Optimisation of the Frozen Showers

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DESY - ATLAS

Tests of FSs (e and γ):

- in different detectors (EMB and EMEC)
- for different particles (e, pions, photons, muons)
- with different particle energies (5 and 64 GeV)
- with/without killing of e
- with different low energy thresholds

(1k events, only generated level plots, r13.0.20)

Studies of FS library:

- new clustering algorithm
- optimisation of cluster radius
- FS library for higher energies

Frozen Showers in barrel (eta=0.25)

fs1: FS(e) + full sim

fs3: FS(e+γ) + full sim

64 Gev	*time*	*Deposited Energy*	*number of hits*
full	12.023 +- 0.012	10524.7	583
fs1	0.674 +- 0.009	10422.1	327
fs1, kill(false)	0.692 +- 0.009	10396.3	267
fs3	0.507 +- 0.009	10575.2	270
fs3, kill(false)	0.503 +- 0.008	10585.8	222

5 Gev	*time*	*Deposited Energy*	*number of hits*
full	1.180 +- 0.005	749.6	158
fs1	0.302 +- 0.005	726.7	120
fs1, kill(false)	0.307 +- 0.006	724.3	88
fs3	0.266 +- 0.004	748.0	115
fs3, kill(false)	0.270 +- 0.004	752.1	91

fs* kill(false) means FS down to 1 MeV

$\rightarrow$ photon FS library brings ~25% improvement in time for high energy and ~12% for low energy electrons

$\rightarrow$ with kill option timing is generally better (by few percent)

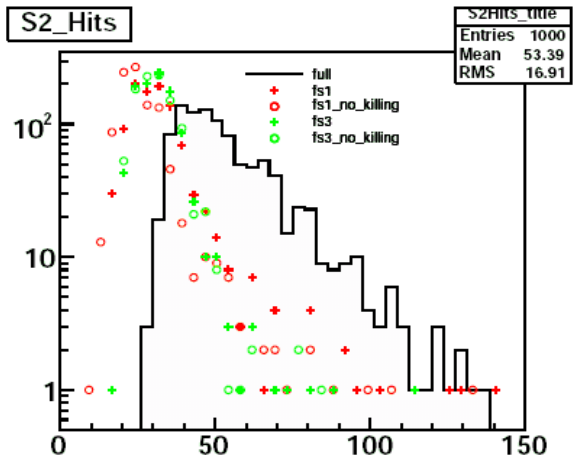
$\rightarrow$ photon library reduces the total energy shift

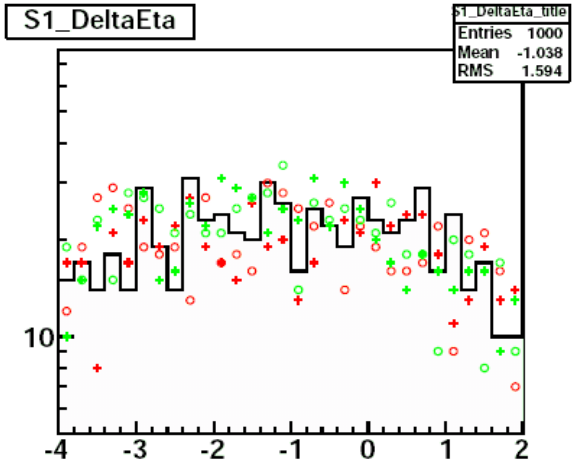
Low energy (5 GeV) electrons in barrel (eta=0.25)

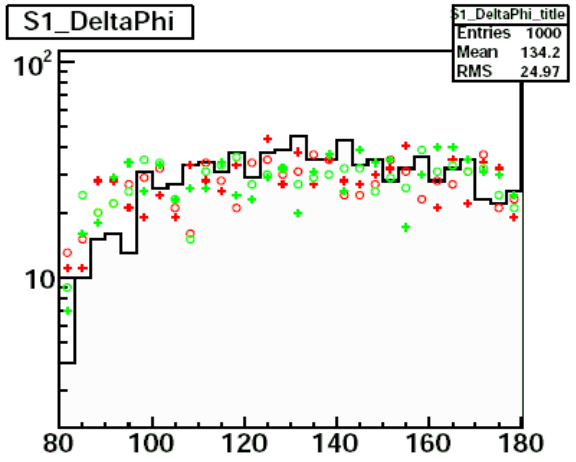
— full simulation

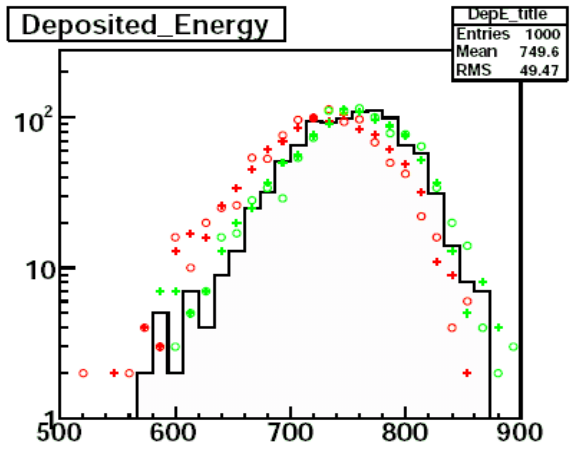
∗ FS(e) ∗ FS(e+γ)

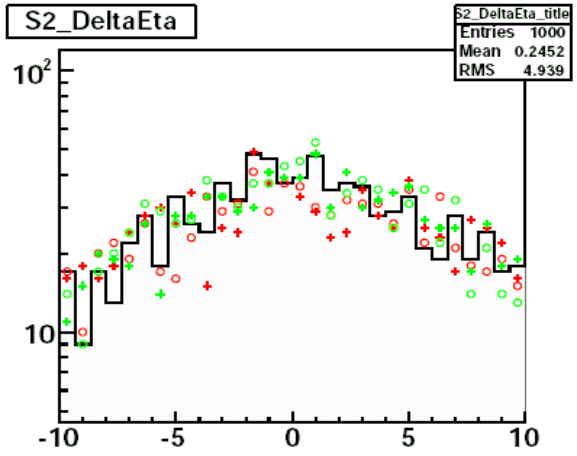
o FS(e), no kill o FS(e+γ), no kill

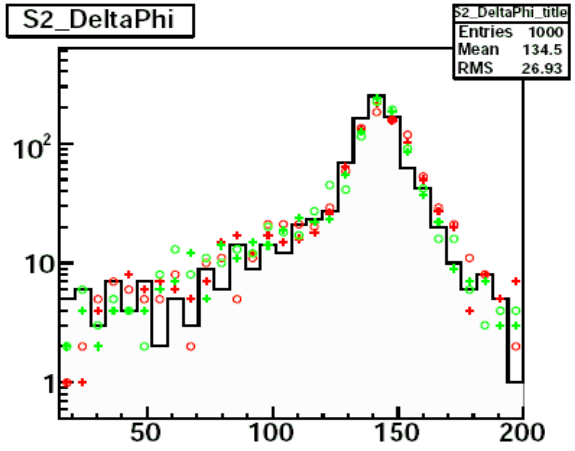










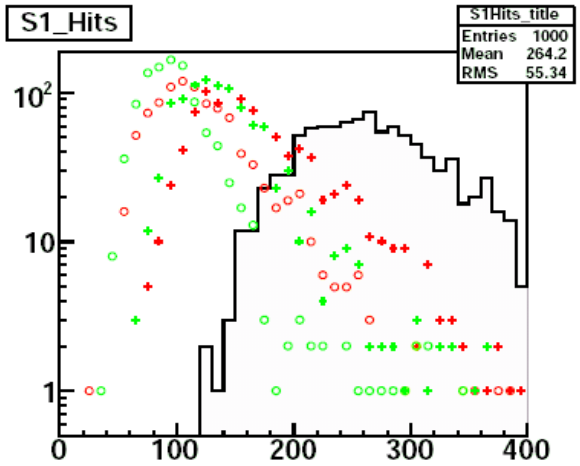


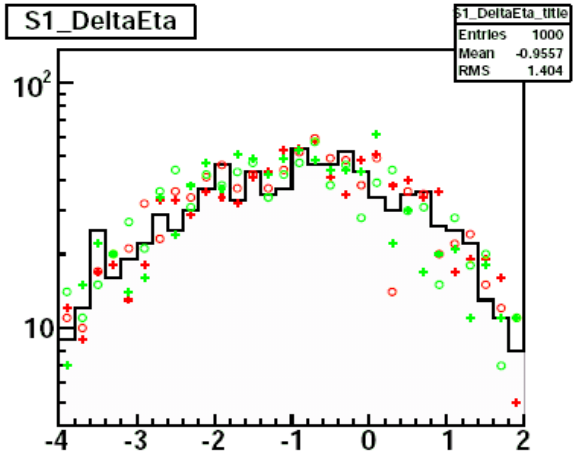
High energy (64 GeV) electrons in barrel (eta=0.25)

