FE SIMULATION AND JETS/MET-RELATED ISSUES

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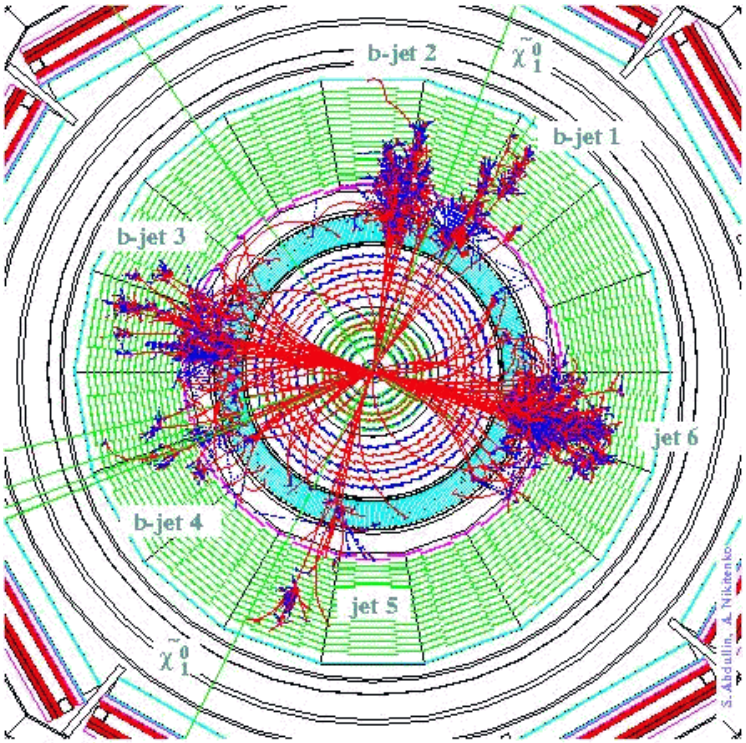
- Progress on inclusive SUSY trigger at low lumi
- First look at the jet / di-jet resolution vs ECAL thresholds
- Update on HCAL FE simulation (new / old signal shape)

INCLUSIVE SUSY TRIGGER @ $2 * 10^{33}$ $cm^{-2} s^{-1}$



- **Generic SUSY :**

  multijet + (leptons) + E_T^{miss} events

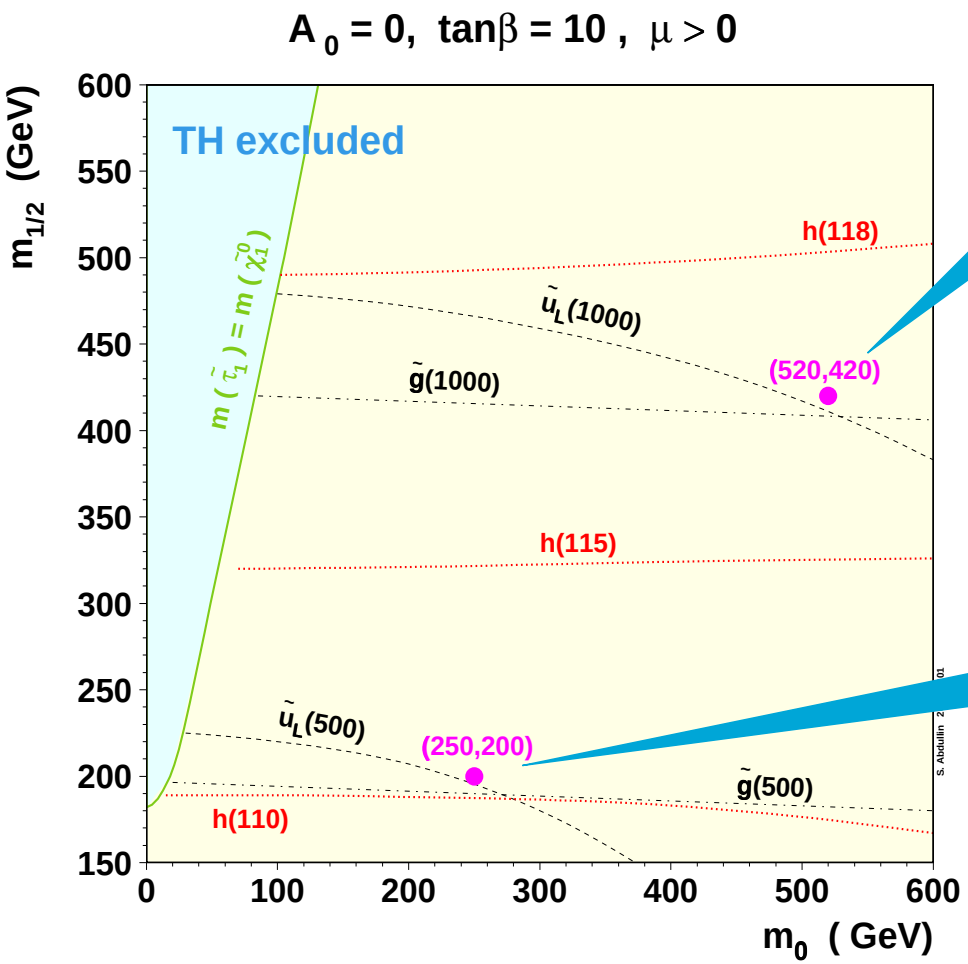
- **Two mSUGRA points**

  are available for low-lumi study

  - M_{SUSY} ~ 500 GeV (beyond Tevatron II reach)
    ~ 1000 GeV
  - $m(\tilde{g}) \cong m(\tilde{q})$
  - $\tan\beta = 10$ ("preferred")
  - $\mu > 0$ - the sign doesn't play a big role,

    though positive one is favoured by g-2 "indirect" constraint - anomaluos magnetic momentum of muon

PROBING POINTS



$m(\tilde{\chi}_1^0) = 177.5$ GeV $m(h) = 116.8$ GeV

$m(\tilde{t}_1) = 726$ GeV

$\sigma = 2.24$ pb, requires $\int Ldt < 100\ pb^{-1}$

typical cuts :

$\not{E}_T > 300$ GeV, $N_j \geq 4$

2 $E_T^j > 200, 100, 50$ GeV

$m(\tilde{\chi}_1^0) = 79.0$ GeV $m(h) = 110.7$ GeV

$m(\tilde{t}_1) = 352$ GeV

$\sigma = 115$ pb, requires $\int Ldt < 10\ pb^{-1}$

typical cuts :

$\not{E}_T > 200$ GeV, $N_j \geq 3$

1 $E_T^j > 100, 50, 50$ GeV

- Cuts efficiency for the signal : 20 - 50 % (0.5 - 1 TeV)

MORE PROBING POINTS ?

- Inclusive SUSY signatures (except some degenerate cases) have a kind of "compensating" effect due to multi-particle cascade decays
  - less jets -> harder jets
  - missing E_T slightly depends on internal mass hierarchy (lighter $\tilde{\chi}_1^0$ -> more boosted etc.)

- After cuts optimization the observability of inclusive SUSY signal depends mainly on the mass scale of strongly interacting sparticles (squarks and gluino)

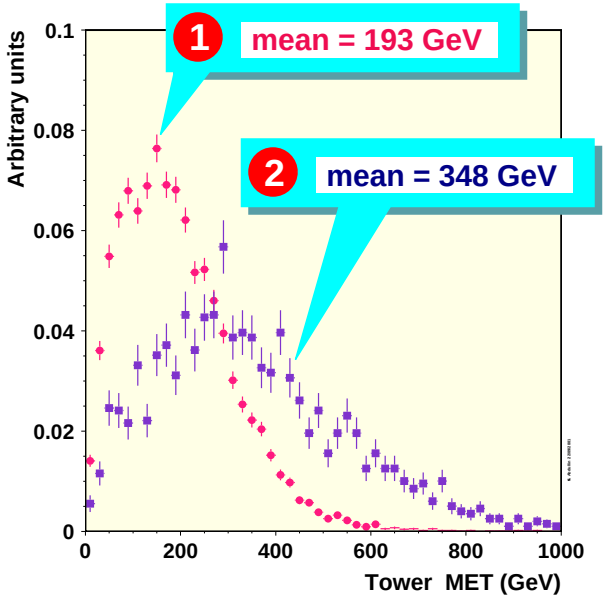
BACKGROUND

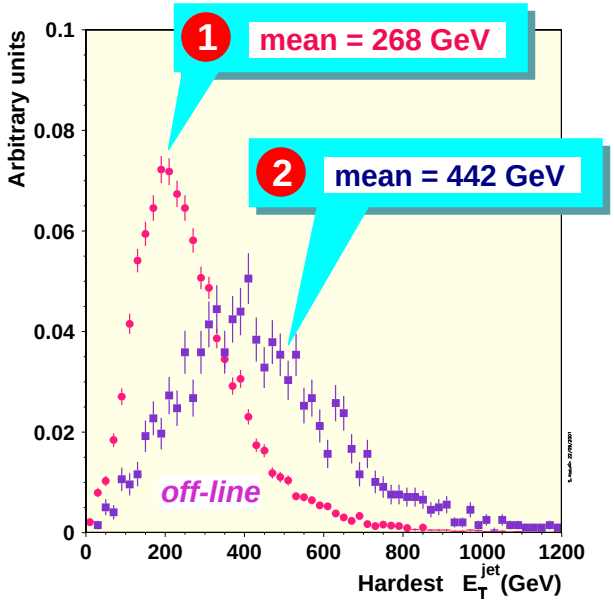
- **SM background for fairly low SUSY mass scale (0.5-1 TeV) :**
  - single(Wtb)/double top production, multijet QCD (incl. $b\bar{b}$ + X), W/Z + multijets } comparable

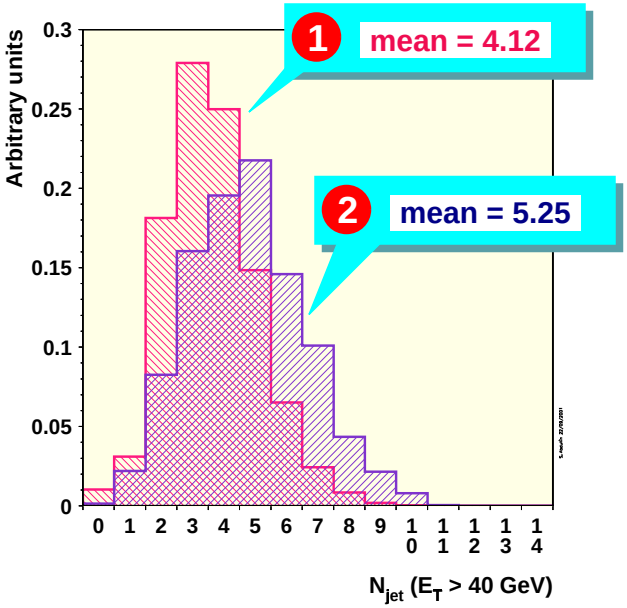
- **Even 0.1 fb^{-1} would require**
  - Wj ~ 160,000 events
  - Zj ~ 60,000 events } $\hat{p}_T$ > 100 GeV
  - $t\bar{t}$ ~ 80,000 events + ~ 30,000 for single top
  - QCD ~ $7 * 10^6$ events } $\hat{p}_T$ > 200 GeV

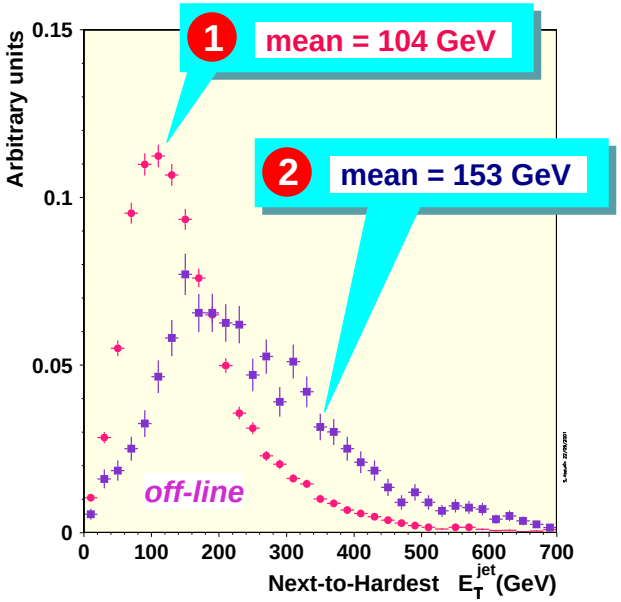
- **Physics TDR challenge ?**

PROBING POINTS DISTRIBUTIONS (I)

