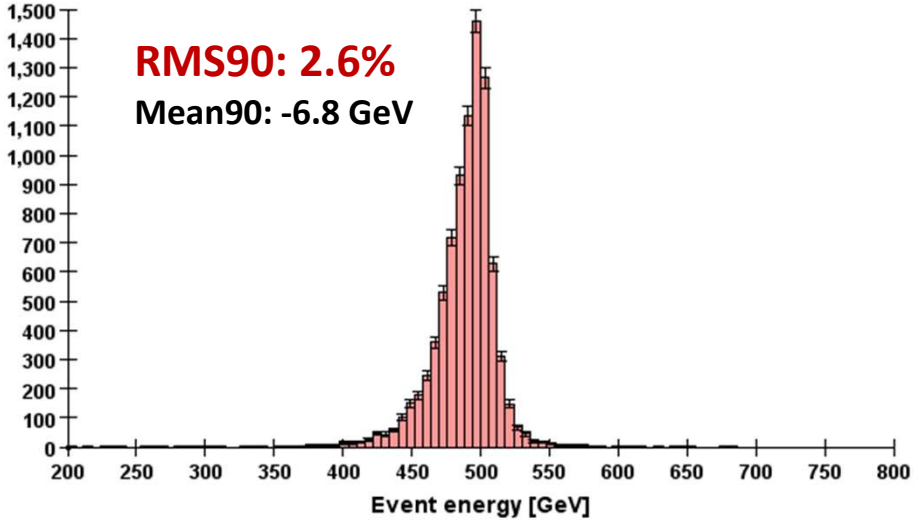
- Perfect shower building
- Event energy resolution is only improved by 0.1 %



	Charged	Neutral	Photon	Purity
Reco as Charged	52.29	1.60	0.89	0.95
Reco as Neutral	5.94	10.27	2.17	0.56
Reco as Photons	3.06	0.80	23.00	0.86
Efficiency	0.85	0.81	0.88	

Event energy resolution : perfect photon

- Perfect photon finding and real shower building
- Event energy resolution improved from 3.1% to 2.6%
- An improved photon finding would help



	Charged	Neutral	Photon	Purity
Reco as Charged	52.79	4.07	0.50	0.92
Reco as Neutral	6.56	8.44	0.12	0.56
Reco as Photons	1.88	0.00	25.65	0.93
Efficiency	0.86	0.67	0.98	