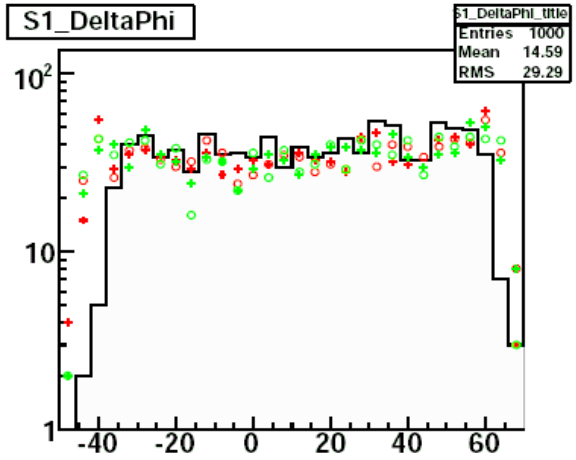
— full simulation

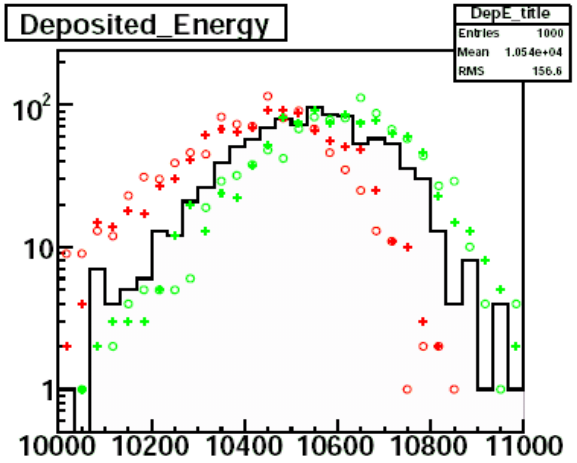
∗ FS(e) ∗ FS(e+γ)

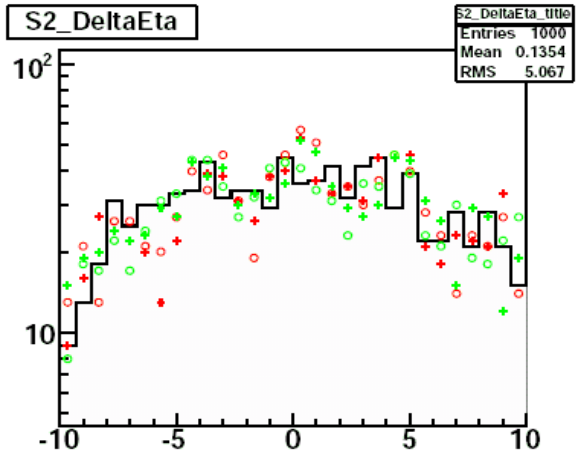
o FS(e), no kill o FS(e+γ), no kill

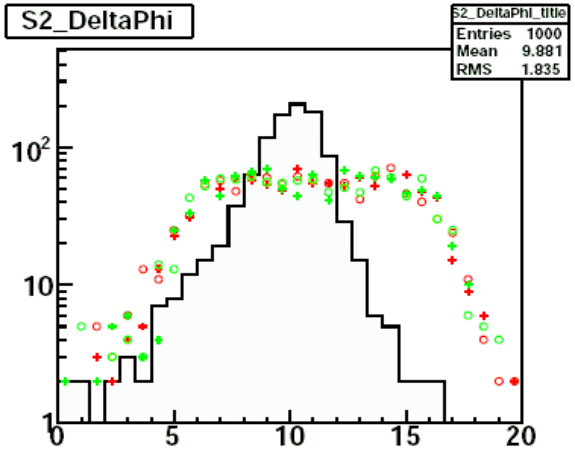












Frozen Showers in EMEC (eta=2)

no killing,

e, γ FS libs down to 1 MeV

g - gain in time using FS(e+γ)

s(F,) - shift of deposited E with respect to full simulation*

Particle Energy: 64 GeV. Detector: EMEC ($\eta = 2.0$)				
	e^-	μ^-	γ	π^o
option	timing (s)	timing (s)	timing (s)	timing (s)
F	32.48 ± 0.02	0.46 ± 0.01	32.63 ± 0.03	32.53 ± 0.02
1	1.38 ± 0.01	0.37 ± 0.01	0.98 ± 0.02	1.25 ± 0.02
3	1.06 ± 0.01	0.37 ± 0.01	0.74 ± 0.02	1.11 ± 0.02
g(3)	23.2%	0.0%	24.5%	11.2%
option	dep.en.(MeV)	dep.en.(MeV)	dep.en.(MeV)	dep.en.(MeV)
F	5904 ± 5	174 ± 3	6009 ± 6	5945 ± 5
1	5885 ± 5	179 ± 5	6008 ± 5	5928 ± 6
3	5886 ± 5	180 ± 4	6000 ± 6	5939 ± 5
s(F,1)	0.3%	−2.9%	0.0%	0.3%
s(F,3)	0.3%	−3.4%	0.1%	0.1%

Particle Energy: 5 GeV. Detector: EMEC ($\eta = 2.0$)				
	e^-	μ^-	γ	π^o
option	timing (s)	timing (s)	timing (s)	timing (s)
F	2.50 ± 0.00	0.29 ± 0.00	2.52 ± 0.00	2.44 ± 0.00
1	0.44 ± 0.01	0.25 ± 0.00	0.25 ± 0.01	0.36 ± 0.01
3	0.38 ± 0.00	0.26 ± 0.00	0.21 ± 0.01	0.31 ± 0.01
g(3)	13.6%	−4.0%	16.0%	13.8%
option	dep.en.(MeV)	dep.en.(MeV)	dep.en.(MeV)	dep.en.(MeV)
F	388 ± 1	131 ± 0	423 ± 2	397 ± 2
1	385 ± 1	129 ± 0	424 ± 2	400 ± 1
3	386 ± 1	130 ± 0	421 ± 2	398 ± 2
s(F,1)	0.7%	1.5%	−0.2%	−0.7%
s(F,3)	0.5%	0.8%	0.5%	−0.2%

Frozen Showers in EMEC (eta=2)

with killing

g - gain in time using FS(e+γ)
- almost factor of 2 gain!

s(F,) - shift of deposited E with respect to total E*

Particle Energy: 64 GeV. Detector: EMEC ($\eta = 2.0$)				
	e^-	μ^-	γ	π^o
option	timing (s)	timing (s)	timing (s)	timing (s)
F	32.48 ± 0.02	0.46 ± 0.01	32.63 ± 0.03	32.53 ± 0.02
1	1.33 ± 0.01	0.37 ± 0.01	0.94 ± 0.02	1.20 ± 0.02
3	0.80 ± 0.01	0.36 ± 0.01	0.51 ± 0.02	0.68 ± 0.02
g(3)	40.7%	0.0%	46.3%	43.3%
option	dep.en.(MeV)	dep.en.(MeV)	dep.en.(MeV)	dep.en.(MeV)
F	5904 ± 5	174 ± 3	6009 ± 6	5945 ± 5
1	5857 ± 5	177 ± 4	5983 ± 5	5904 ± 6
3	5917 ± 5	180 ± 4	6027 ± 6	5956 ± 6
s(F,1)	0.8%	−1.7%	0.4%	0.7%
s(F,3)	−0.2%	−3.4%	−0.3%	−0.2%

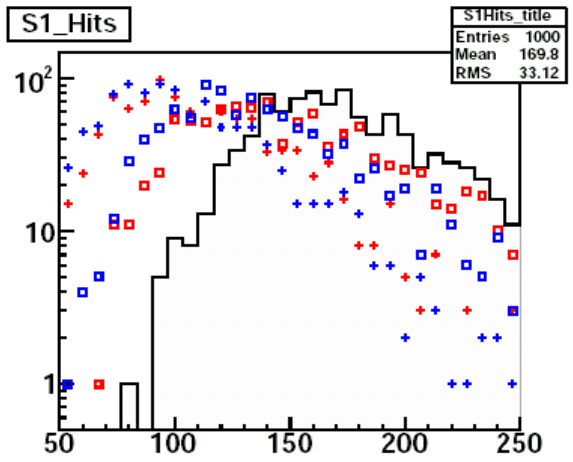
Particle Energy: 5 GeV. Detector: EMEC ($\eta = 2.0$)				
	e^-	μ^-	γ	π^o
option	timing (s)	timing (s)	timing (s)	timing (s)
F	2.50 ± 0.00	0.29 ± 0.00	2.52 ± 0.00	2.44 ± 0.00
1	0.43 ± 0.01	0.25 ± 0.00	0.24 ± 0.01	0.33 ± 0.01
3	0.35 ± 0.00	0.25 ± 0.00	0.18 ± 0.01	0.28 ± 0.01
g(3)	25.5%	0.0%	28.0%	15.1%
option	dep.en.(MeV)	dep.en.(MeV)	dep.en.(MeV)	dep.en.(MeV)
F	388 ± 1	131 ± 0	423 ± 2	397 ± 2
1	379 ± 1	127 ± 1	419 ± 2	396 ± 2
3	387 ± 1	127 ± 0	426 ± 2	401 ± 2
s(F,1)	2.3%	3.0%	0.9%	0.2%
s(F,3)	0.3%	3.0%	−0.7%	−1.0%