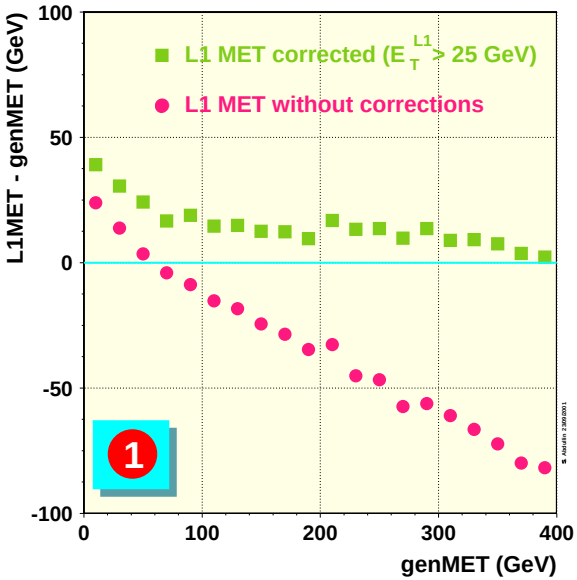


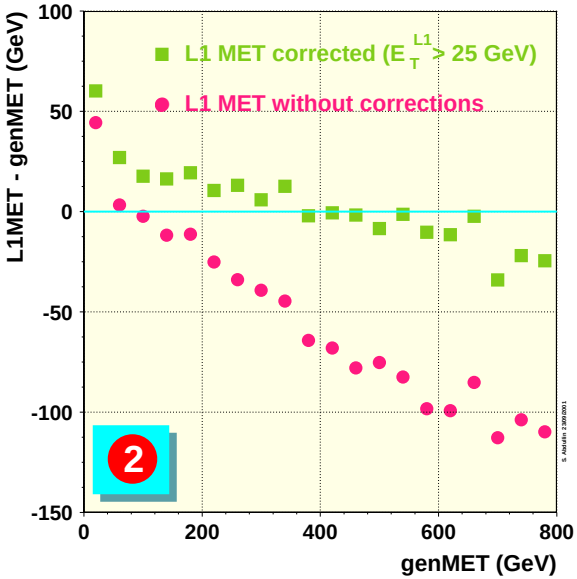






JET ENERGY CORRECTIONS APPLIED

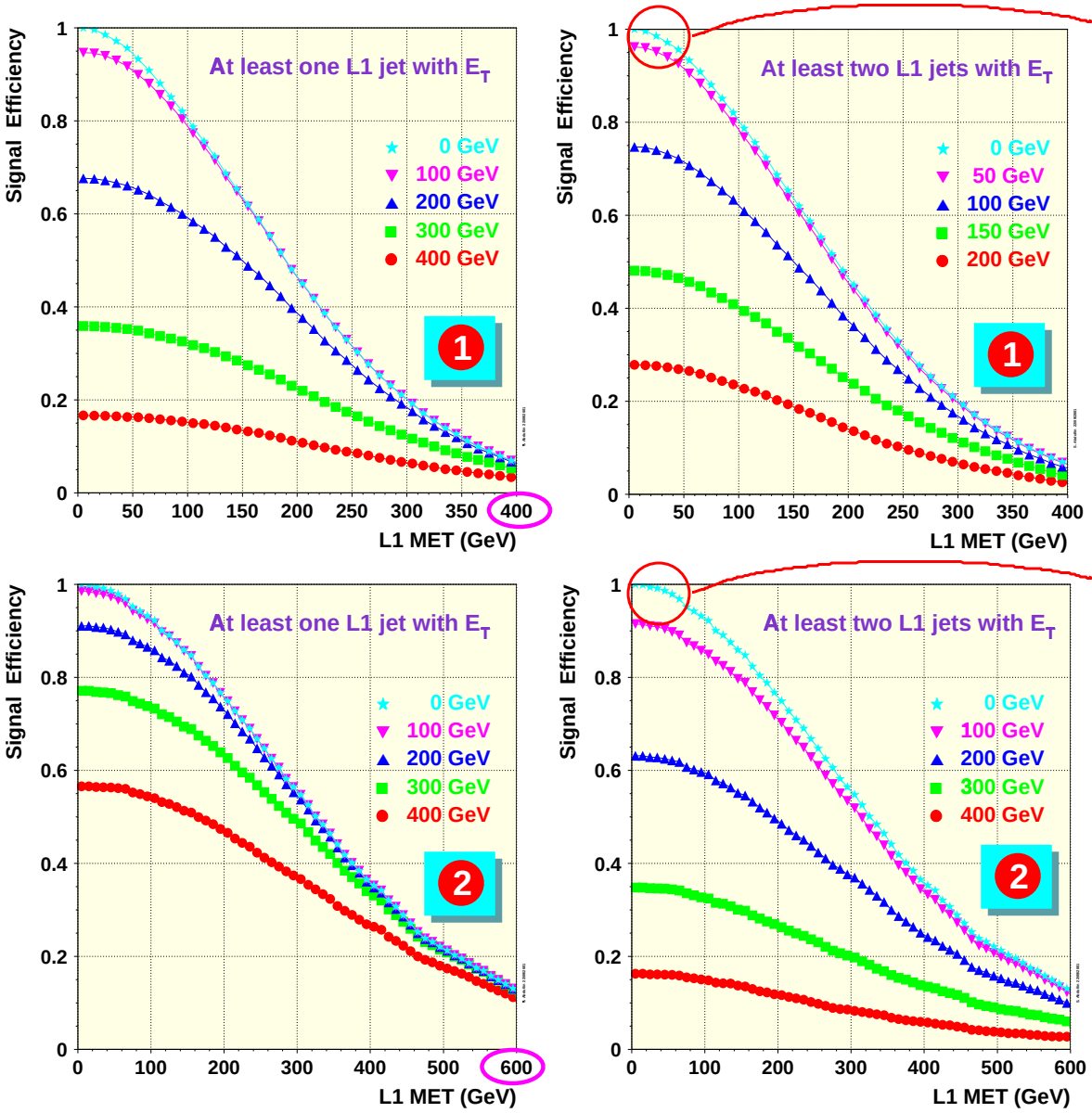




Jet corrections

- Andrei Krokhotine's for **high luminosity**
  http://home.fnal.gov/~sceno/jpg/fall2000jetcorr/...
- applied to both L1, L2 objetcs
- Jets corrected : E_T > 25 GeV
- L2 (towers) MET :
  corrections on tower E_T x,y-components in L2 jets are added
- L1 MET :
  corrections on L1 jets E_T x,y-components are added

L1 MSUGRA SIGNAL EFFICIENCY



rate ~ 0.2 Hz at $2 * 10^{33}$ cm^{-2} s^{-1}

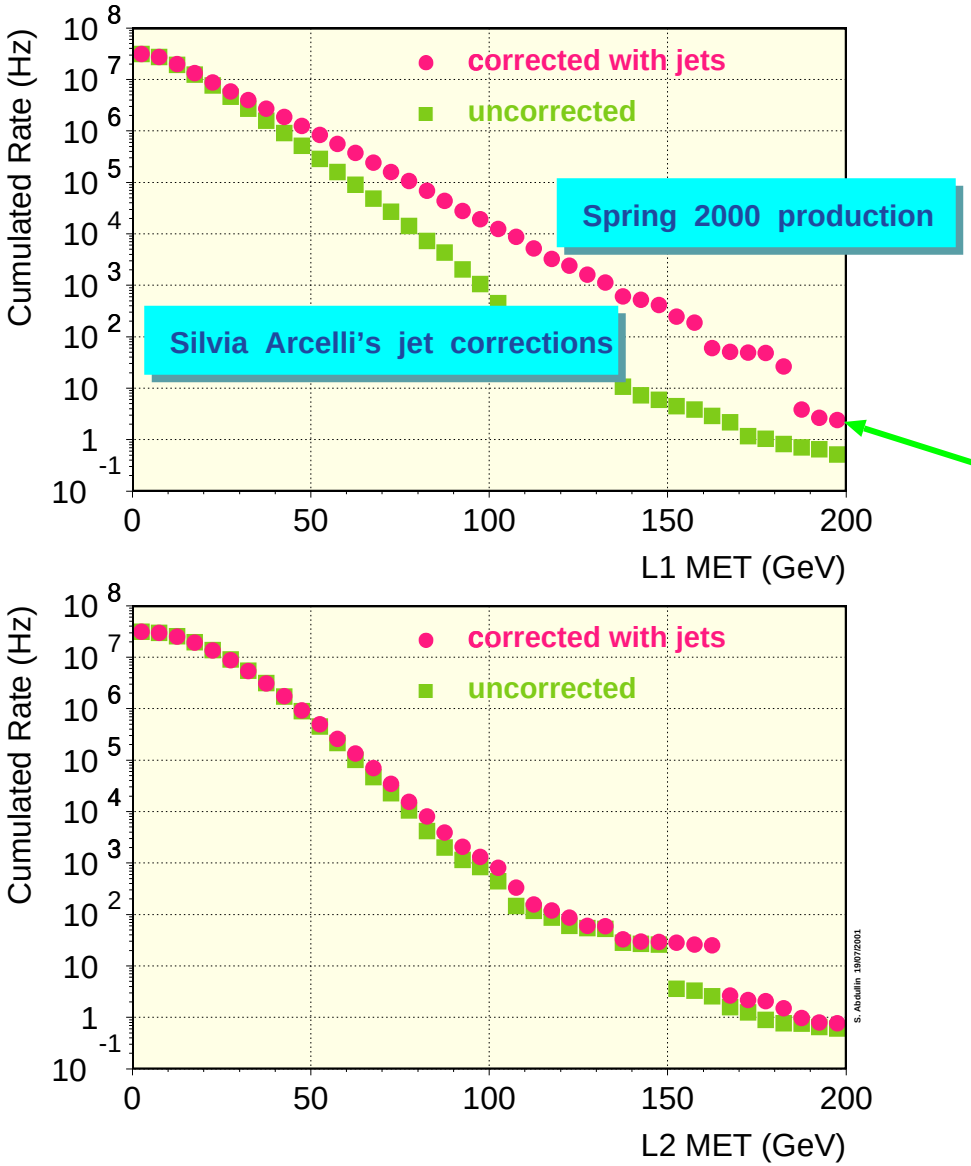
rate ~ 0.004 Hz

- $2 * 10^{6}$ Hz / mb

- From fast MC (CMSJET) we know MET is the main mean to disentangle the signal from huge background
- Not the multijet signature alone !

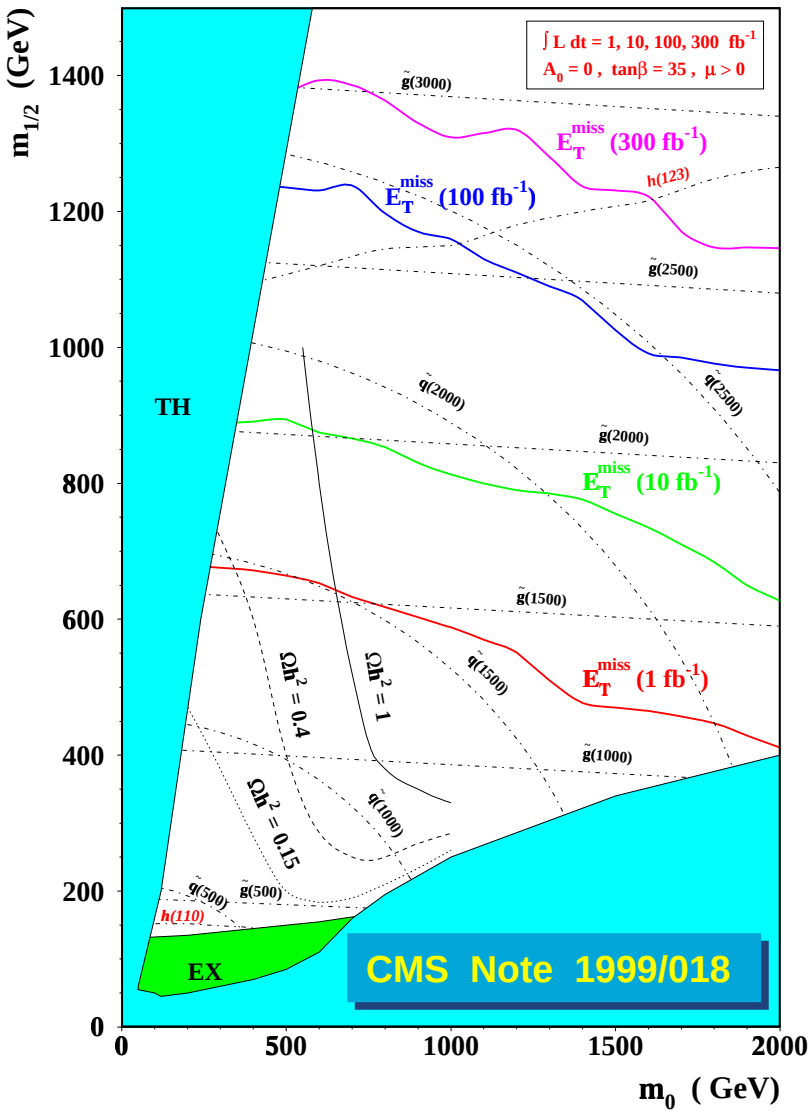
BACKGROUND

QCD MET Rates at High Luminosity (weighted bins)



- **At low luminosity**
  - **<17.3> min. bias events per bunch crossing ⟶ <3.5>**
  - **expected < 0.5 Hz for QCD background at L1 MET = 200 GeV**
  - **expected < ? Hz for QCD background at L1 MET = 300-400 GeV**

CONCLUSIONS (SUSY TRIGGER AT LOW LUMI)



- Even though everybody knows SUSY is so easy to discover via excess of multijet + missing E_T events versus SM expectations ...
- Even though our simple estimates show it's likely so ...
- It's worth getting more precise bkgd estimates at high MET (main handle of bkgd suppression !)
  - more high-p_T QCD samples
  - top (single/double) production
  - W/Z + jets at high-p_T
- M_{SUSY} ~ 2 TeV is probably reachable already at low lumi ?

JET / DI-JET RESOLUTION vs ECAL THRESHOLDS

- What we are worrying about ?
- Data samples
- Di-jet results
- Z′ results

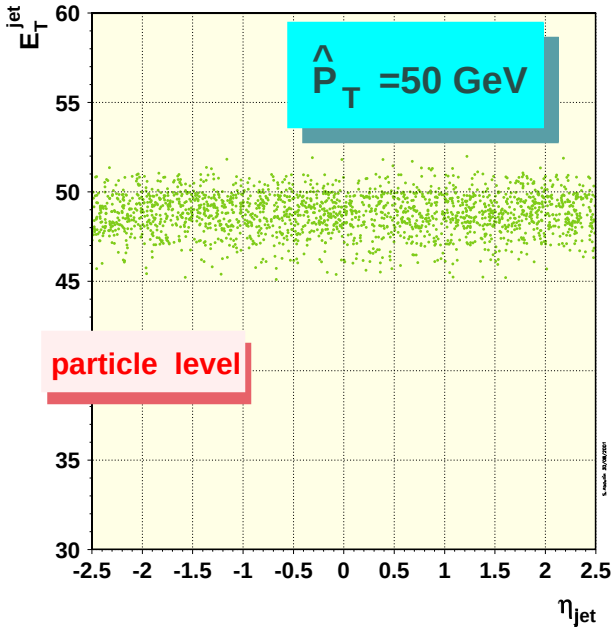
WHAT'S THE PROBLEM WITH ECAL THESHOLDS ?