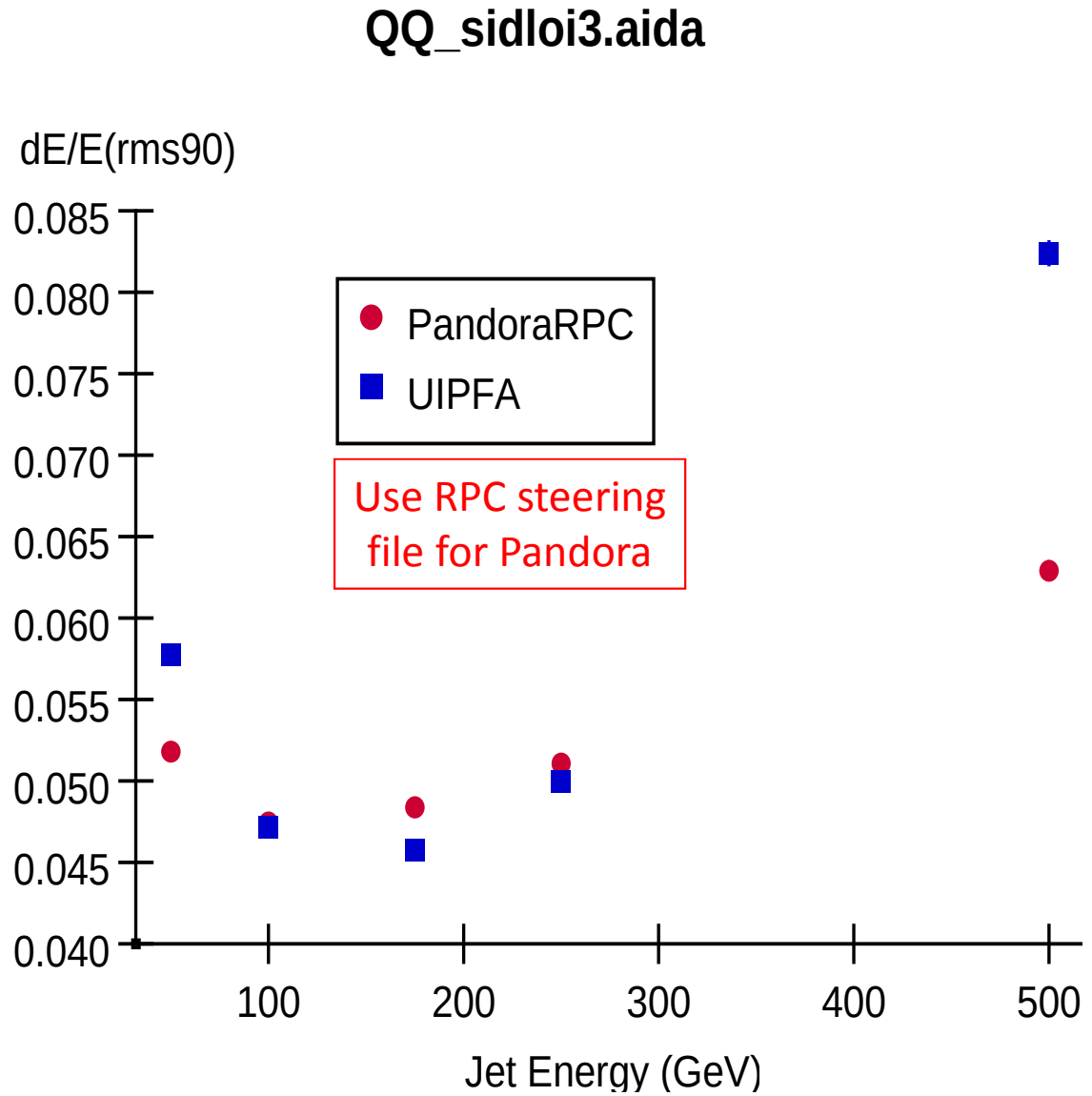
Results for Iowa PFA

- Baseline energy resolution at LOI (2009) = 3.5%
- Event energy resolution with improvements (now) = 3.1%
- Perfect shower building = 3.0%
- Perfect photon finding and real shower building = 2.6%