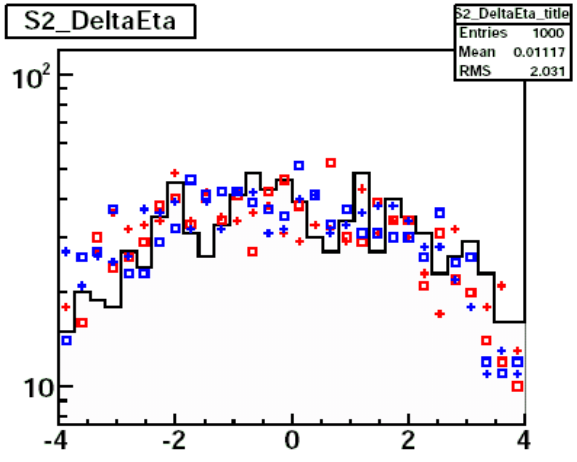
High energy (64 GeV) electrons in EMEC (eta=2)

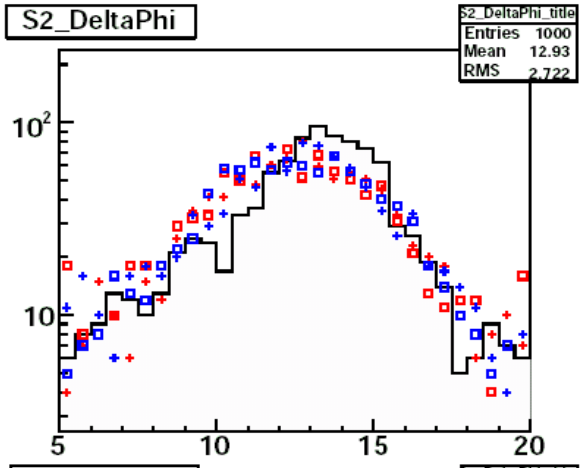
— full simulation

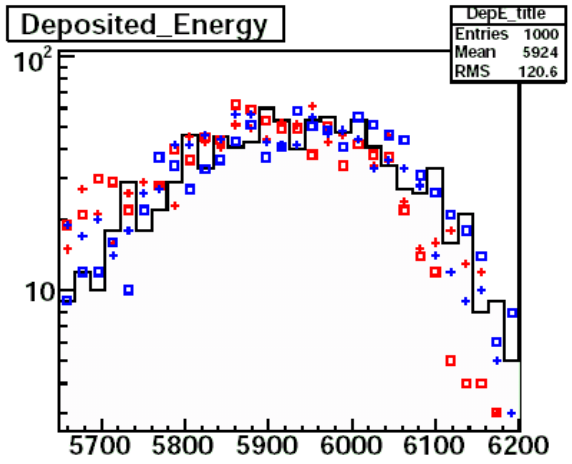
□ FS(e) □ FS(e+γ)

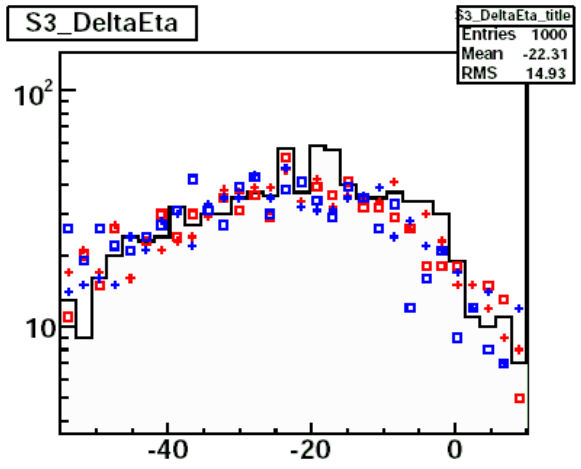
\+ FS(e), no kill + FS(e+γ), no kill

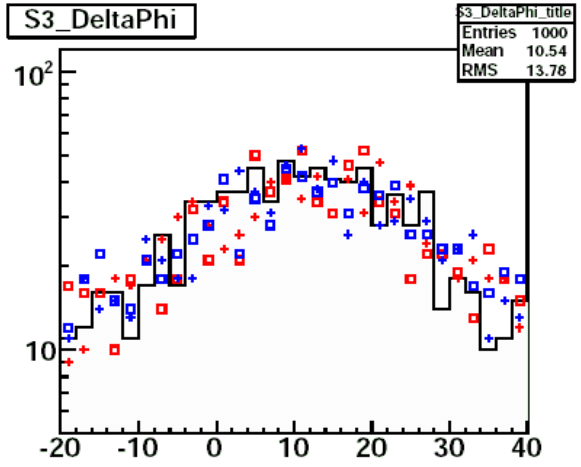










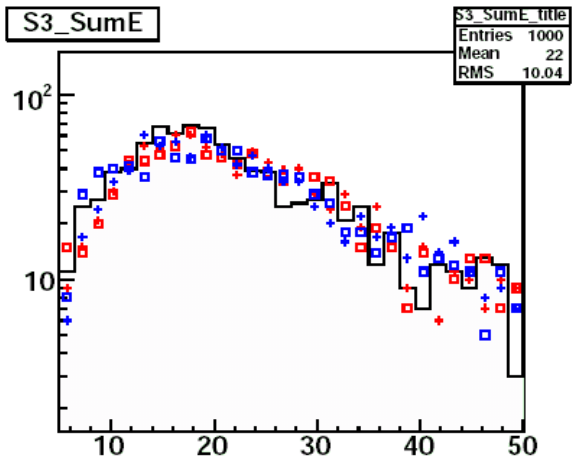


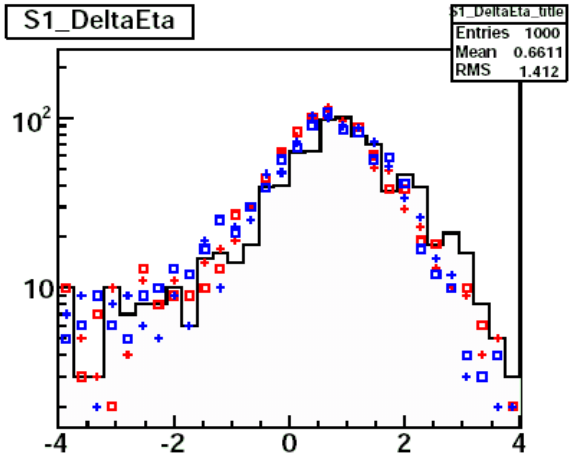
High energy (64 GeV) photons in EMEC (eta=2)

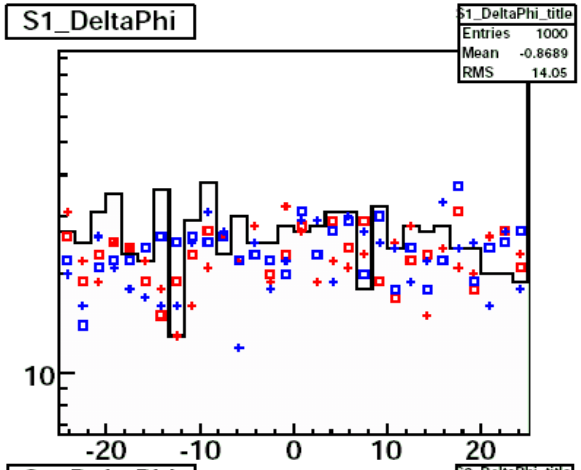
— full simulation

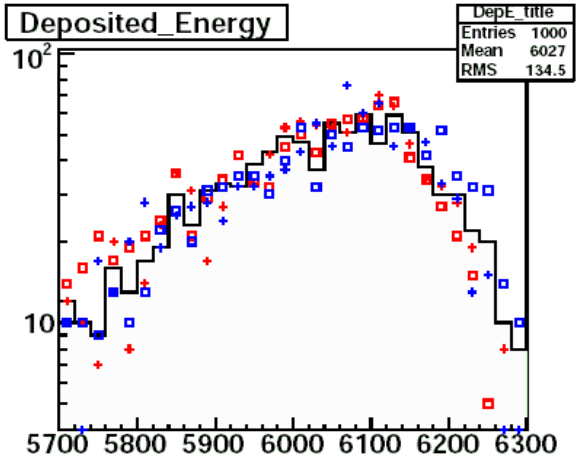
□ FS(e) □ FS(e+γ)