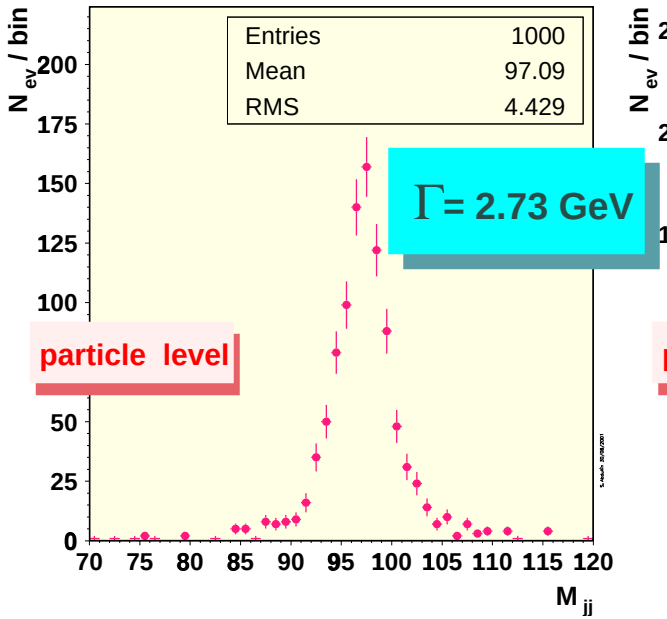
- ECAL selective readout assumes a significant reduction (factor ~ 20) of full data (10 frames) samples stored for the subsequent off-line analysis
  - Zero suppression above some cut (2.5 σ ?) out of "interesting" regions
  - All (or almost) preserved in specified (ECAL L1) "interesting" regions
- What about jet (di-jet) energy reslution and missing E_T measurement precision ?
- ECAL community : it's OK, not a main limiting factor ...

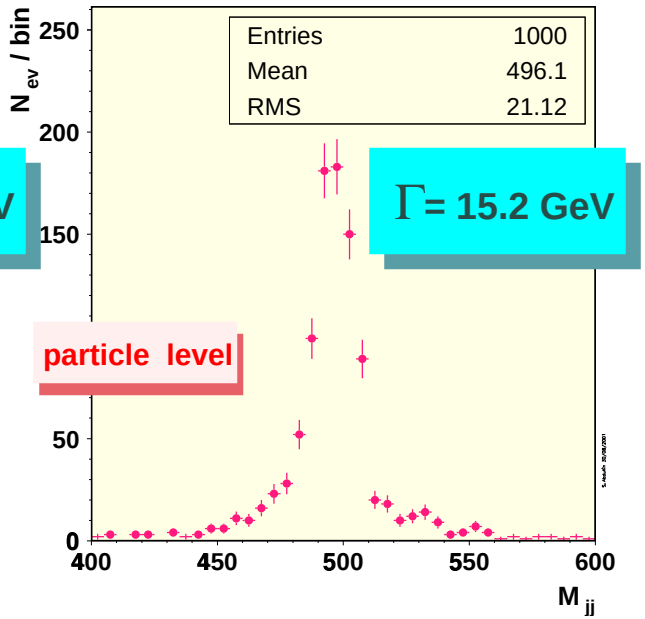
hope so !

SAMPLES

- QCD di-jet (u,d)
- $Z'(100) \rightarrow j\,j$ ($u\bar{u}$, $d\bar{d}$)
- $Z'(500) \rightarrow j\,j$ ($u\bar{u}$, $d\bar{d}$)







- ISR / FSR
  multiple interaction } off
- Particle-level preselection :
  min. 2 jets with E_T > 30 GeV
  within η < 2.5

- underlying event - off
  Z' decays at rest

- Particle-level preselection :
  min. 2 jets with E_T > 30 GeV
  within η < 2.5

CALCULATIONAL DETAILS

Readout thresholds

Set No	HCAL threshold (MeV)	ECAL threshold (MeV) barrel	ECAL threshold (MeV) forward	Comment
1	300	60**	300**	Old HCAL default cuts
2	500	100	500	New HCAL
3	300	60**	300**	idem
4	300	30*	150*	idem
5	300	0	0	idem
6	300	$-\infty$	$-\infty$	idem

** $2\sigma_{noise}$ * $1\sigma_{noise}$

Default ORCA implementation

IterativeCone Jetfinder

- R = 0.5
- Seed = 3 GeV
- E_T^{min} = 30 GeV

- 1 depth layer (HB/HE) + HO
- Layers 1 & 2 "re-weighted"
- Signal integration in 2 bkts
- ADC quantization
- Photo statistics effect
- Hit time jitter
- HF splitted from HB/HE

BACK-OF-ENVELOPE ESTIMATES

"It's so simple, it might even work !"

Dan Green (?)

- **ECAL :** 2500 Xtals in R=0.5, σ = 30 MeV in EB

- **HCAL :** 100 towers,

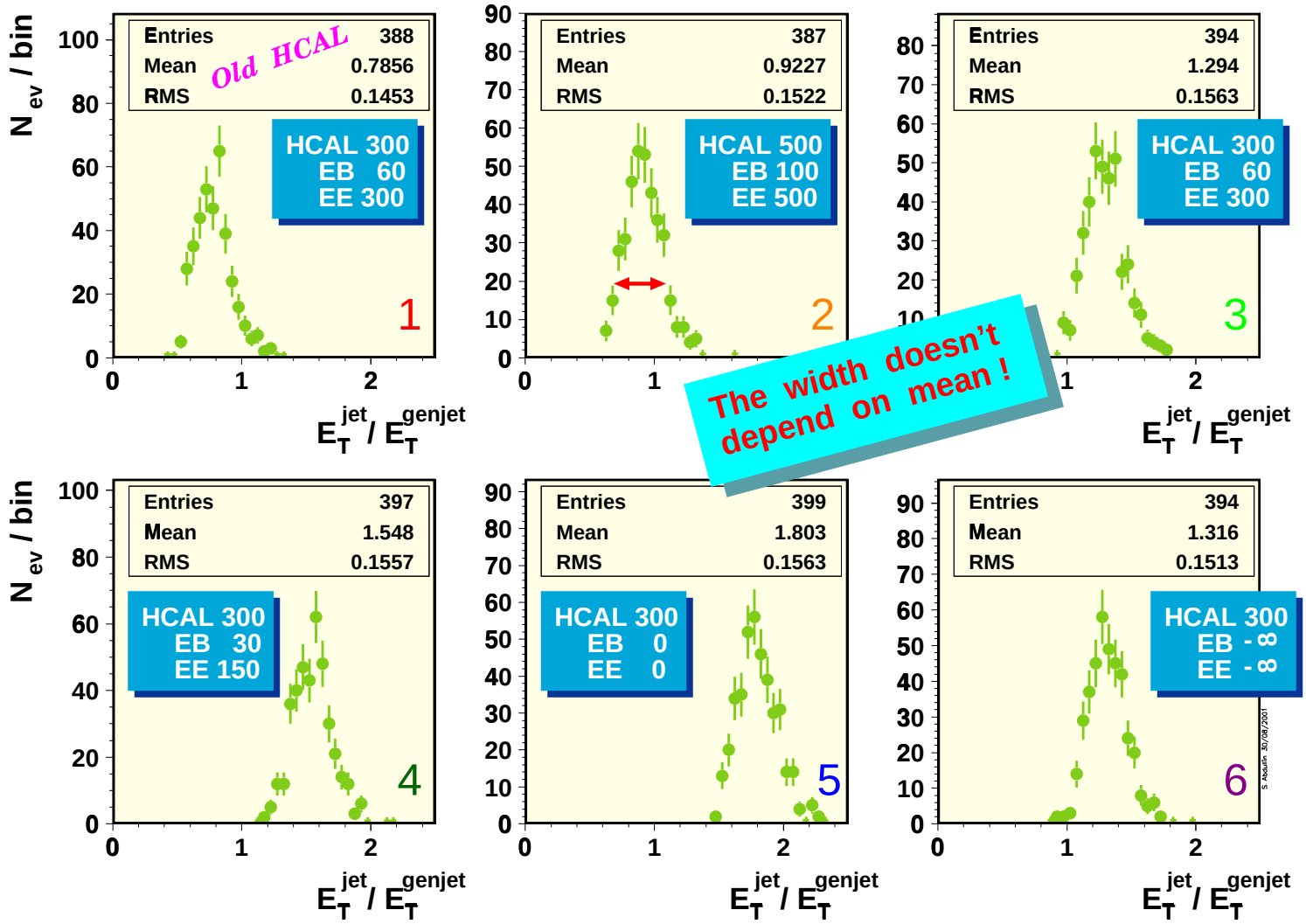
$$\sigma = 200\ \text{MeV} * \text{corr} * \sqrt{2\ \text{readouts} * 2\ \text{layers}} \sim 450\ \text{MeV}$$

+ HO !

cut (σ)	fraction	mean (σ)	jet content (GeV)	
			ECAL	HCAL
0	0.5	0.8	30.0	18.0
1	0.15850	1.524	18.3	10.9
2	0.02875	2.372	5.0	3.0
3	0.00135	3.276	0.3	0.2

DI-JET RESULTS (I)