Comparisons

From Ron Cassell's presentation at the PFA meeting of Mar 31 2011

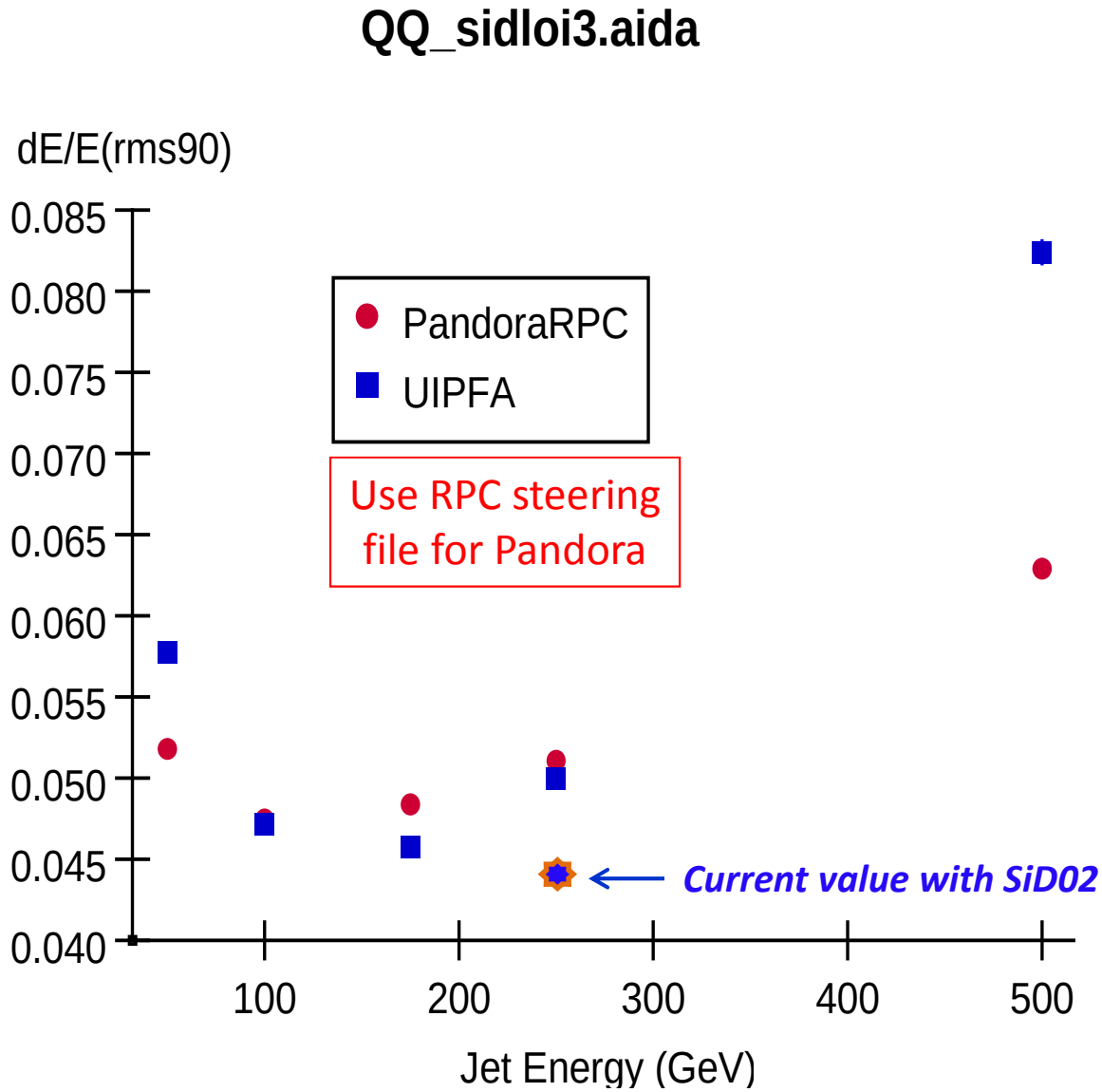
- Cut events with q $|\cos\theta| > 0.95$
- Plot sum of energy of all Reconstructed Particles
- Use distribution (rms90/mean90)*sqrt(2)