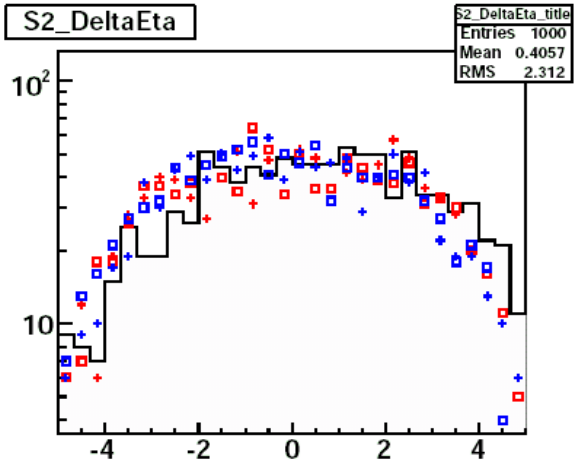
\+ FS(e), no kill + FS(e+γ), no kill

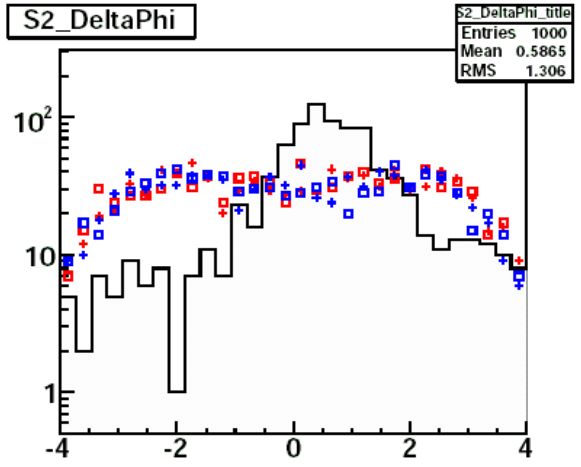










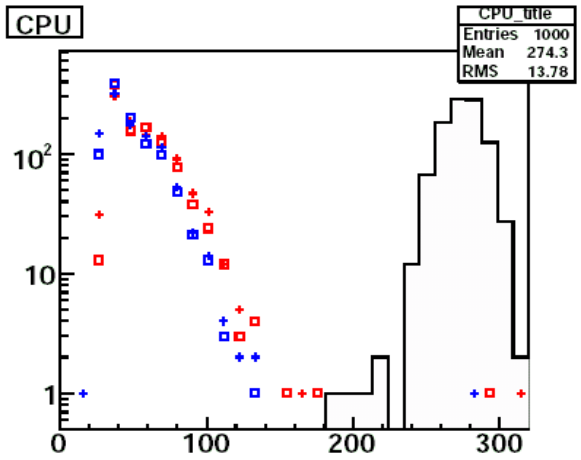


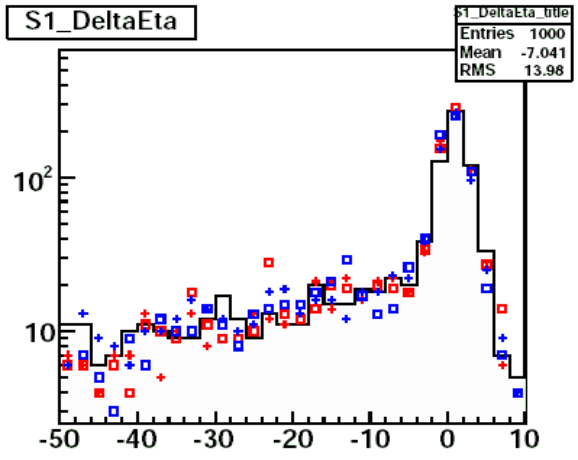
Low energy (5 GeV) photons in EMEC (eta=2)

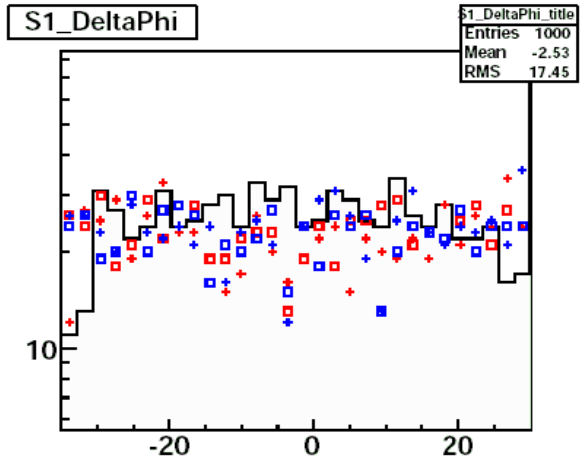
— full simulation

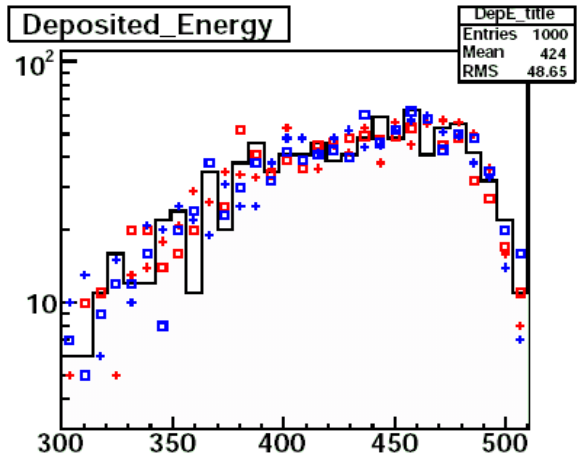
□ FS(e) □ FS(e+γ)

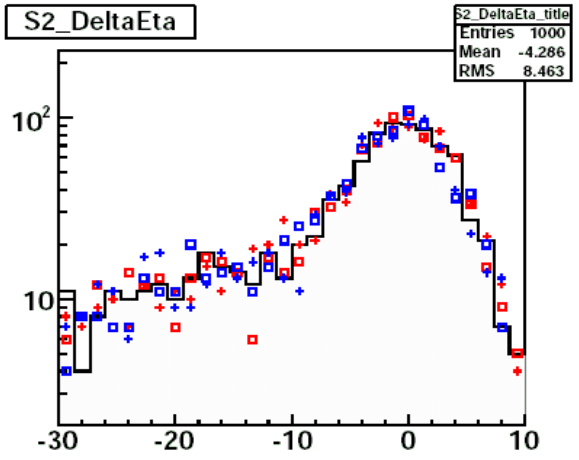
\+ FS(e), no kill + FS(e+γ), no kill

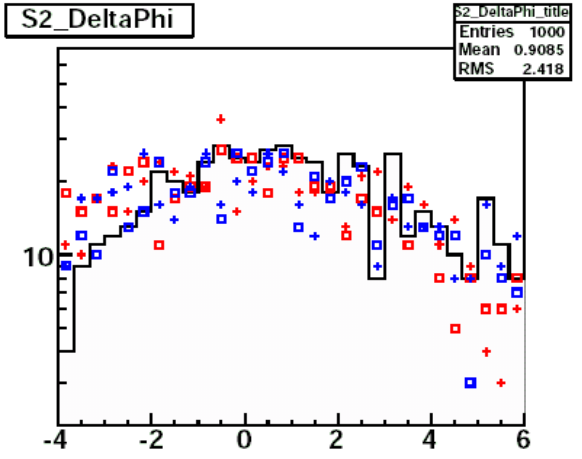










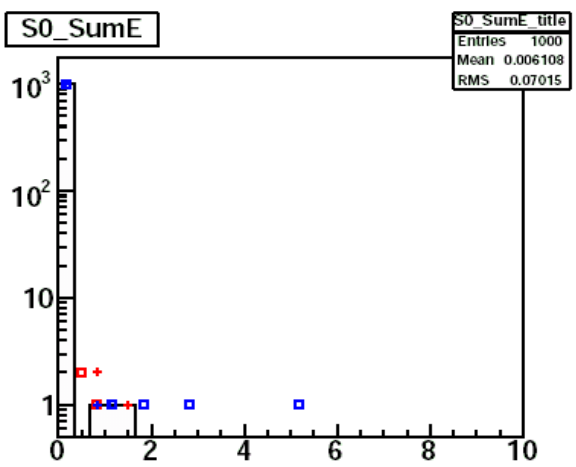


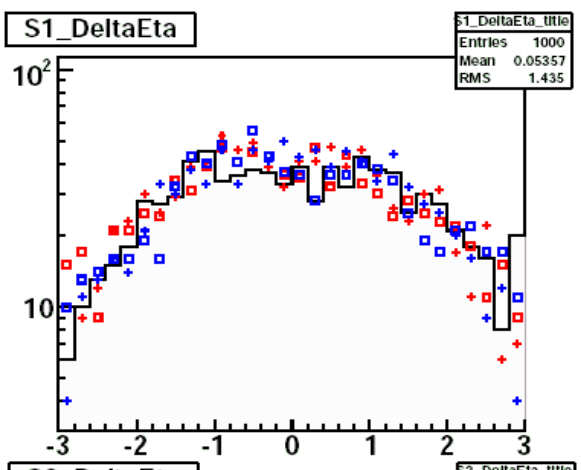
High energy (64 GeV) muons in EMEC (eta=2)