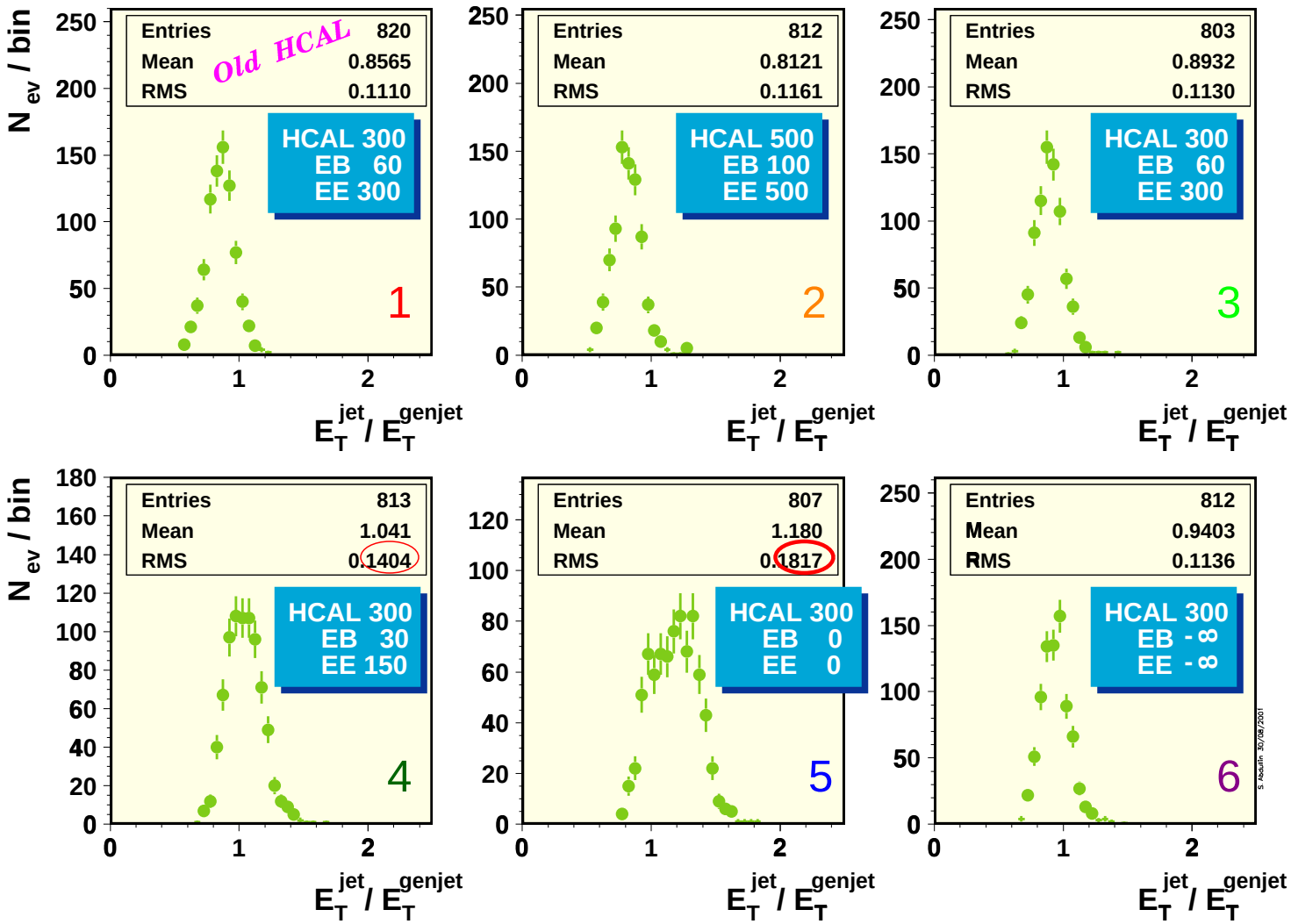
$|\eta| < 0.5$



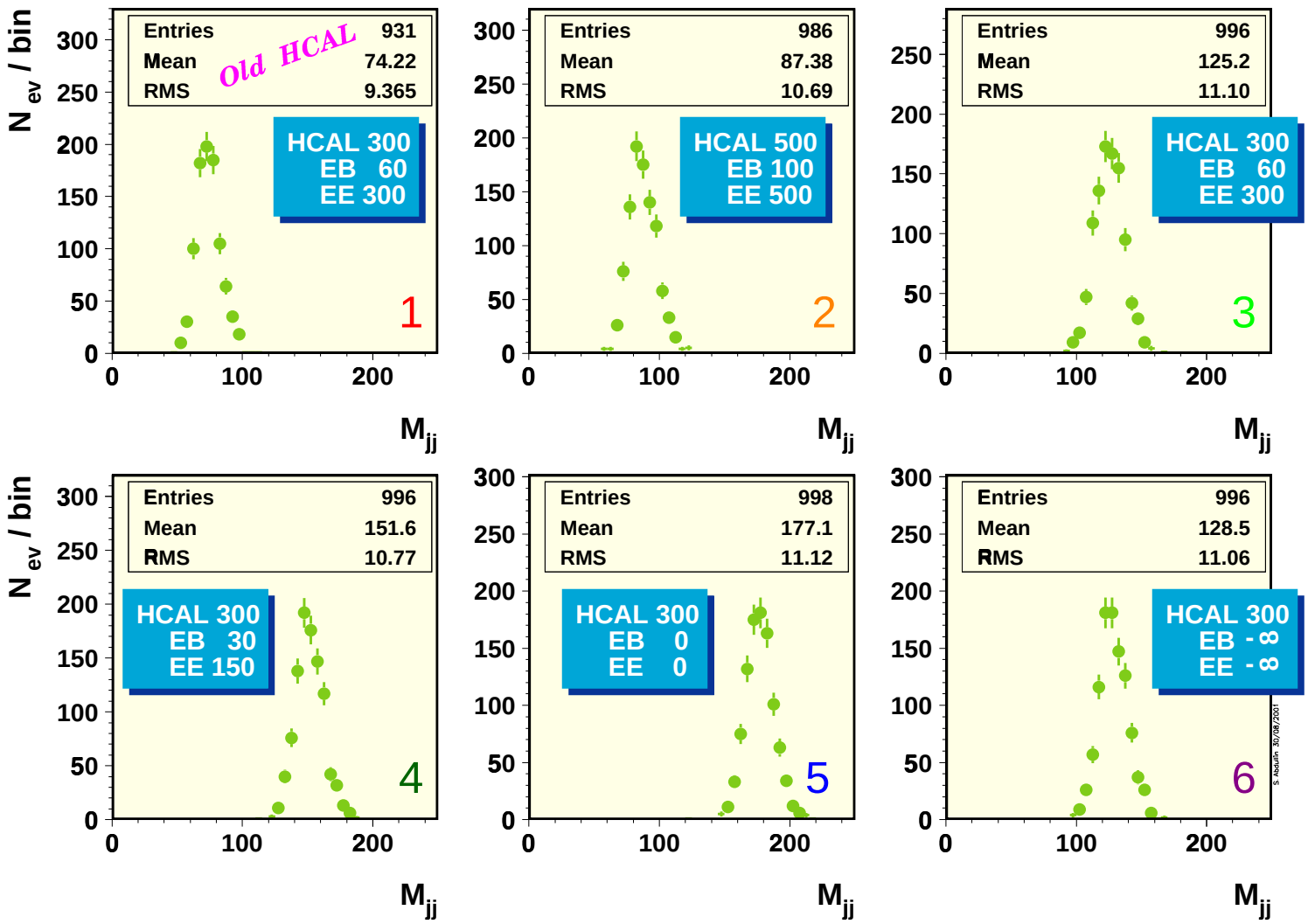
The width doesn't depend on mean !

DI-JET RESULTS (II)

$|\eta| > 1.5$

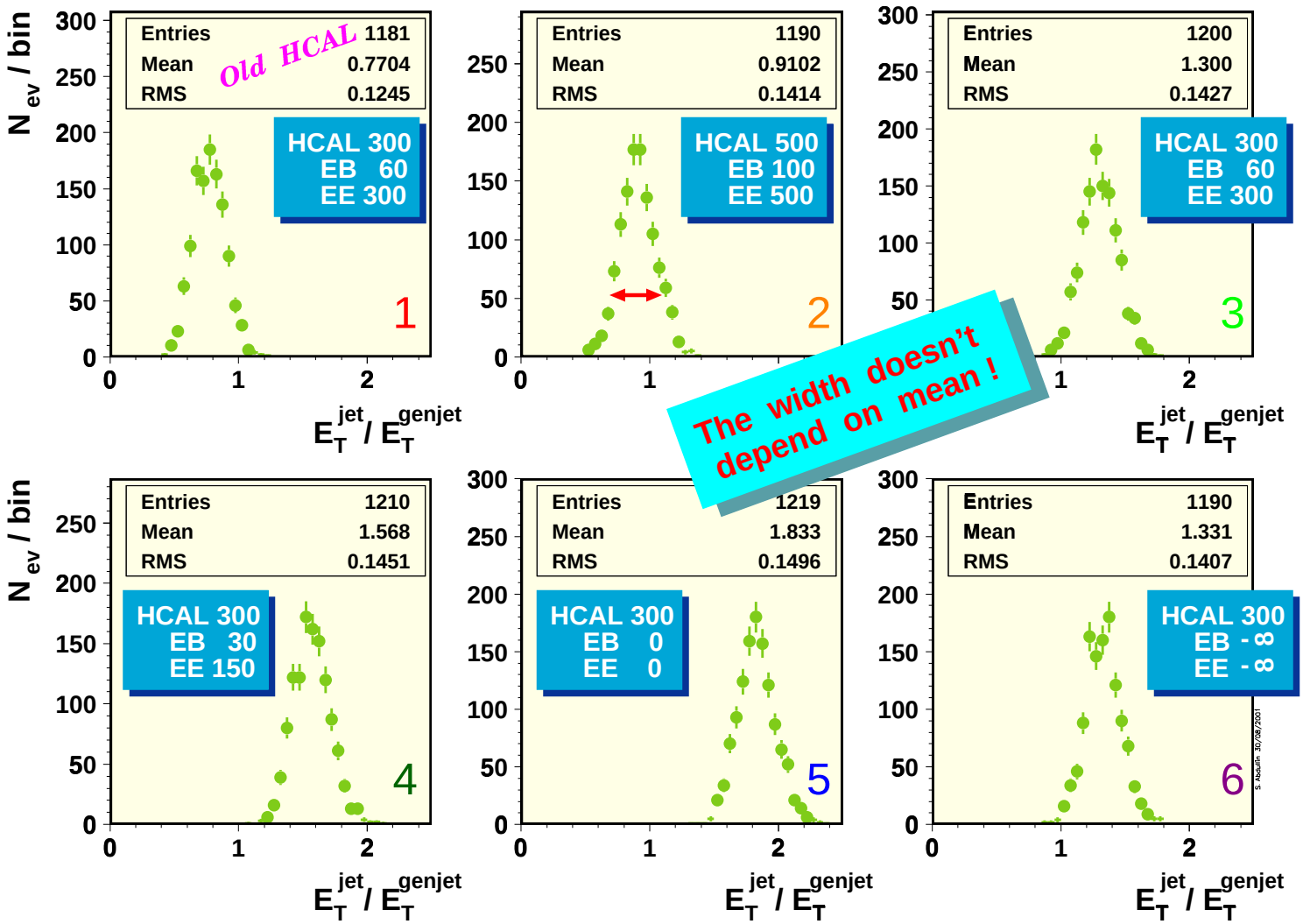


$Z'(100) \to jj$ RESULTS (I)



$Z'(100) \to jj$ RESULTS (II)

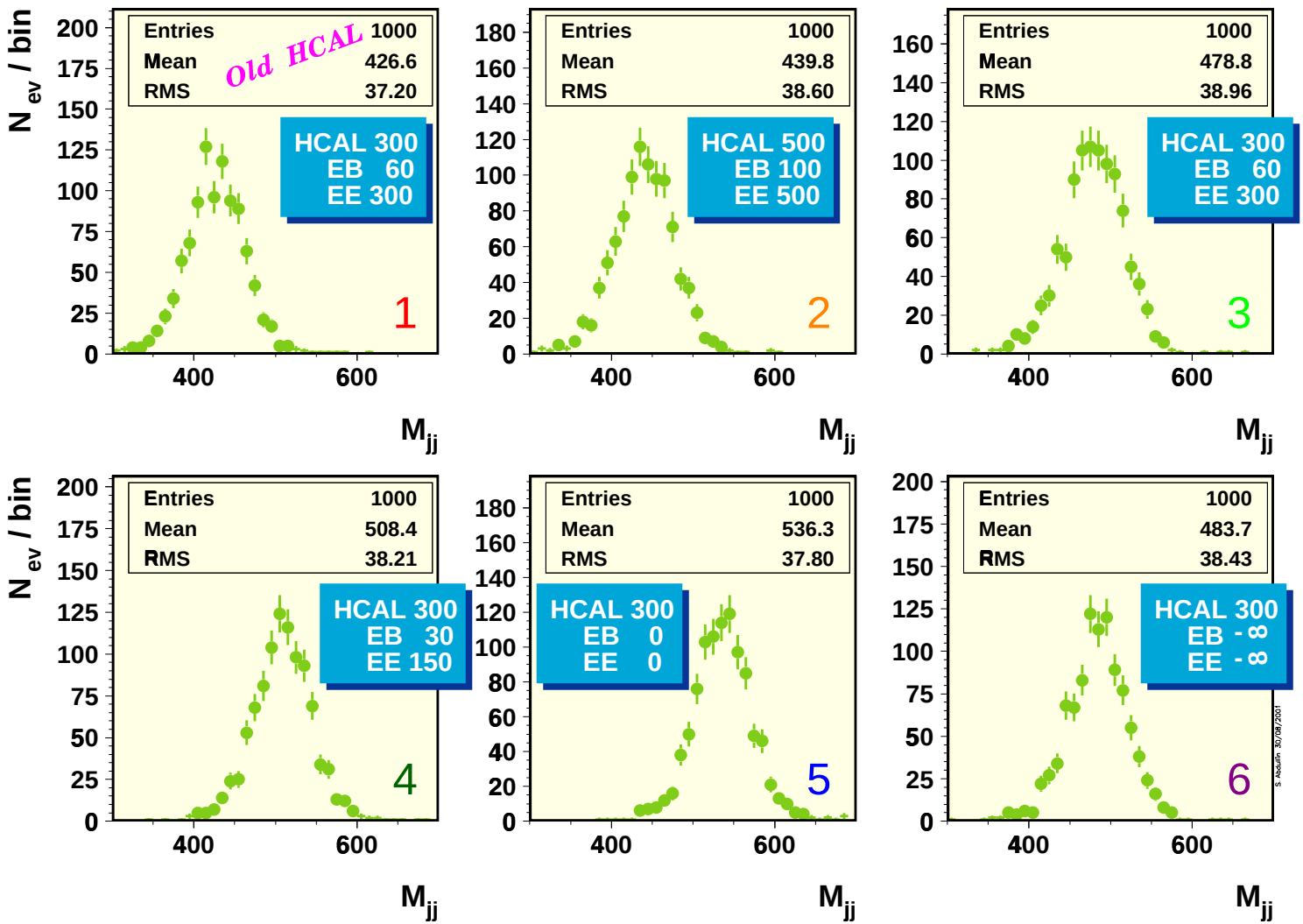
$|\eta| < 0.5$



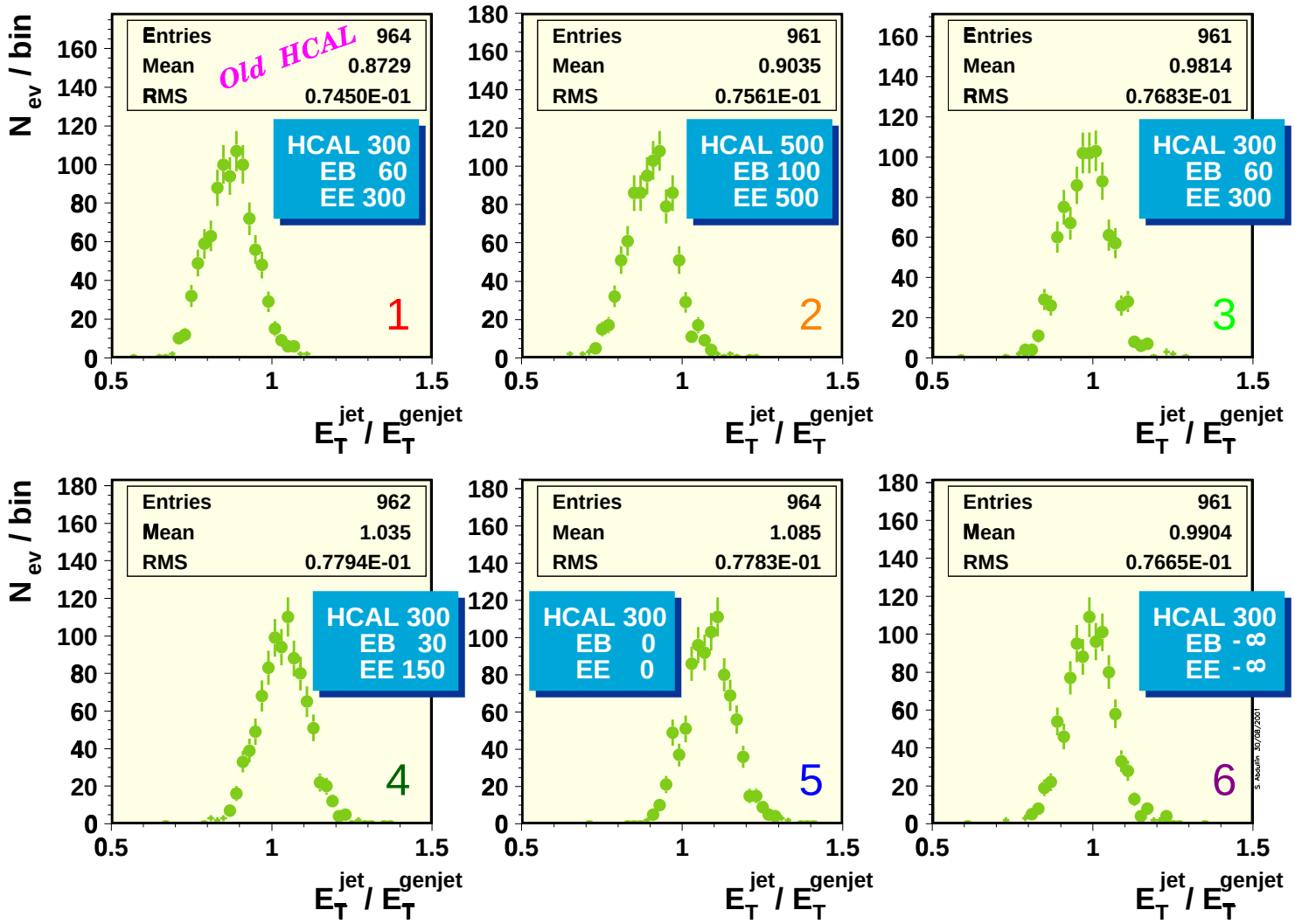
The width doesn't depend on mean !