Comparisons

From Ron Cassell's presentation at the PFA meeting of Mar 31 2011

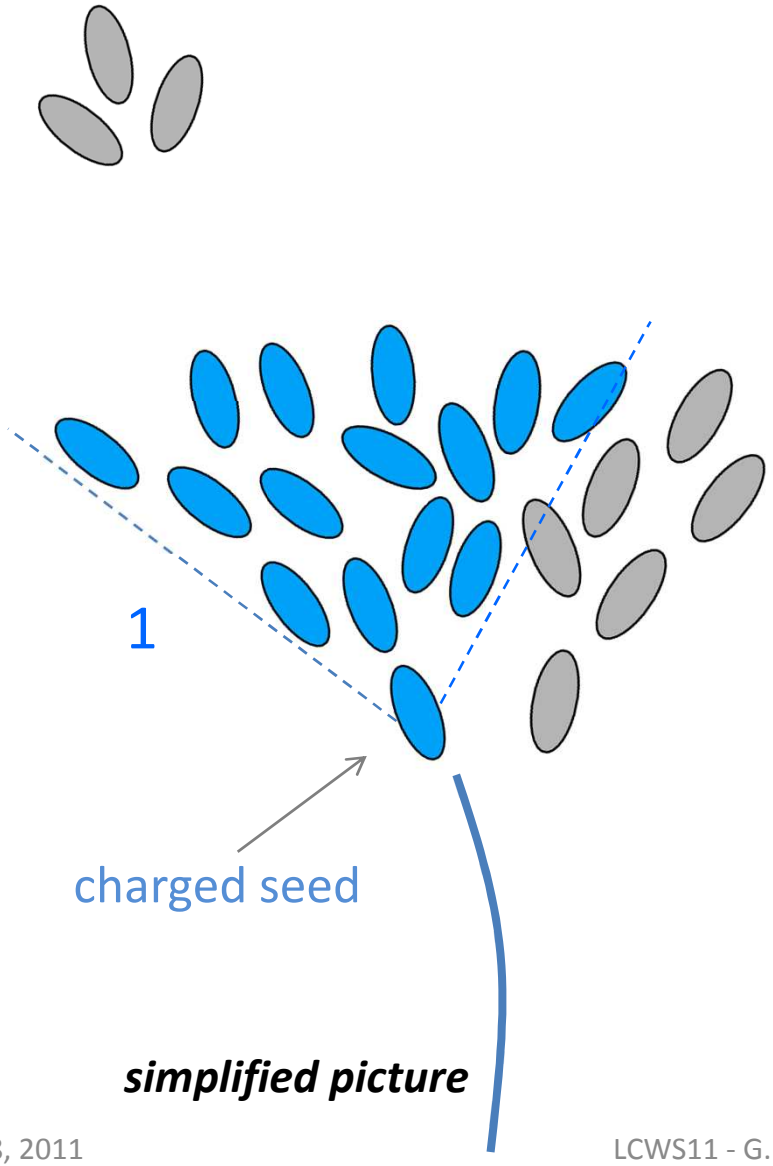
- Cut events with q $|\cos\theta| > 0.95$
- Plot sum of energy of all Reconstructed Particles
- Use distribution (rms90/mean90)*sqrt(2)



New shower building

- First iteration
  - skeleton (simultaneous building of tracks)
  - tight criteria
  - high purity
  - reasonable efficiency
- Second iteration
  - criteria can include information based on the first iteration
  - increase the efficiency
  - add the isolated sub-clusters
  - add the ambiguous sub-clusters
- Third iteration
  - regional and overall event energy momentum balance is taken into account to achieve higher purity and efficiency

New shower building (1st iteration)