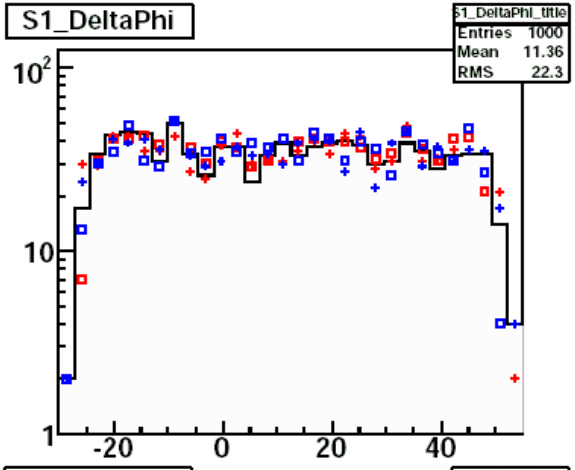
— full simulation

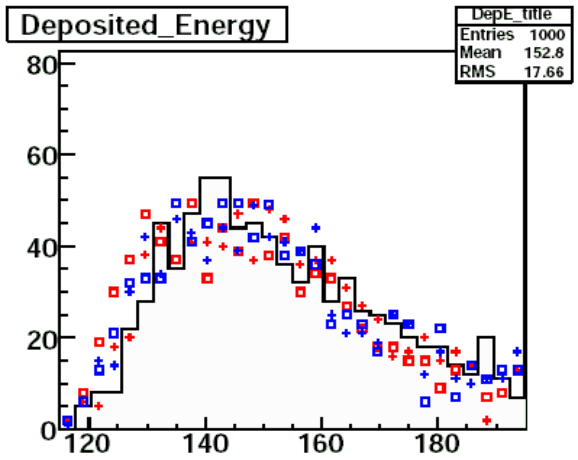
□ FS(e) □ FS(e+γ)

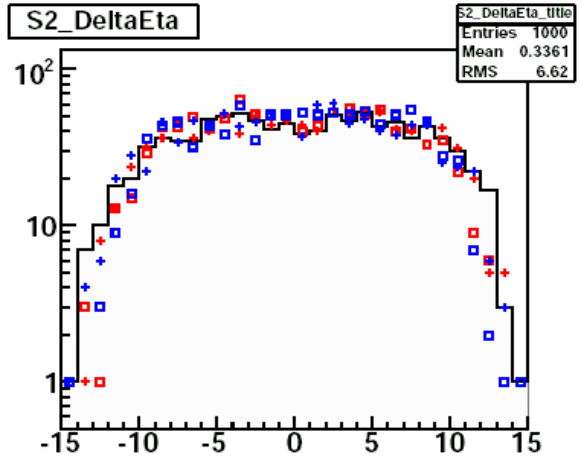
\+ FS(e), no kill + FS(e+γ), no kill

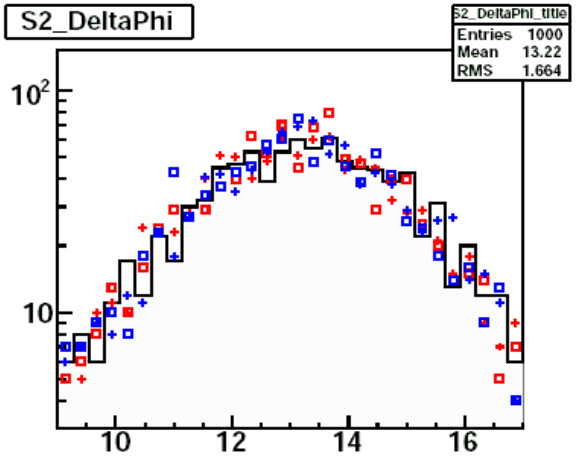










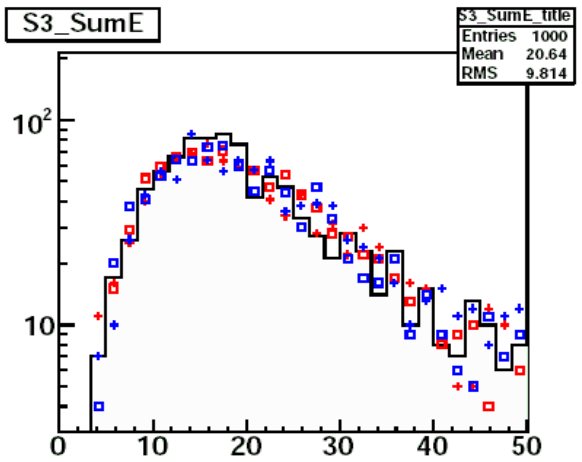


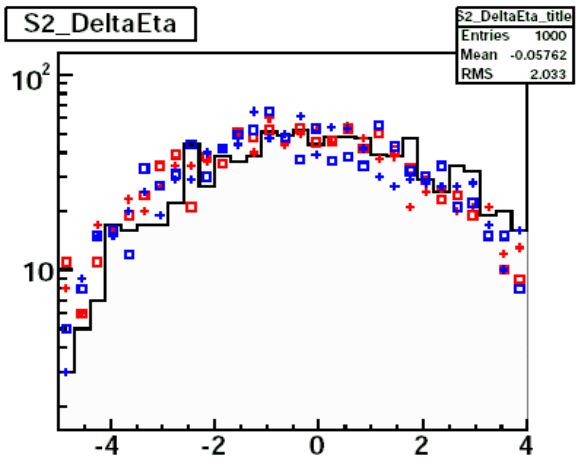
High energy (64 GeV) pions (π^0) in EMEC (eta=2)

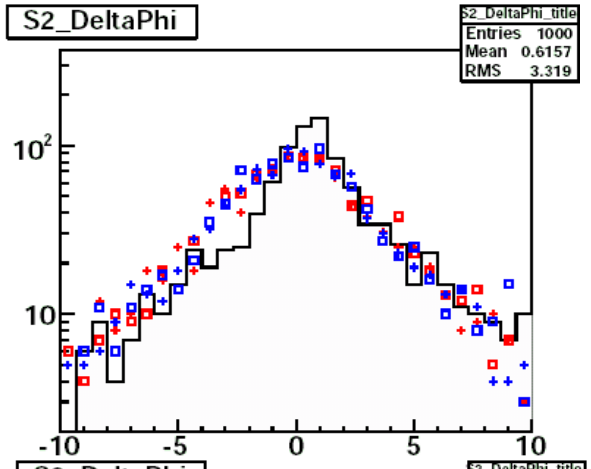
— full simulation

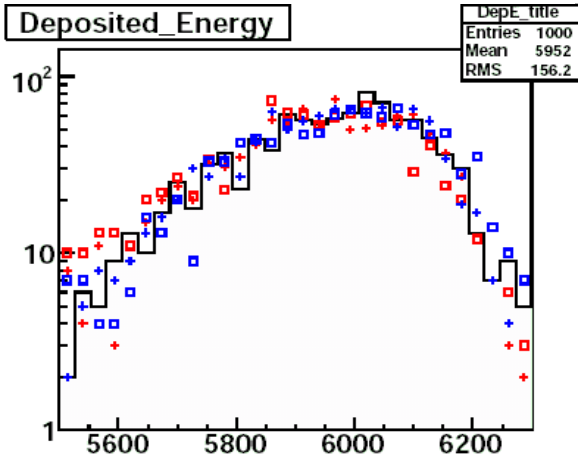
□ FS(e) □ FS(e+γ)

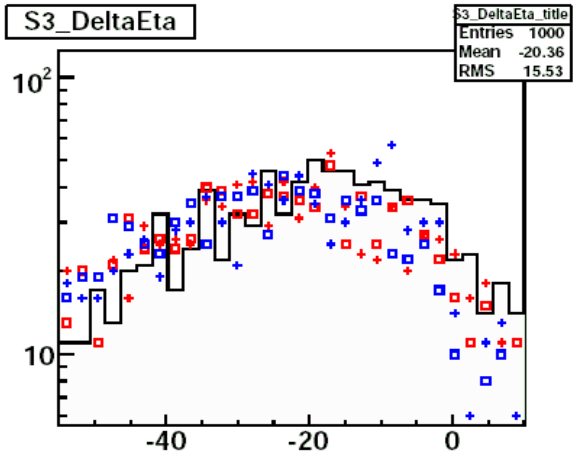
\+ FS(e), no kill + FS(e+γ), no kill

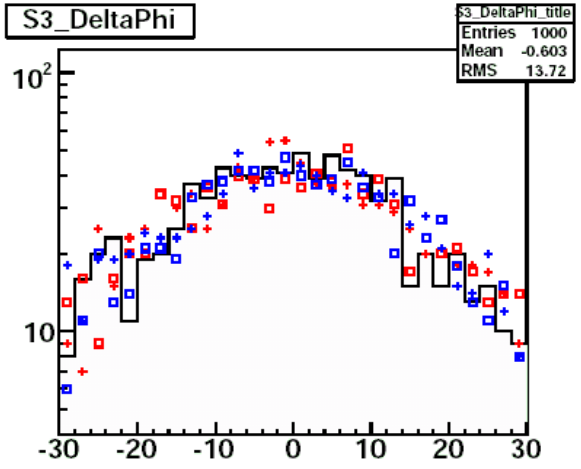








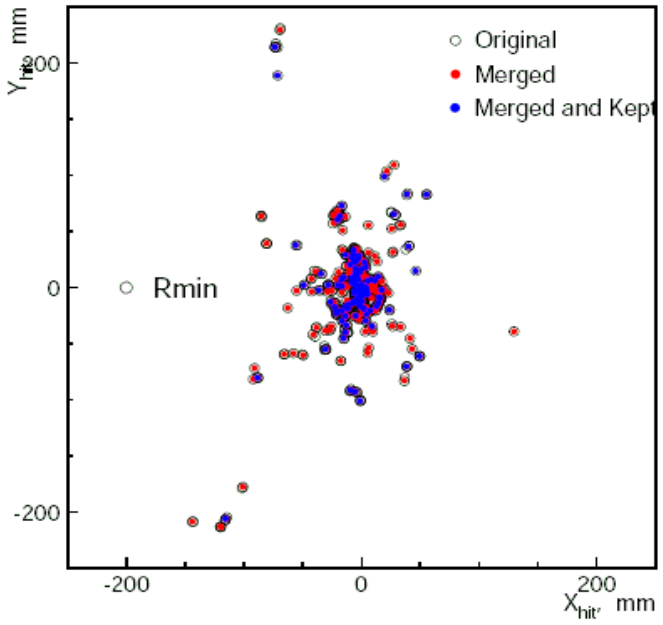




Generating FS library: hit clustering

FS library is created from GEANT4 hits after clustering:

- find a pair of energy deposits with smallest spacial separation R
- if $R < R_{min}$ (5 mm), replace the pair by one point at the center of energy
- repeat first step



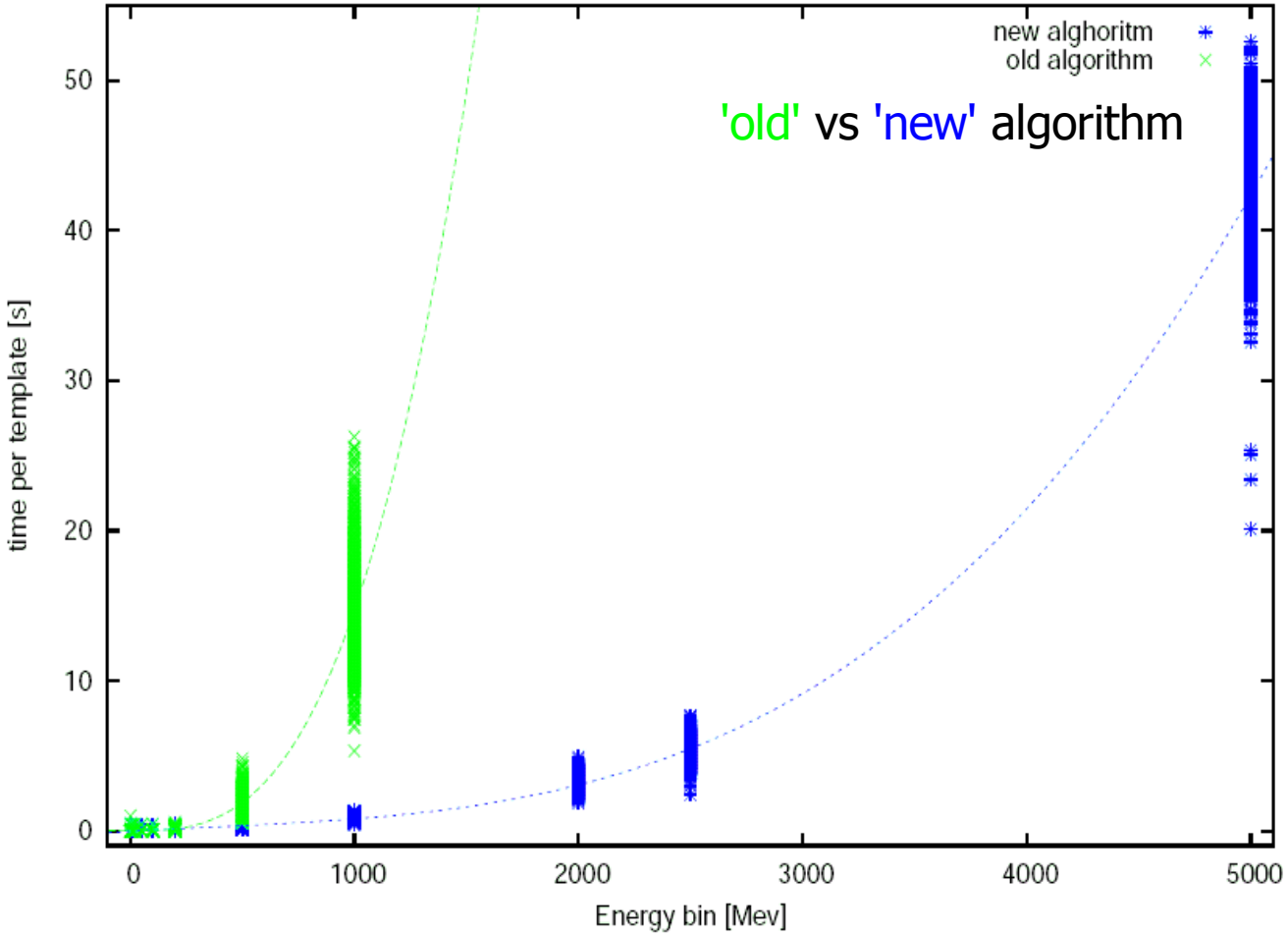
New clustering algorithm (M.Agostini):

- use sorted lists of calculated distances
- recalculate distances only for merged hits