$Z'(500) \to jj$ RESULTS (I)

Similar to Z (100)



$Z'(500) \to jj$ RESULTS (II)



JET / DI-JET SUMMARY

- Generally the widths of jet/di-jet disributions (w/o corrections) seem to be fairly independent on the thresholds
  - a kind of traid-off (?) :
    higher threshold -> less noise -> better resolution, but ...
    higher threshold -> less jet constituents -> worse resolution
- Each set of thresholds require it's own jet energy corrections to see how eventually the resolution changes
- To be continued ...
  - more statistics

UPDATE ON FRONT-END ELECTRONICS SIMULATION

- Last report at HCAL week (June 15, 2001)
  - http://cmsdoc.cern.ch/~abdullin/jetmet/meetings/15jun01/talk.pdf
    update.pdf
- General HCAL code update issues
- Updates on HCAL code in ORCA
- "Straightforward" implemetation problems -> toy MC
- Signal shape : short vs long
- Pure noise consideration
- Signal resolution without pileup
- Shape filter(s)
- Noise + pileup
- Summary
  - http://cmsdoc.cern.ch/~abdullin/jetmet/notes/note_3/in01_037.pdf

Available on CMS information server

CMS IN 2001/037

CMS Internal Note

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September 25, 2001

Update on the HCAL code in ORCA, and Toy Simulations of the Readout Response

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Abstract

We describe a major update to the HCAL code in ORCA which makes the simulation of the HCAL response much more realistic. The new code includes a simulation of the photo statistics of the HPD, integration and quantization of the signal by the QIE, and separate simulations for the HB/HE and the HF. We also describe studies done using a stand-alone version of the code (outside of the ORCA + Objectivity Database framework) that facilitates quantitative estimates of the HCAL readout response. We find that if we use the energy recorded during only one time bucket, we get somewhat better bunch crossing identification efficiency than if we use two time buckets. The energy resolution for fairly low signal is also slightly better with one time bucket collection. In the Appendix we consider the case with the long signal shape, mainly comparing energy collection in 2 time buckets and in 3 ones.

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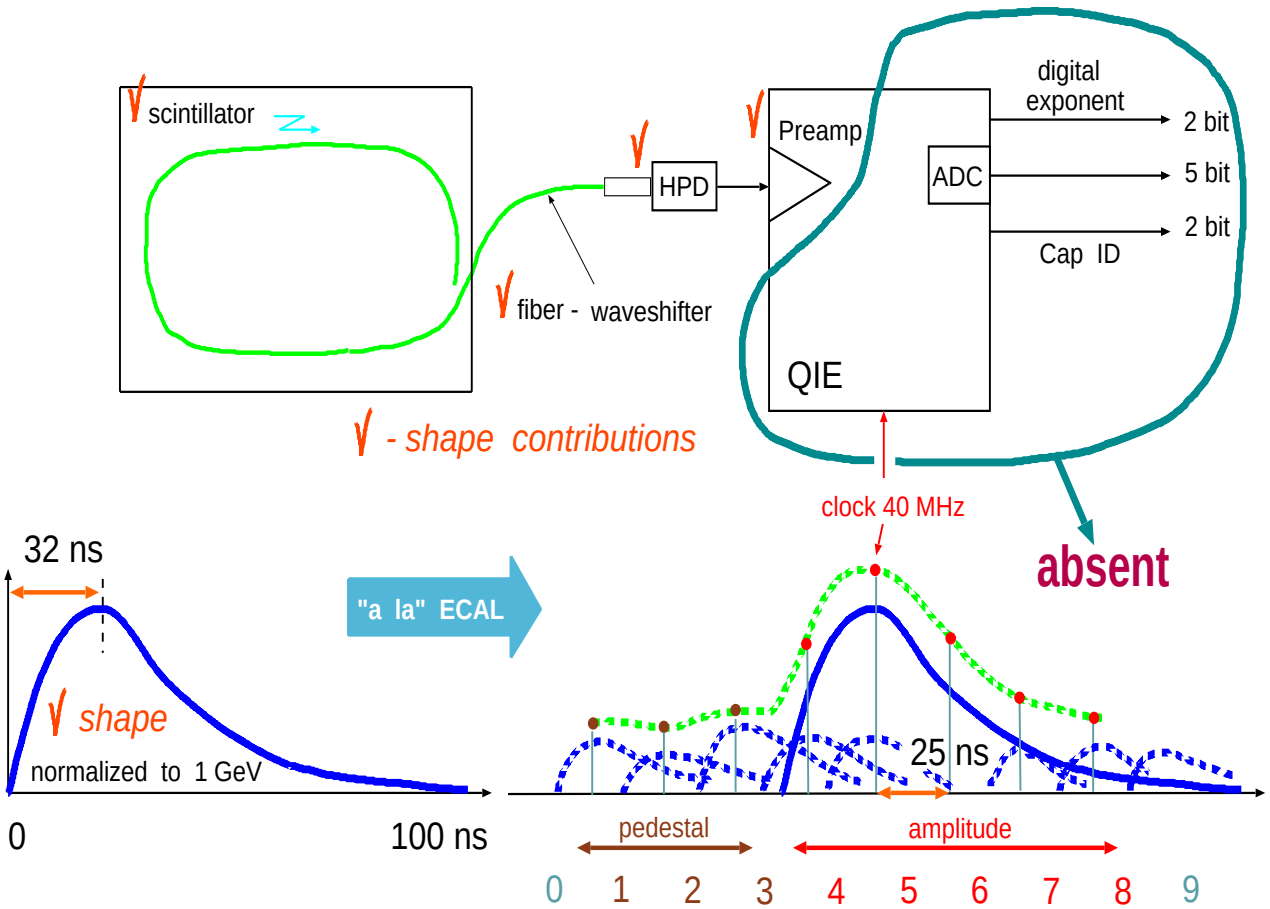
HCAL CODE IN ORCA (UPDATE LIST)



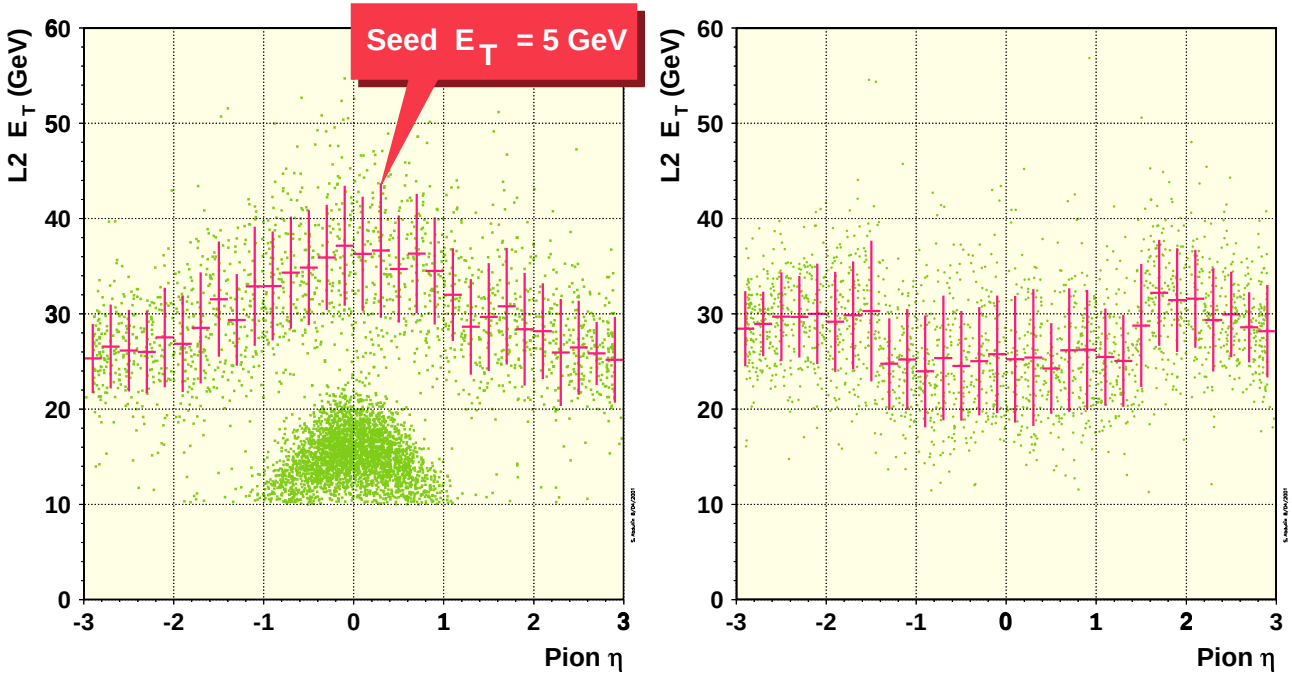
- Realistic noise
- HPD photo staistics effect
- Signal integration in 25 ns time buckets
- ACD quantization
- HF splitting from HB/HE
- Layer 0 and 1 "optical" merging both in HB and HE

ORCA CODE (CALO PACKAGES) CHANGES

- **HcalRealistic** — HF splitted from HB/HE, noise generation, ADC quantization
- **HcalRealisticRec** — signal evaluation (off-line)
- **HcalTrigPrim** — signal evaluation (L1 tgigger)
- **HcalBarrel** — layer 0 and 1 merging with weighting ("optical")

- **CaloHit** — minor change to enable GEANT hits weighting
- **CaloTrigRec** — minor change to split HCAL trigger reconstruction from ECAL one (!)
- **CaloReadout** — HCAL ReadOut treatment is separated from ECAL one (so different !)
  some optional changes (e.g. map -> static vector of CaloTimeSample)
- **CaloRecHit** — some optional changes not related directly to HCAL
- **CaloDetector** — some optional changes not related directly to HCAL
  (e.g. assigns a unique ordinal number to all calo cells for direct ref.)

ORCA IMPLEMENTAION PROBLEMS



- **Calc. details :**
  - double pions p_T = 30 GeV
  - 2 signal + 3 pedestal buckets
  - 2 depth layers
  - IterativeConeAlgorithm with R = 0.5 and seed E_T = 1 GeV

- **In parallel with the code re-writing, there was a need to understand and to optimize the parameters put inside the code**

- **As ORCA is rather a production tool, not an instrument for the studies of the sort, then ...**

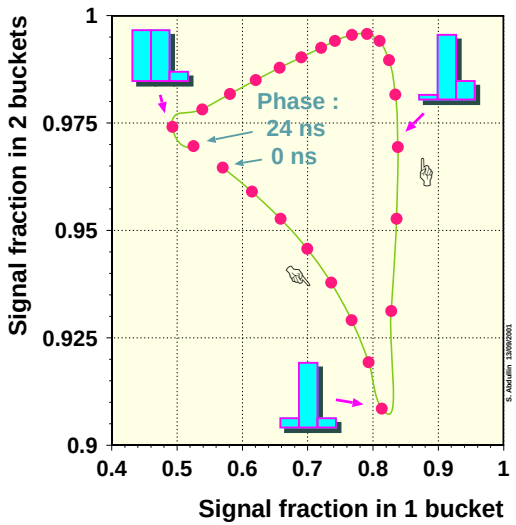
THEN, TOY MC ...

test bed for ORCA

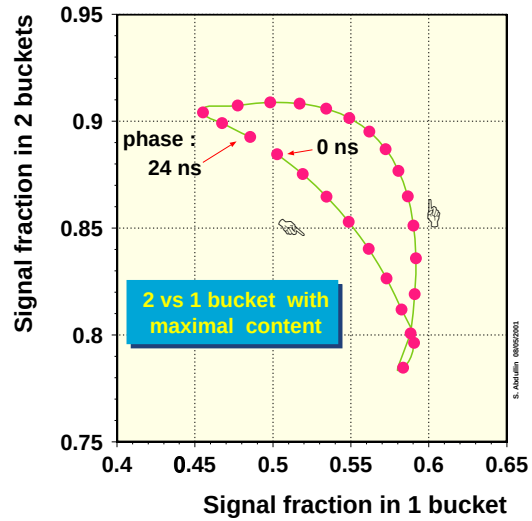
- **Contains almost the same functionality as ORCA does**
  - parameterized and tabulated shape of the signal
  - photo statistics effect
  - QIE integration
  - ADC quantization
  - baseline position (typically smeared) in any of the ADC channels
  - variable number of time buckets analogous to ORCA's CalTimeSample and CaloDataFrame objects
  - Gaussian noise (uncorrelated) injection in all time buckets
  - various options for the signal collection and pedestal estimates
  - adjustable time phase for various collection modes

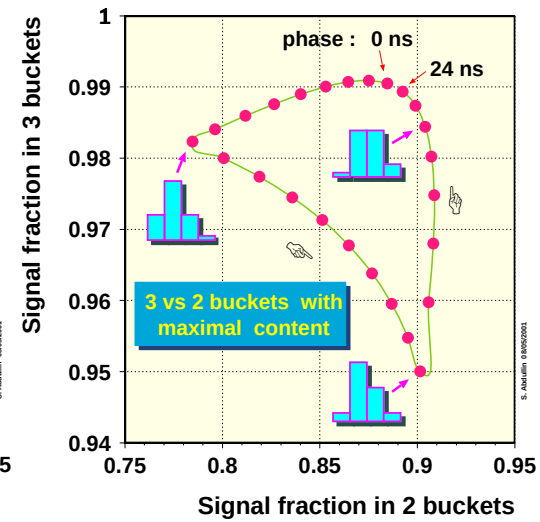
SIGNAL SHAPE

new

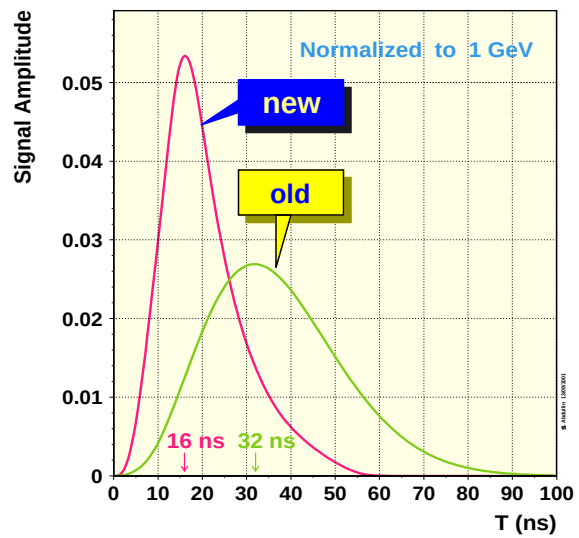


old





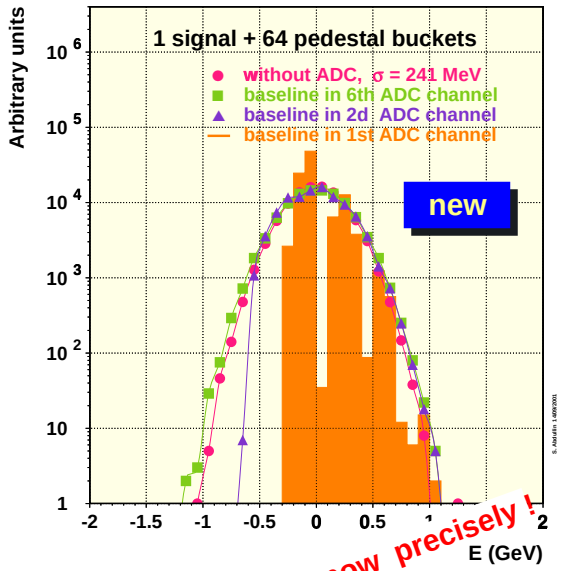
	new	old
Scintillator + wave-length shifter $f_d(t) = exp(-t/\tau_s)$, $\tau_s = 10$ ns		11 ns
HPD $f_{HPD}(t) = 1.0 + (t/\tau_{HPD})$, $\tau_{HPD} = 12$ ns		10 ns
Preamplifier $f_p(t) = t * exp(-t/\tau_p)$, $\tau_p = 5$ ns		25 ns