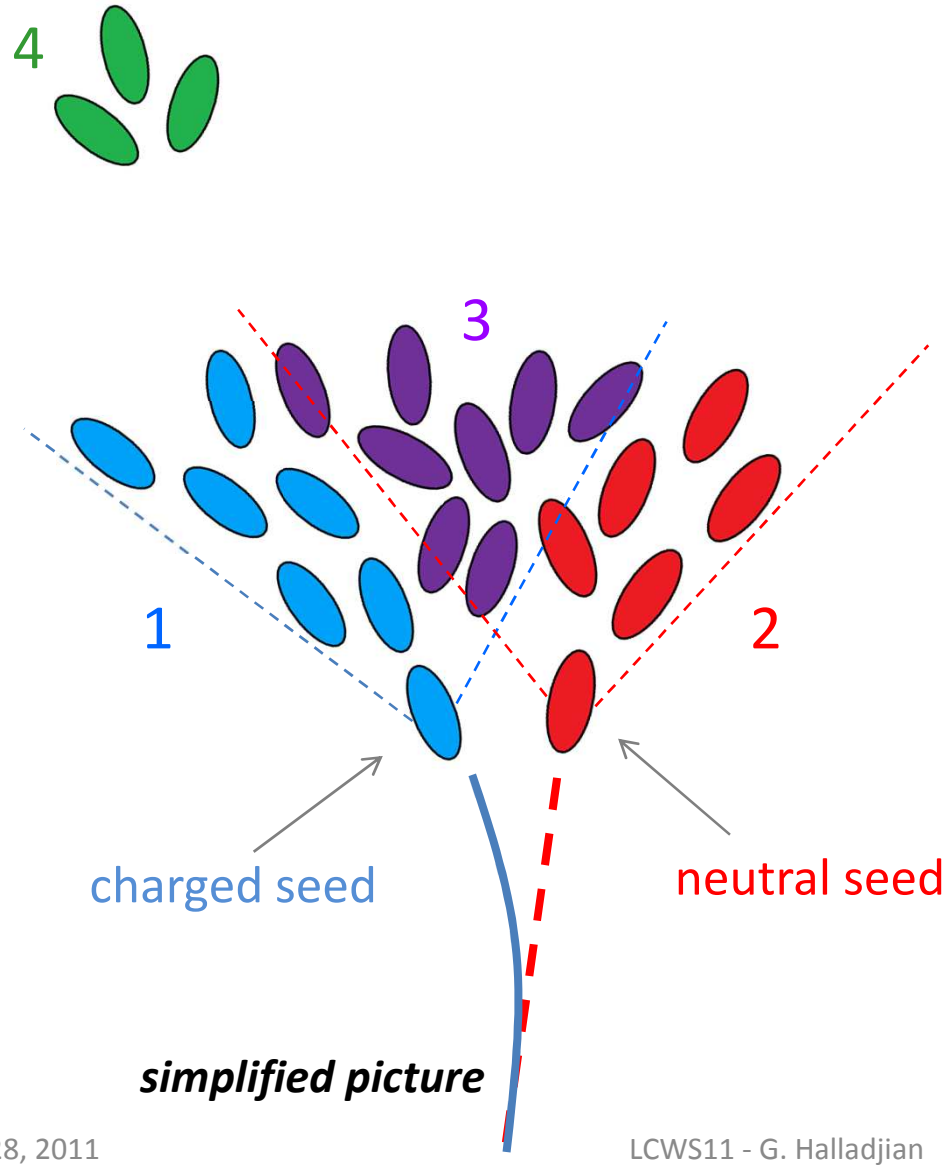
- First iteration:
  - all charged showers are build simultaneously
  - overlaps between the showers are allowed

1- charged shower

New shower building

- First iteration
  - skeleton (simultaneous building of tracks)
  - tight criteria
  - high purity
  - reasonable efficiency
- Second iteration
  - criteria can include information based on the first iteration
  - increase the efficiency
  - add the isolated sub-clusters
  - add the ambiguous sub-clusters
- Third iteration
  - regional and overall event energy momentum balance is taken into account to achieve higher purity and efficiency

New shower building (2nd iteration)



- Second iteration:
  - neutral showers seeded by unused clusters
  - overlaps between the showers are allowed