- improvement in speed ~ $N^3 \rightarrow N^2$

Tests of new hit clustering algorithm

Time needed to generate and record an event for the FS library versus energy

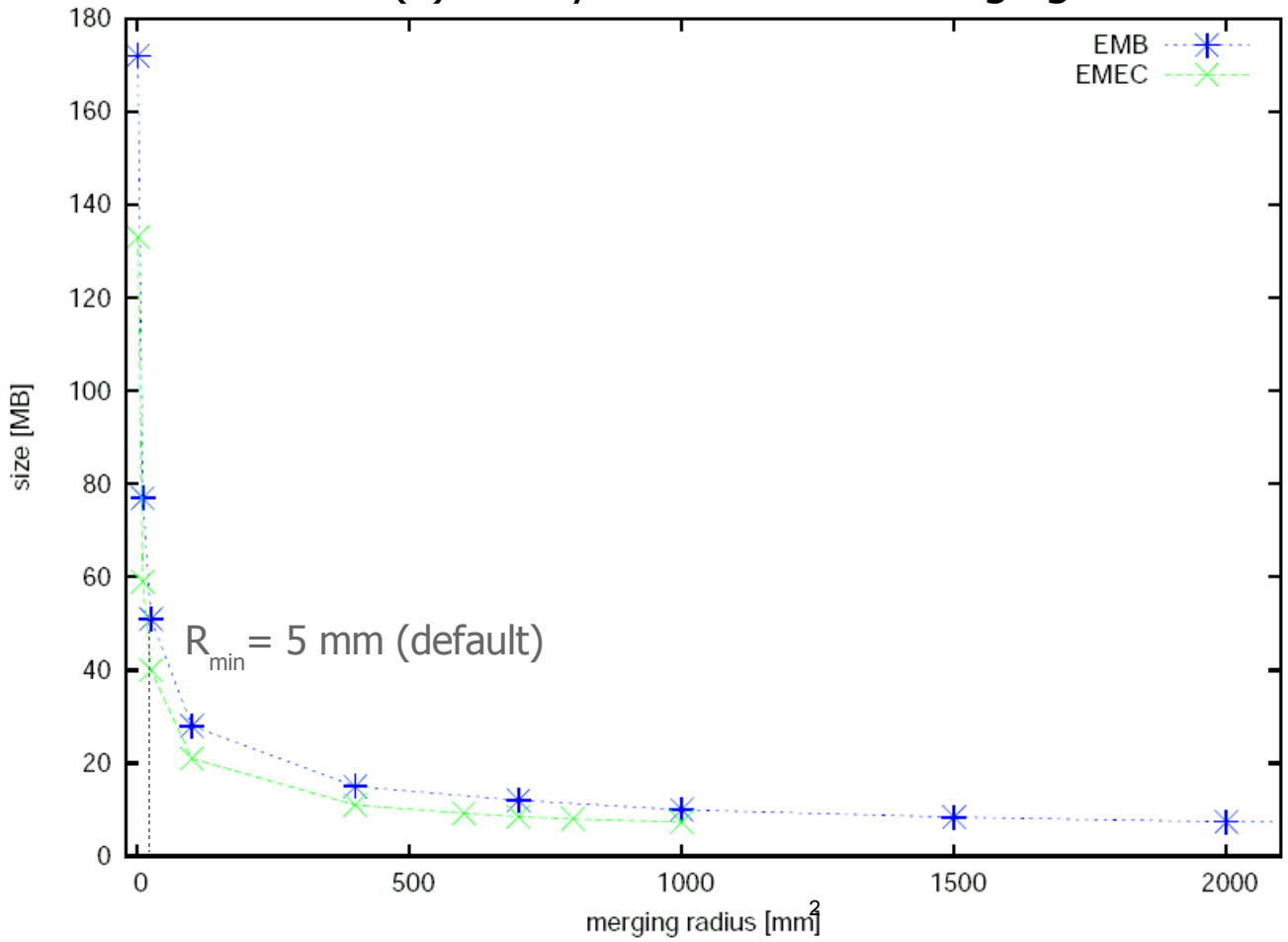


→ to generate 1 GeV energy bin with new algorithm is factor ~20 faster

→ FS libraries created with two different algorithms are same

Optimisation of the cluster radius R_{min}

Size of the FS(e) library versus cluster merging radius R



Similar behavior in EMB and in EMEC

Comparison of different cluster radius R_{min} in EMEC

— full simulation

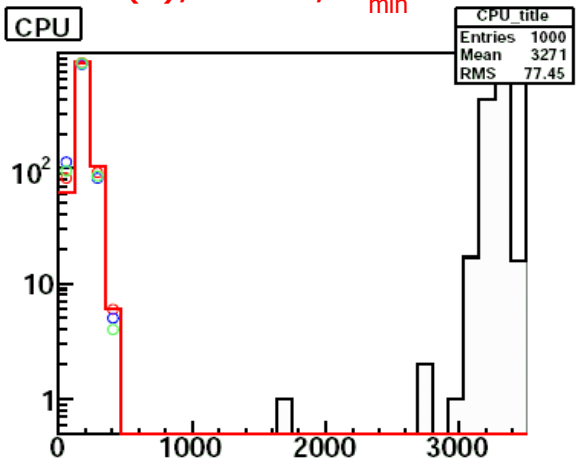
— FS(e), no kill, R_{min} = 5 mm

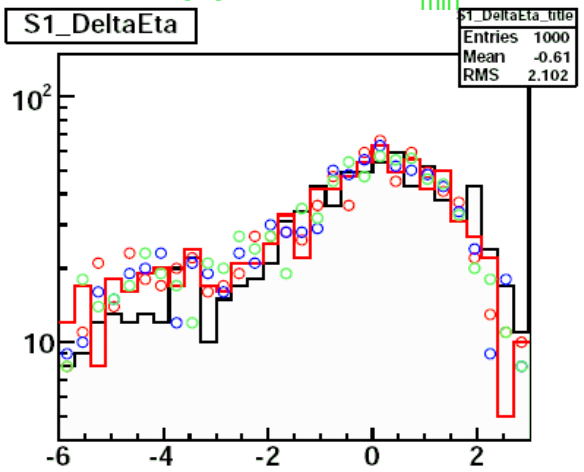
o FS(e), no kill, R_{min} = 20 mm

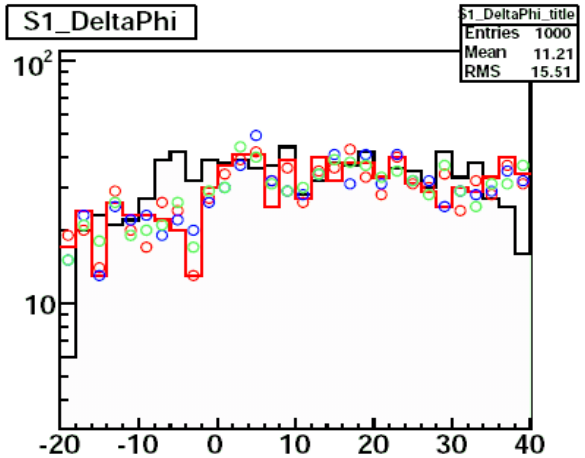
o FS(e), no kill, R_{min} = 24.5 mm

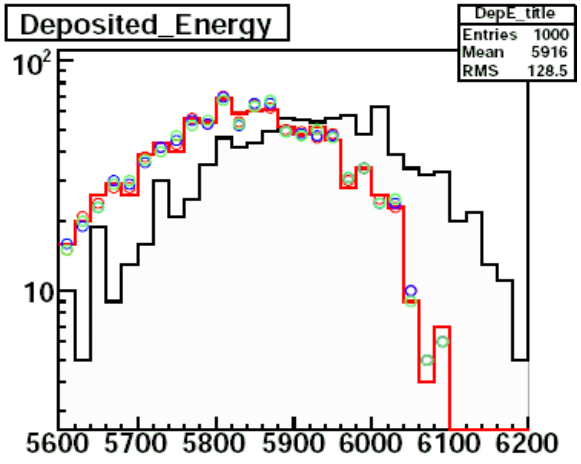
o FS(e), no kill, R_{min} = 28.3 mm

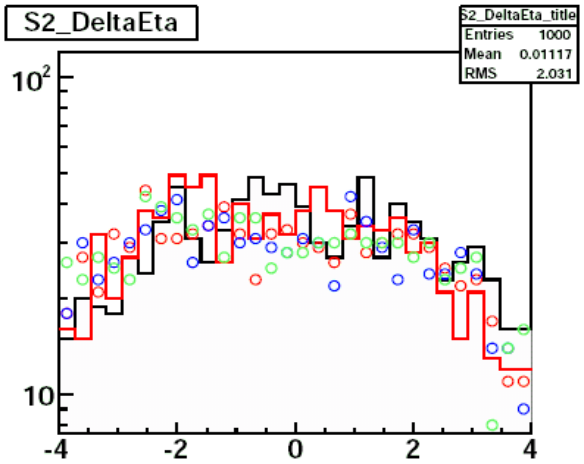
eta = 2, E=64 GeV

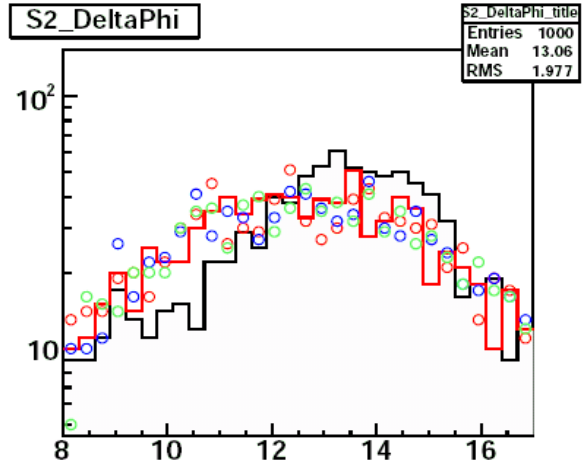












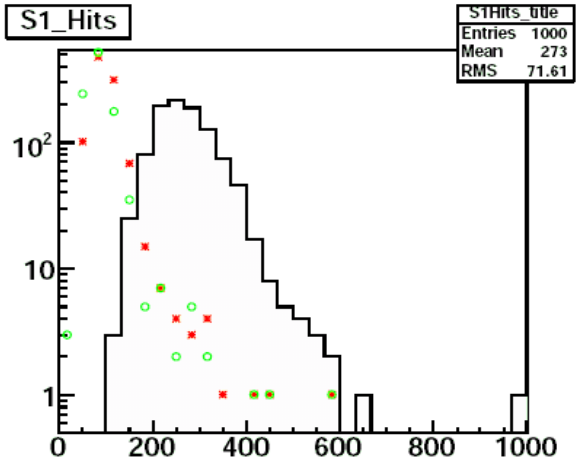
Comparison of distributions for different cluster radius R_{min}

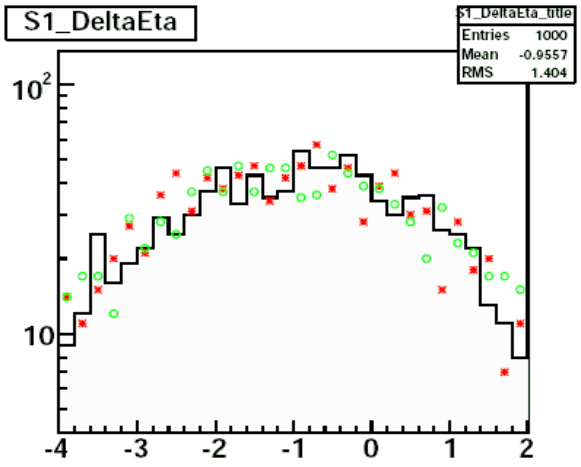
— full simulation

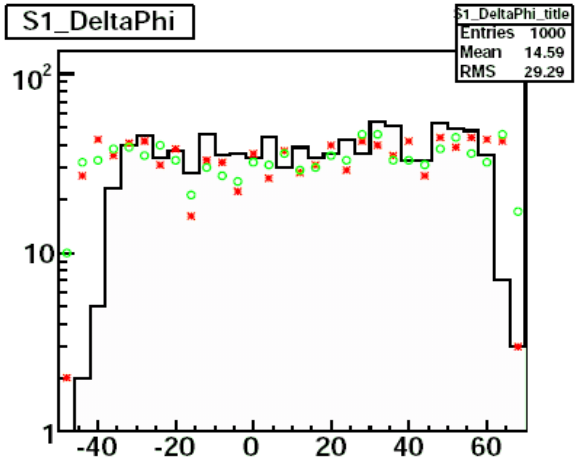
* FS(e+γ), no kill, R_{min} = 5 mm

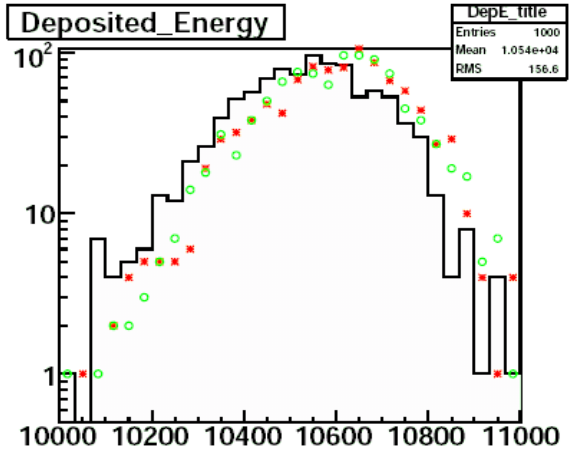
o FS(e+γ), no kill, R_{min} = 24.5 mm (libraries created with new clustering algorithm)