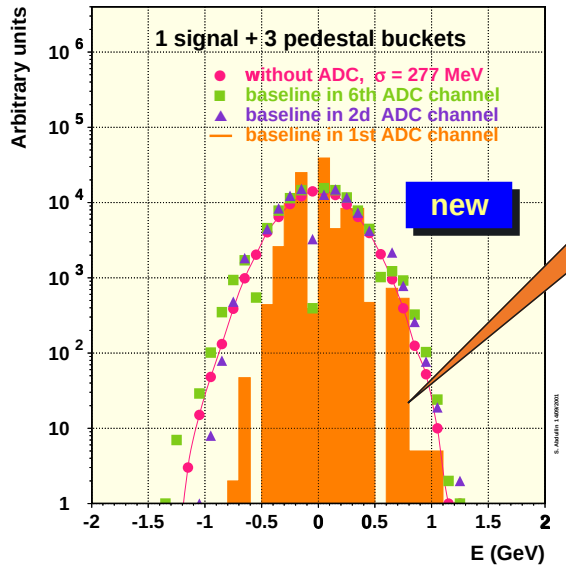


TOY MC : CALCULATIONAL DETAILS

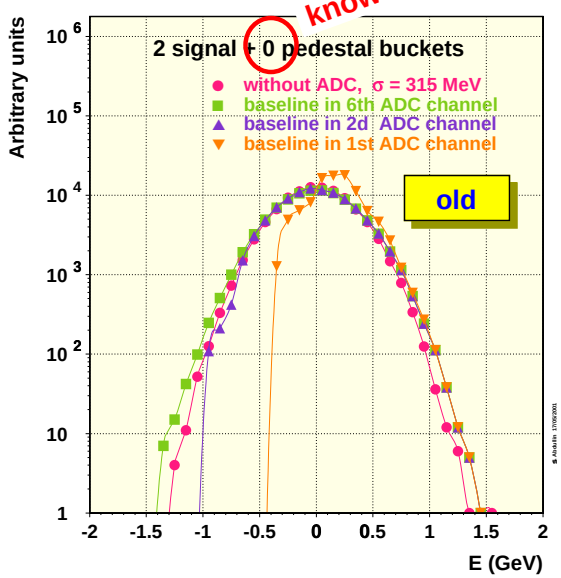
- Gaussian uncorrelated noise σ = 2 pe ~ 200 MeV per time bucket per readout ("fast component")
- Flat random "drift" of the baseline (noise average) within one ADC channel ("slow component")
- Default baseline position - in the 2nd ADC channel
- LSB = minimal size of the ADC channel = 3 pe ~ 300 MeV (at the beginning of the first ADC range)
- 10 pe per GeV is assumed (might be more, closer to HB/HE)
- Pedestal estimate as a running average of 64 sequential digitized time buckets is denoted as "64 pedestal buckets"

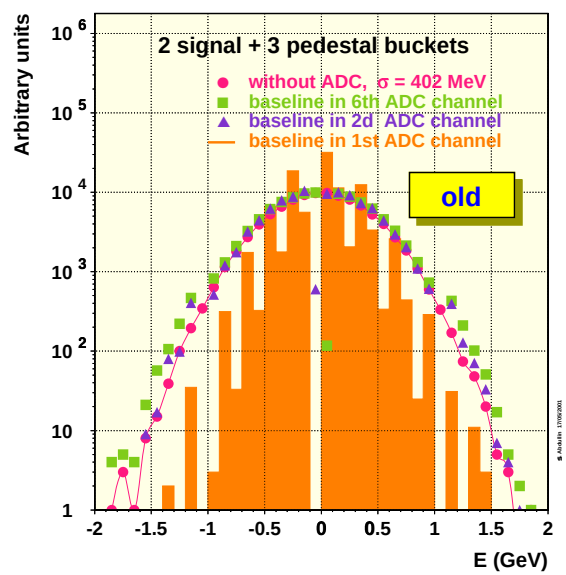
NOISE-INDUCED "SIGNAL" DISTRIBUTIONS



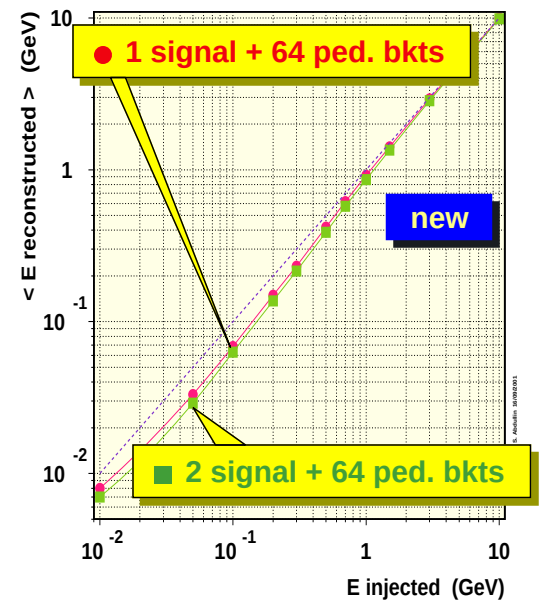


know precisely !

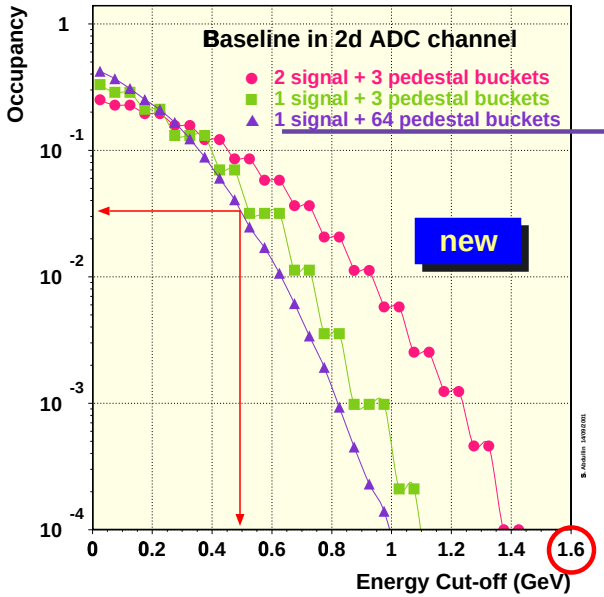


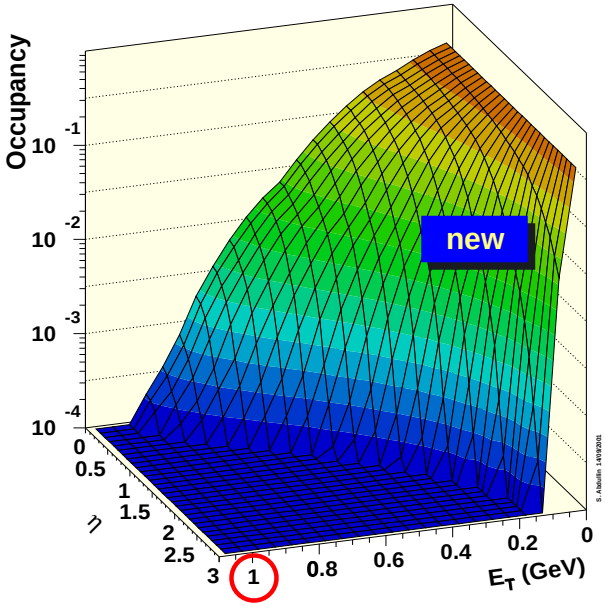


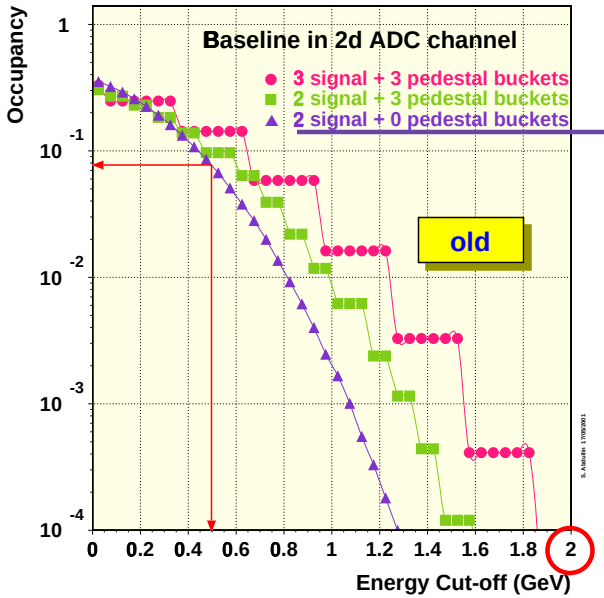
Baseline in the 1st ADC ch.