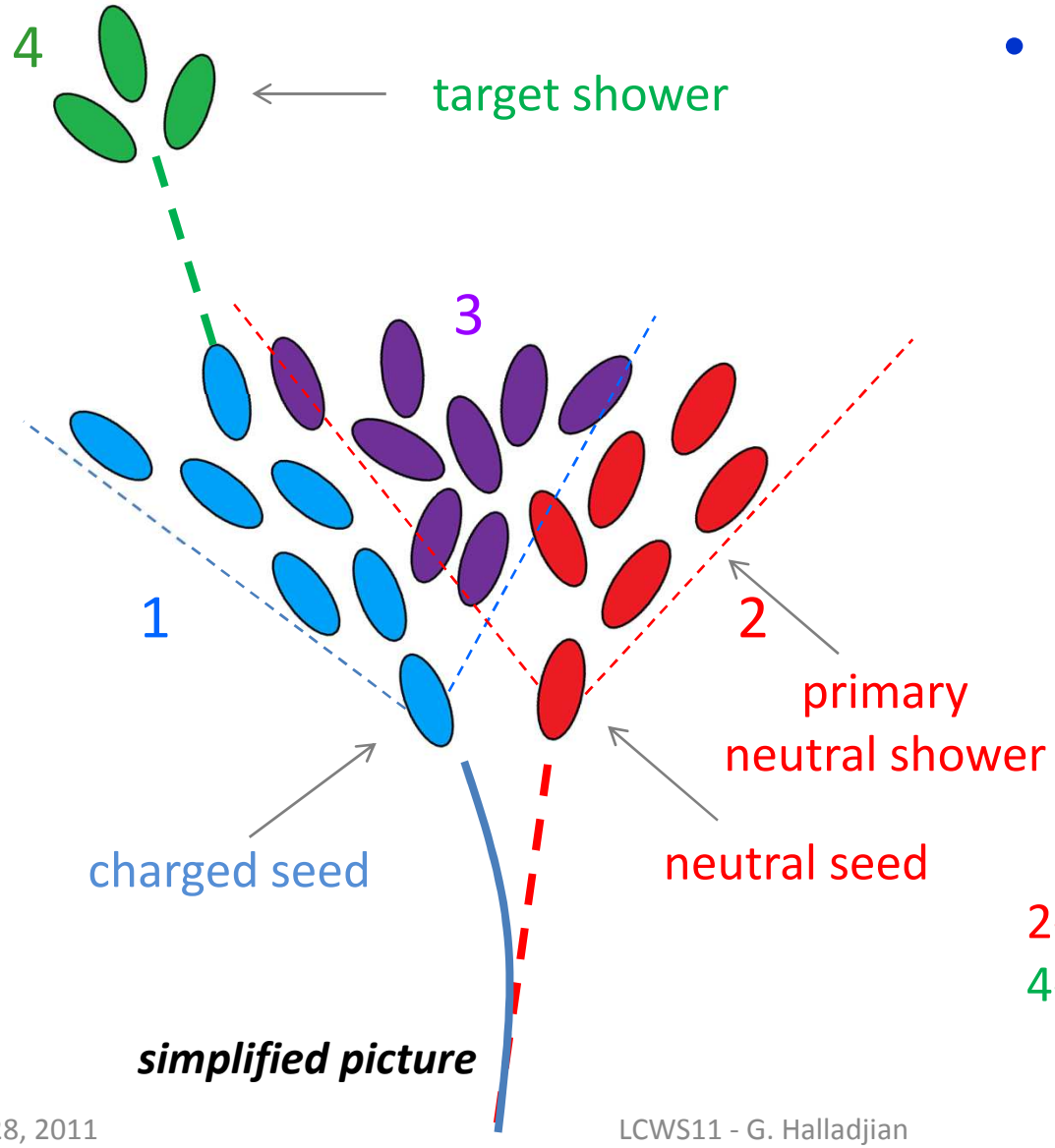
1- charged shower

2- neutral shower

3- Shared sub-clusters between charged and neutral showers

4- neutral shower

New shower building (2nd iteration)



- Second iteration:
  - based on a likelihood, distinguish between primary neutral showers and secondary neutral showers
  - based on an other likelihood, link the secondary neutral showers to charged and primary neutral showers

2- primary neutral shower
4- secondary neutral shower

New shower building

- First iteration
  - skeleton (simultaneous building of tracks)
  - tight criteria
  - high purity
  - reasonable efficiency
- Second iteration
  - criteria can include information based on the first iteration
  - increase the efficiency
  - add the isolated sub-clusters
  - add the ambiguous sub-clusters
- Third iteration
  - regional and overall event energy momentum balance is taken into account to achieve higher purity and efficiency

New shower building

THE UNIVERSITY OF IOWA

- First iteration ☑
  - skeleton (simultaneous building of tracks)
  - tight criteria
  - high purity
  - reasonable efficiency
- Second iteration ☑
  - criteria can include information based on the first iteration
  - increase the efficiency
  - add the isolated sub-clusters
  - add the ambiguous sub-clusters
- Third iteration (ongoing)
  - regional and overall event energy momentum balance is taken into account to achieve higher purity and efficiency