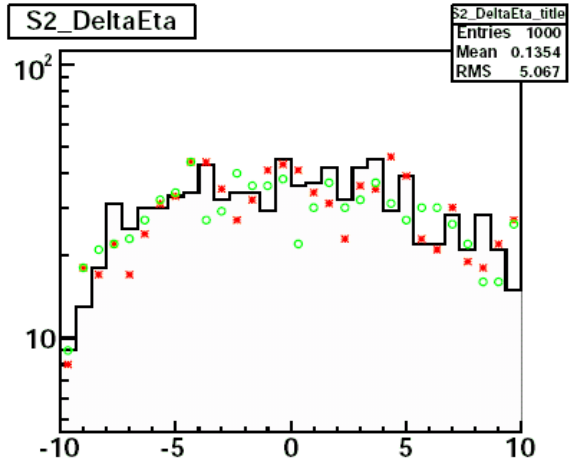
eta = 0.25, E=64 GeV

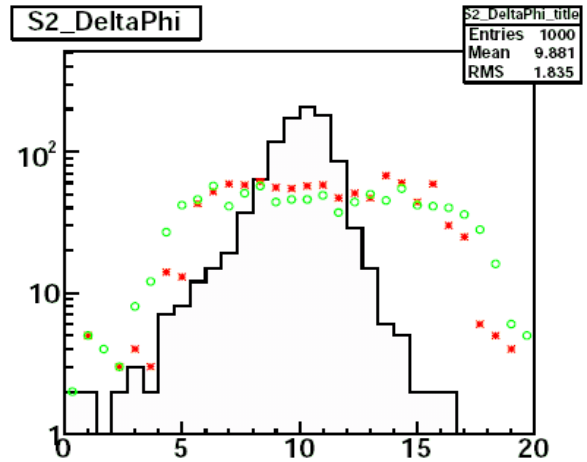












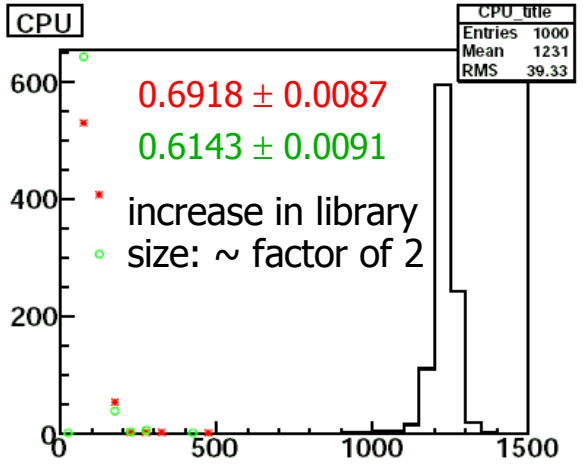
FS libraries extended to higher energies

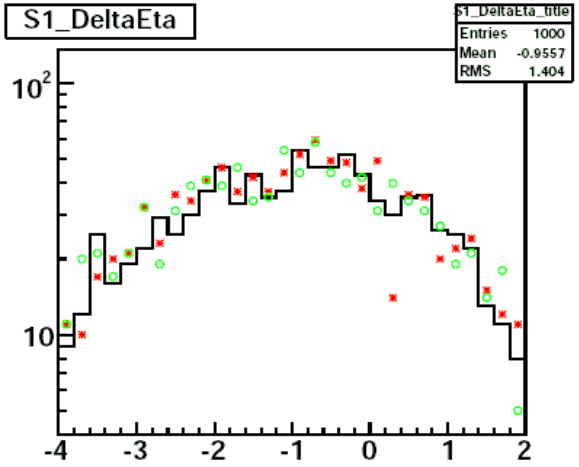
— full simulation

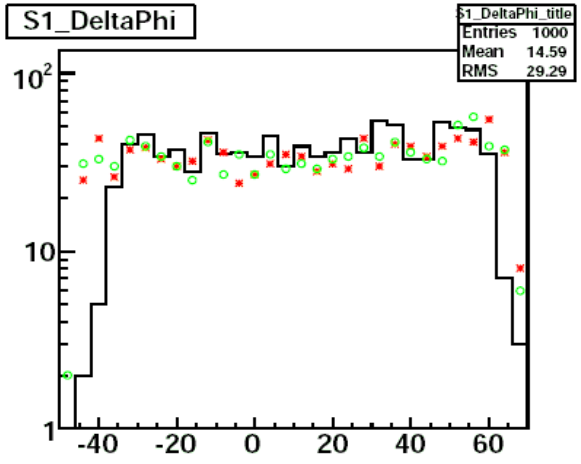
* 1 MeV < FS(e) < 1 GeV < full sim, no kill

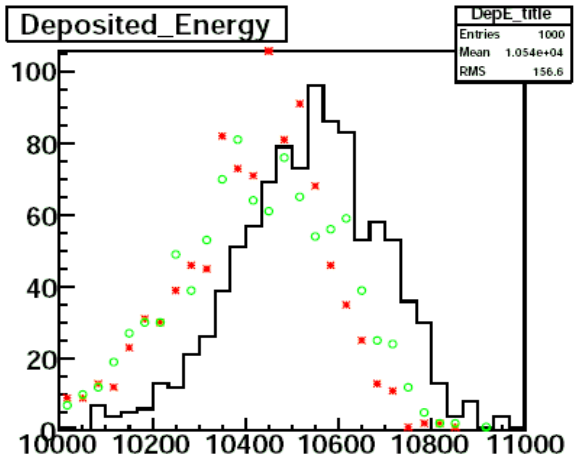
o 1 MeV < FS(e) < 2 GeV < full sim, no kill (additional bin at 2 GeV)

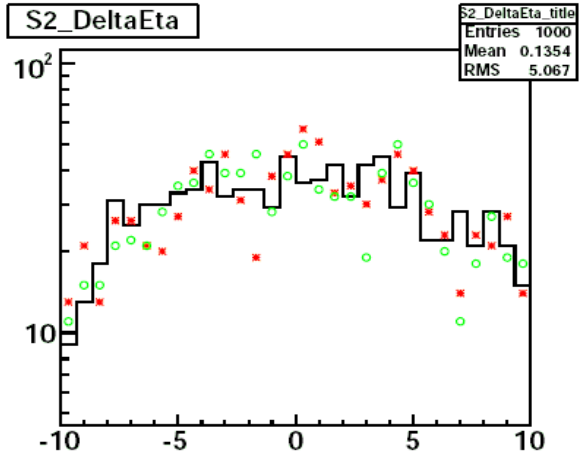
eta = 0.25, R_{min} = 5 mm (default)

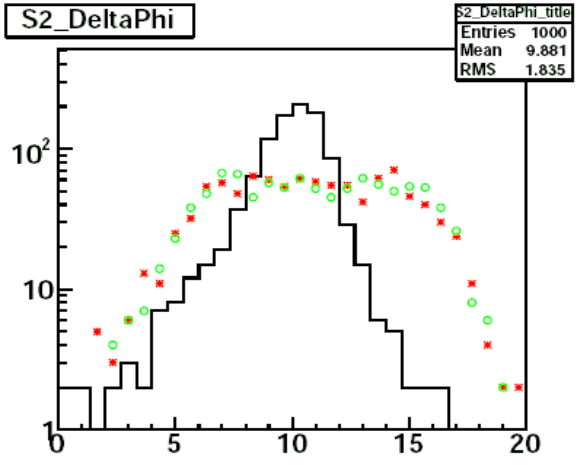












Summary

Tests of FSs:

- a number of different tests have been performed for FS libraries
- photon library improves energy distributions and timing (depending on particle type and conditions)
- killing of low energy particles also brings few % improvement in speed (still under investigation)

Studies of FS library:

- new clustering algorithm increase the FS flexibility (library time, size, R_{min}, energy threshold studies, ...)
- on-going studies for FS libraries with various cluster radius R_{min} (EMB and EMEC)
- FS libraries may be used for higher energies