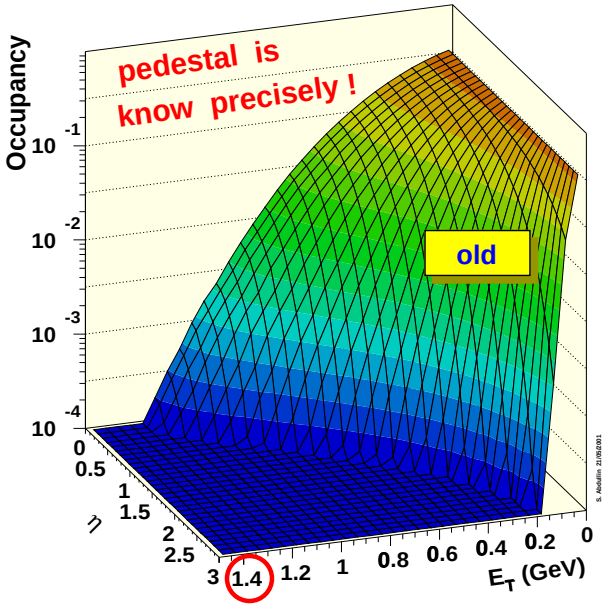


NOISE-INDUCED OCCUPANCY

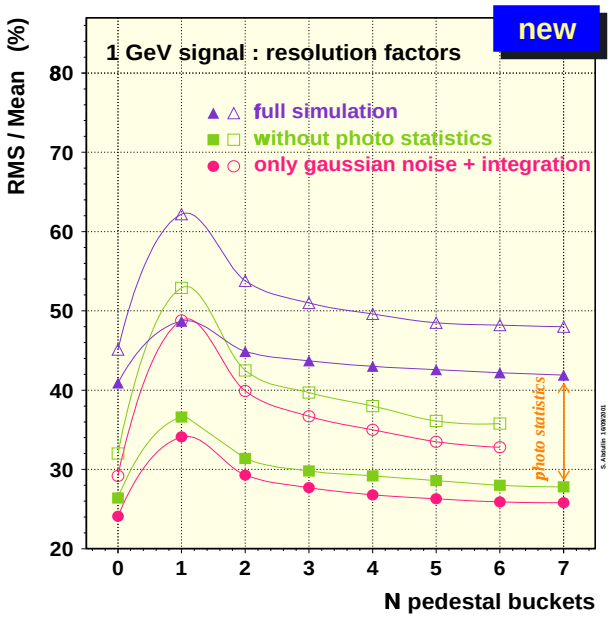


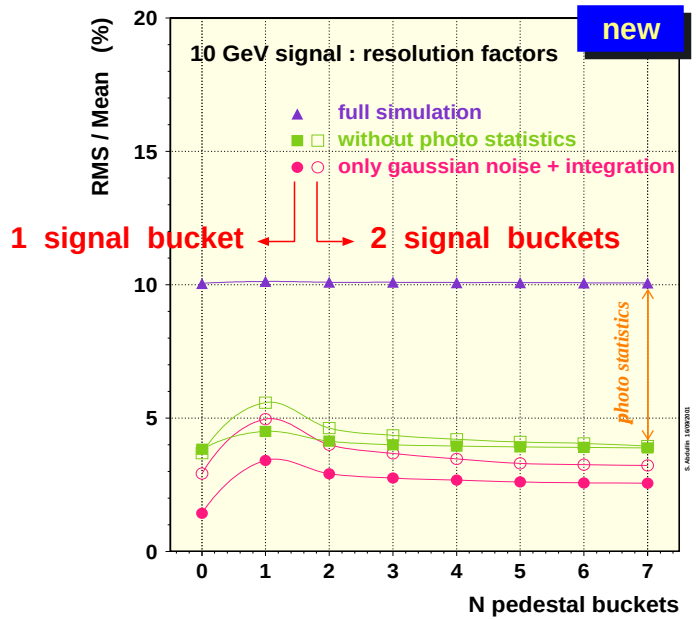


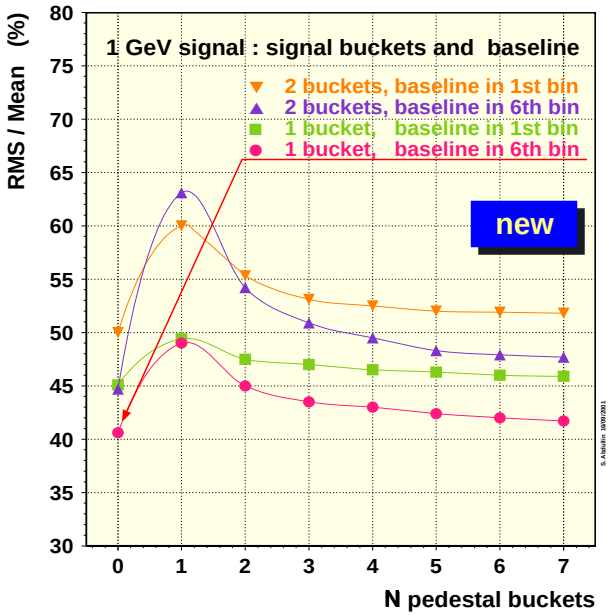


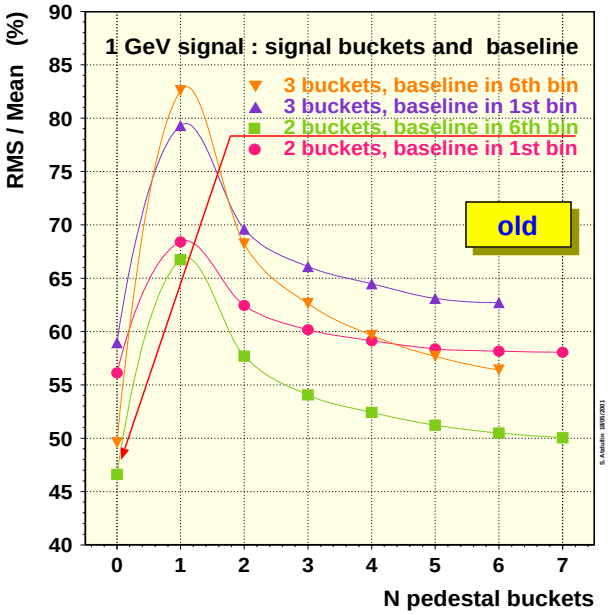


NOISE + SIGNAL

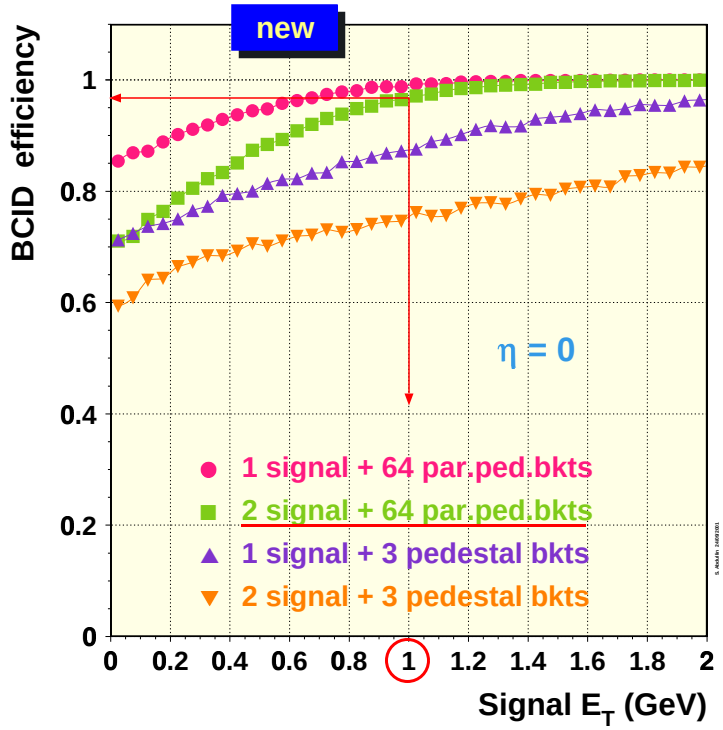


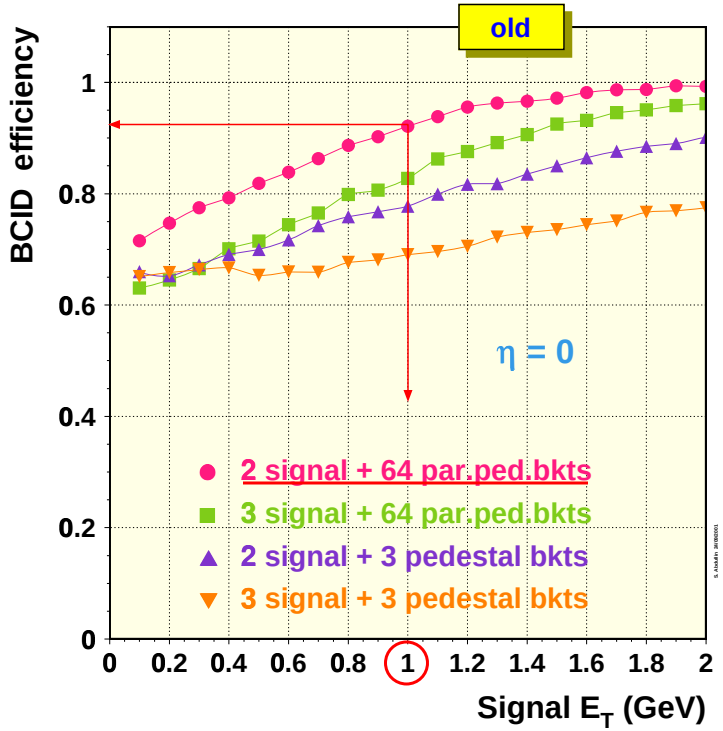






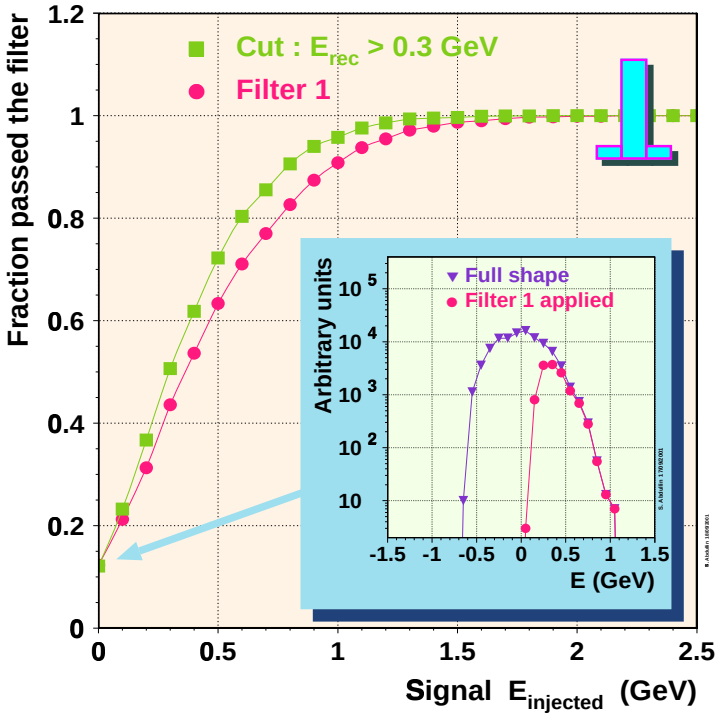
SIGNAL BCID (NOISE ONLY)

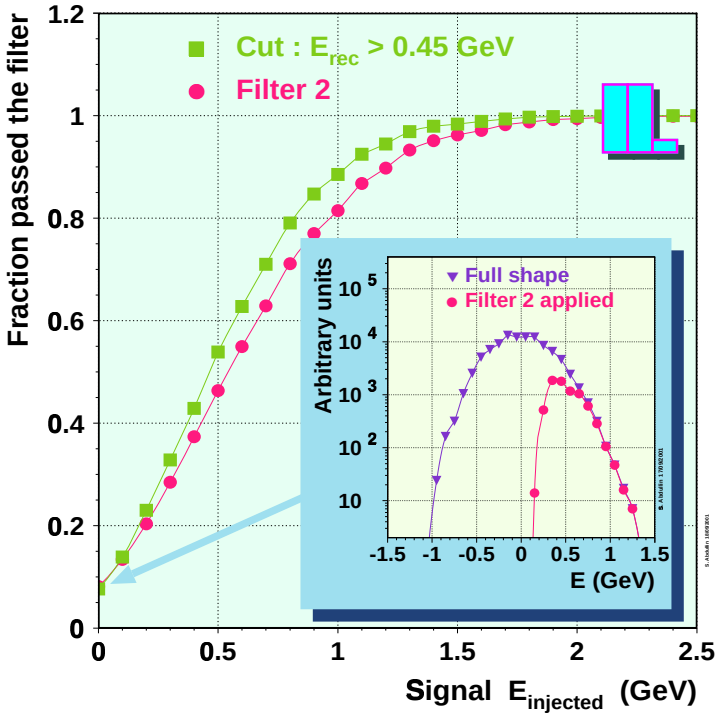




- The signal is evaluated with weights corresponding to the "true time"
- Then - with weights pattert shifted by +/- 1 time bucket
- BCID is OK if the signal is maximal (≥) with zero shift

SHAPE FILTER (FOR NOISE)





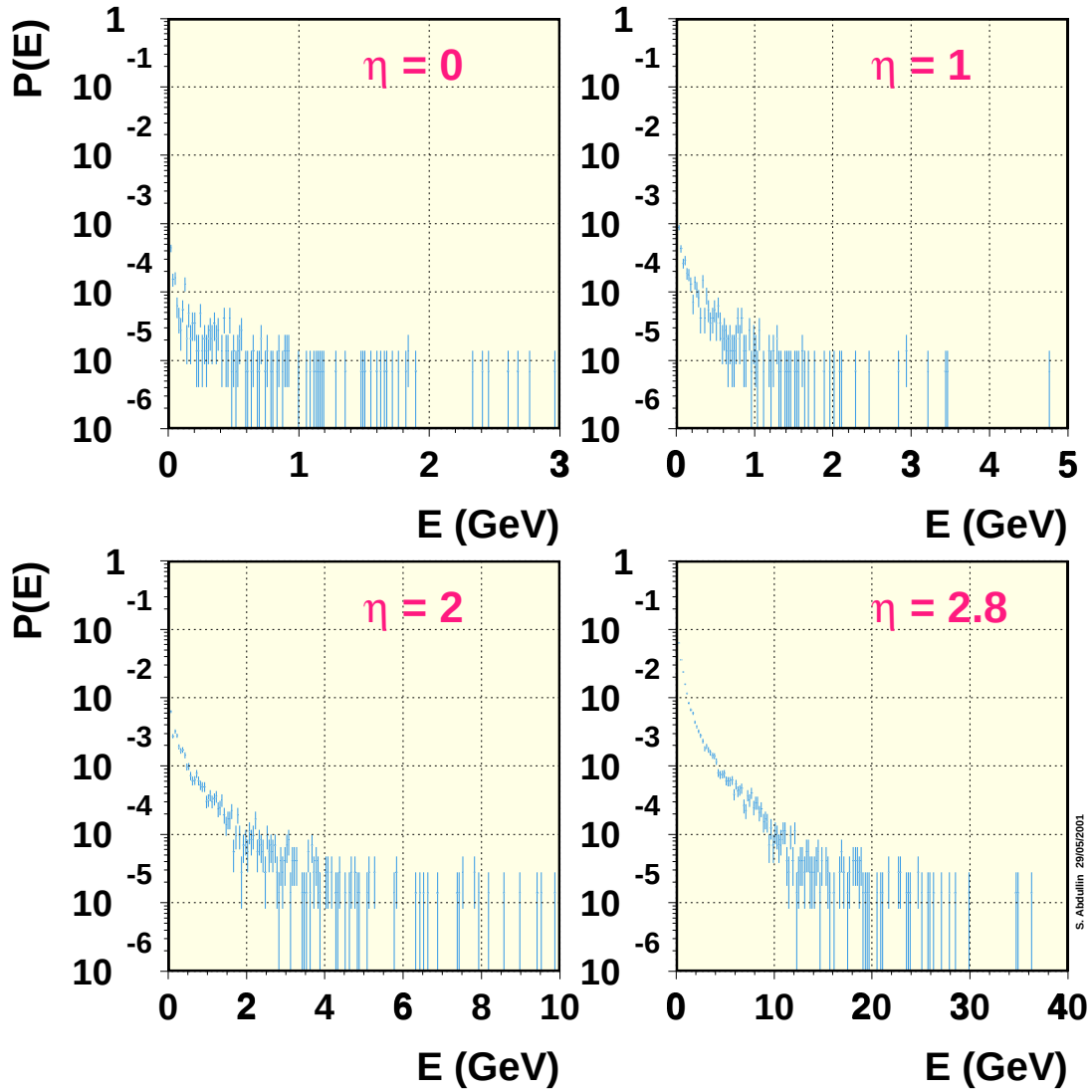
- Signal bucket content ≥ 1 ADC count
- -1 / +1 time bucket content < peak bucket one

- Both signal buckets content ≥ 1 ADC count
- diff (max, min) ≤ 3 ADC counts

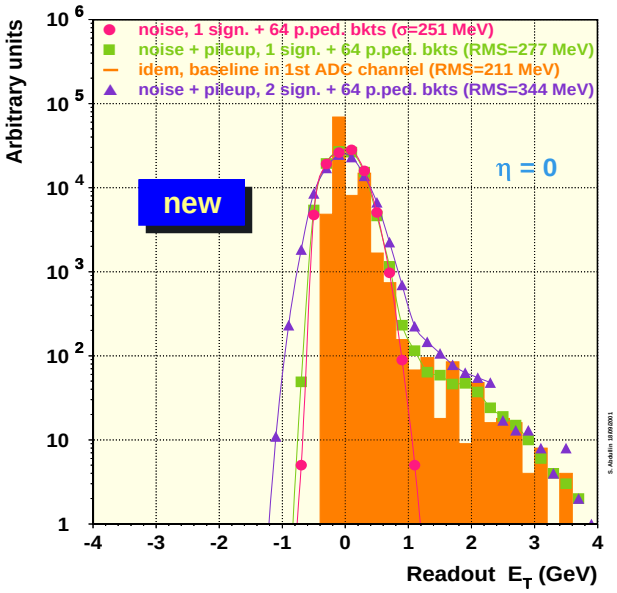
- **High noise level (+ big LSB) hampers shape-based noise filtering**