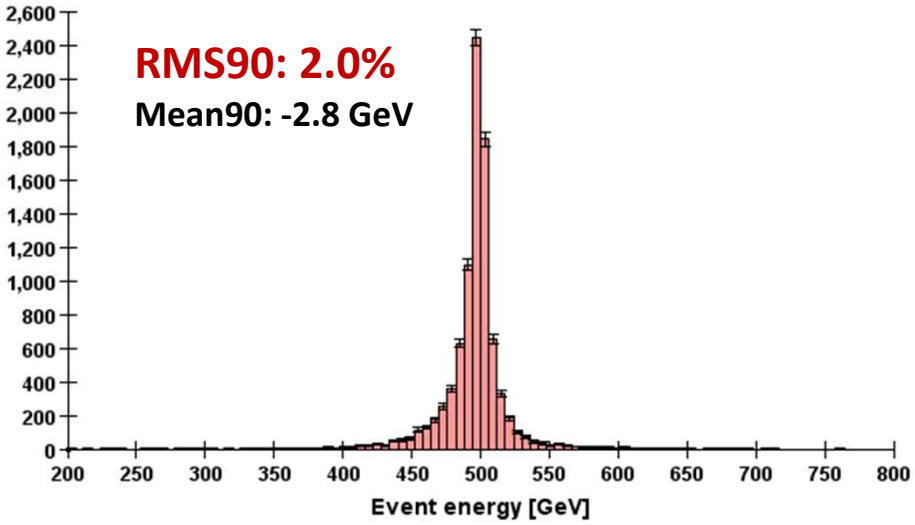
Conclusion

- Improvements in the setup
  - sub-cluster finding
  - photon veto
  - track-seed matching (2 problematic cases are found and fixed)
- Significant improvement in the scoring
- Photon finding needs to be improved
  - 3.1% → 2.6% with perfect photon
  - 3.1% → 3.0% with perfect shower building
- New shower building algorithm is in progress
  - 1st iteration ☑
  - 2nd iteration ☑
  - 3rd iteration (on going)
- **Current event energy resolution = 3.1%**

Back Up

Energy resolution : perfect photon & shower building

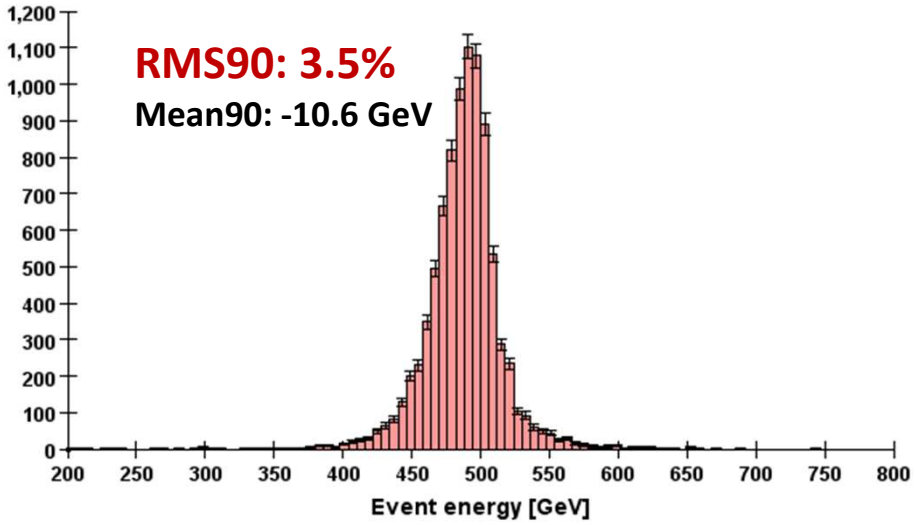
- Perfect:
  - Photon finding
  - Shower building



	Charged	Neutral	Photon	Purity
Reco as Charged	53.44	1.60	0.39	0.96
Reco as Neutral	5.86	11.03	0.13	0.65
Reco as Photons	1.86	0.00	25.67	0.93
Efficiency	0.87	0.87	0.98	

Energy resolution : perfect photon, DTree & shower building

- Perfect:
  - Photon finding
  - DTree clustering
  - Shower building



	Charged	Neutral	Photon	Purity
Reco as Charged	50.42	3.97	3.66	
Reco as Neutral	8.35	7.94	1.73	0.44
Reco as Photons	2.59	0.73	20.61	0.87
Efficiency	0.82	0.63	0.79	