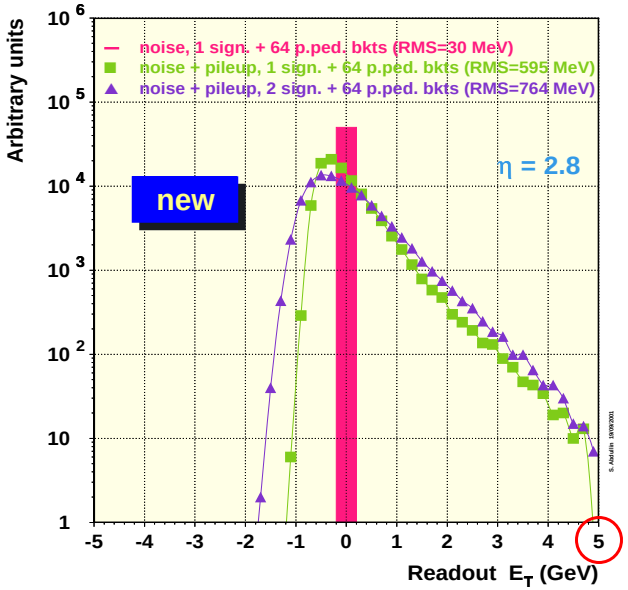
PILEUP IN TOY MC

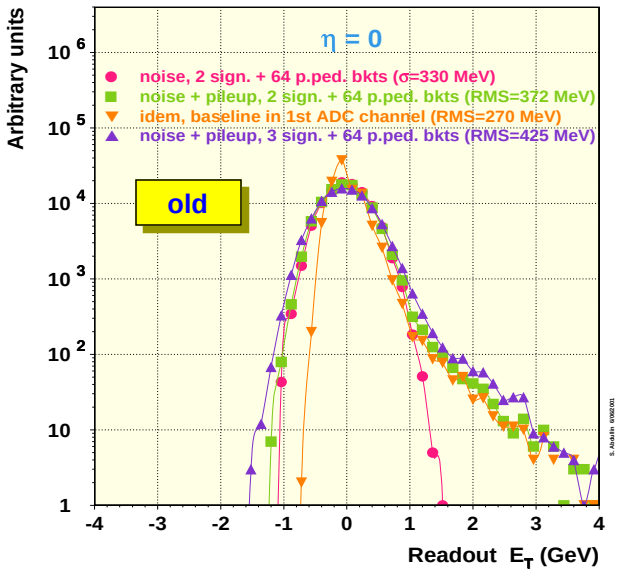
Single minimum bias events (ORCA_4_5_1)

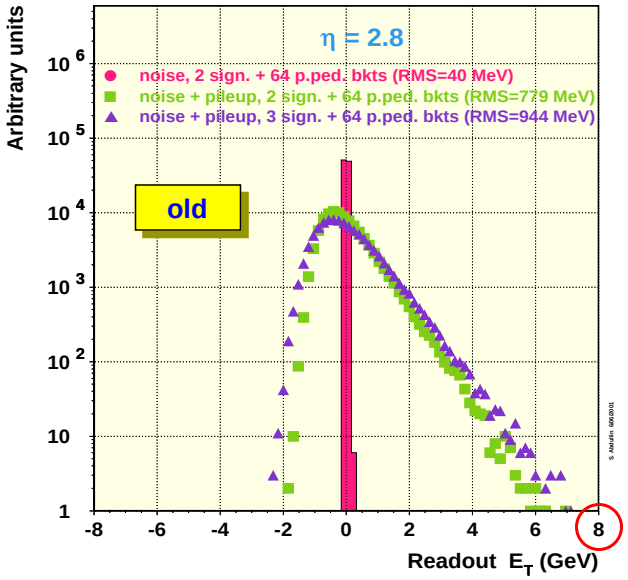


READOUT RESPONSE TO NOISE + PILEUP

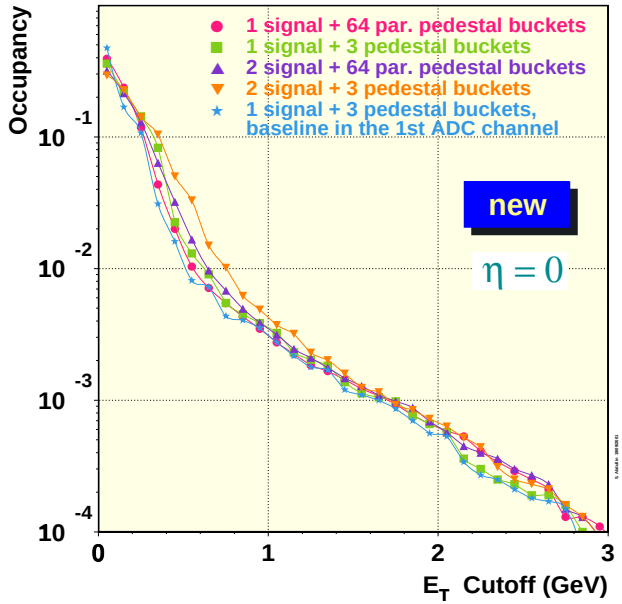


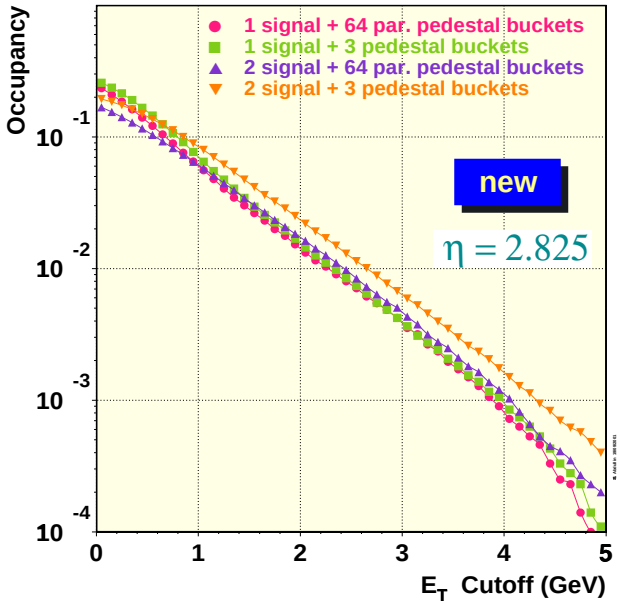


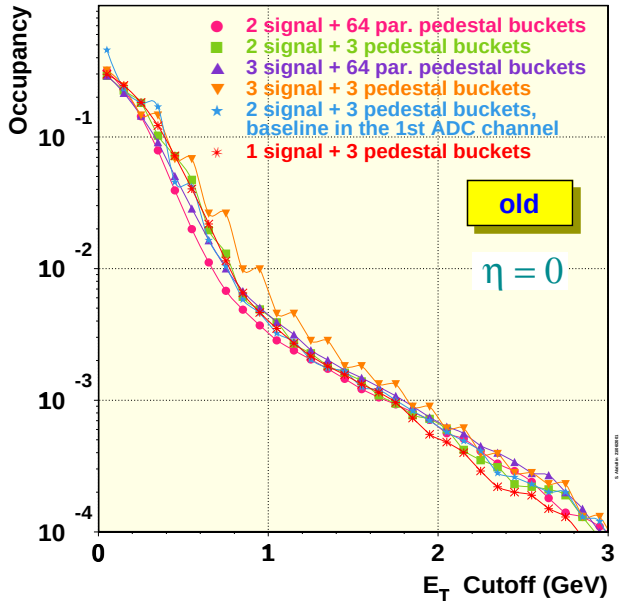


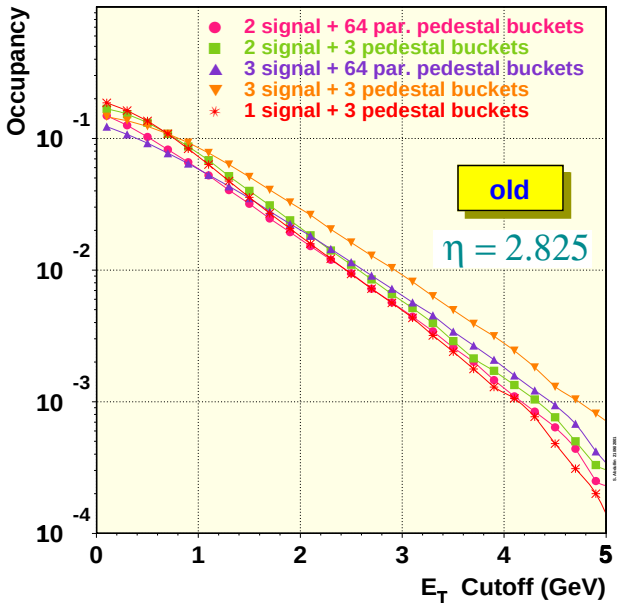


OCCUPANCY (NOISE + PILEUP)

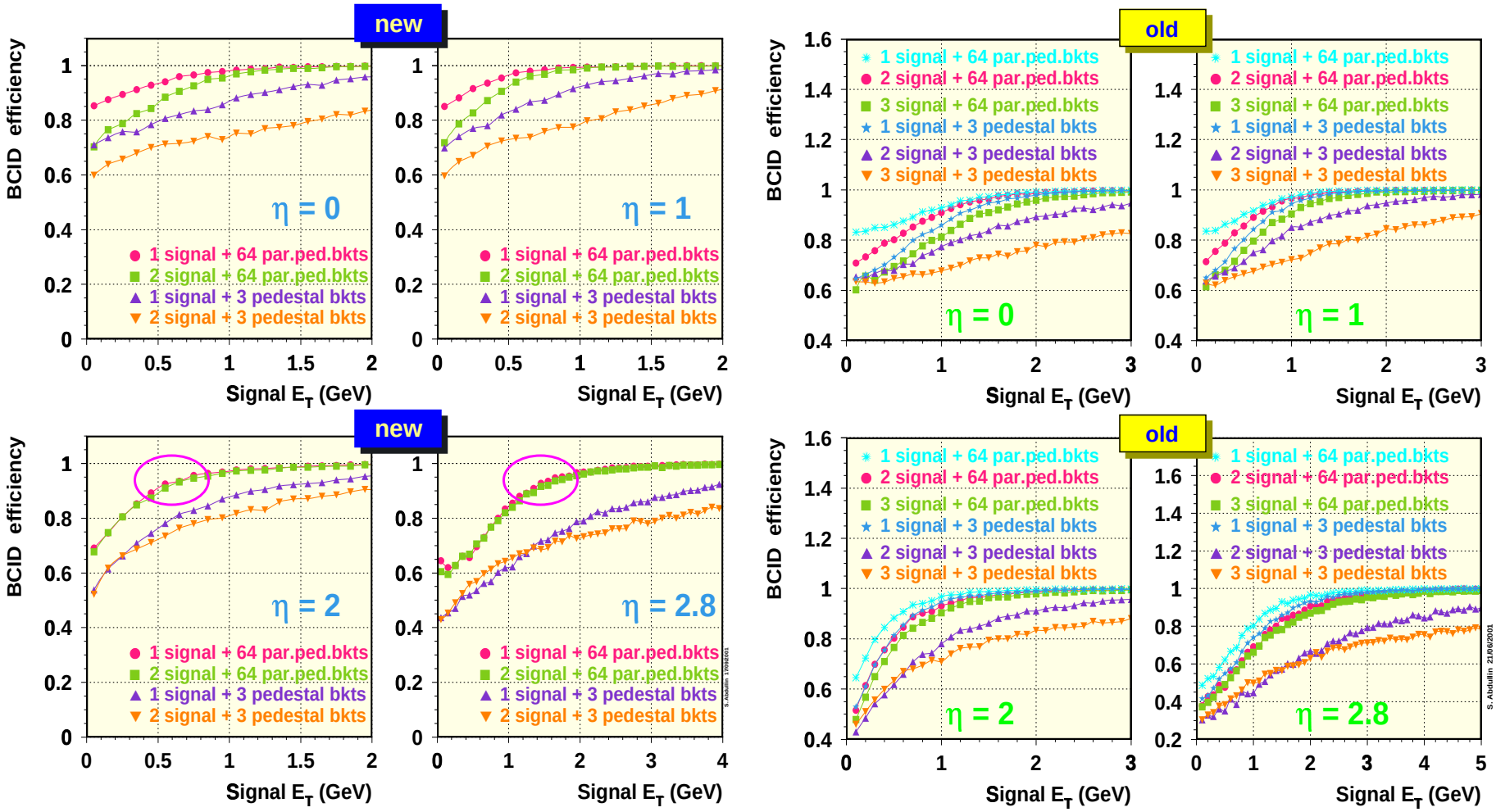








BCID IN CASE OF PILEUP



- The smaller number of buckets - the better BCID

FE SIMULATION SUMMARY

- HCAL code in ORCA updated
- Clearly, the shorter is the signal - the better ...
  - signal resolution
  - BCID
  - occupancy
- Toy MC simulation without pileup :
  - 1,2,... bukets signal content is stable (~ 1%) within 5-6 ns provided time phase is properly tuned
  - 1-bucket collection yields better resolution for low energy signal than 2-buckets one (short signal)
  - idem for 2 vs 3 buckets (long signal)
  - photo statistics effect dominates oved other resolution factors in case of high-energy signal (> 5 GeV) given fixed noise
- Toy MC simulation with pileup :
  - in terms of E_T the situation in HB is similar to no-pileup case
  - in HE pileup dominates (over noise)
  - BCID is better for 1-bucket collection mode (without presamples !)
- More conclusions (as a base for decisions) ...