FRONT END ELECTRONICS in ORCA

and SOME SIMULATION RESULTS

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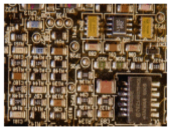
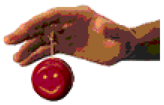


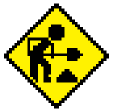
Front end electronics (FE) simulation

- changes/amendments
- first tests
- things to do



Toy simulation of the readout

- noise issues (low luminosity)
- noise + pileup (high luminosity)



Provisional conclusions

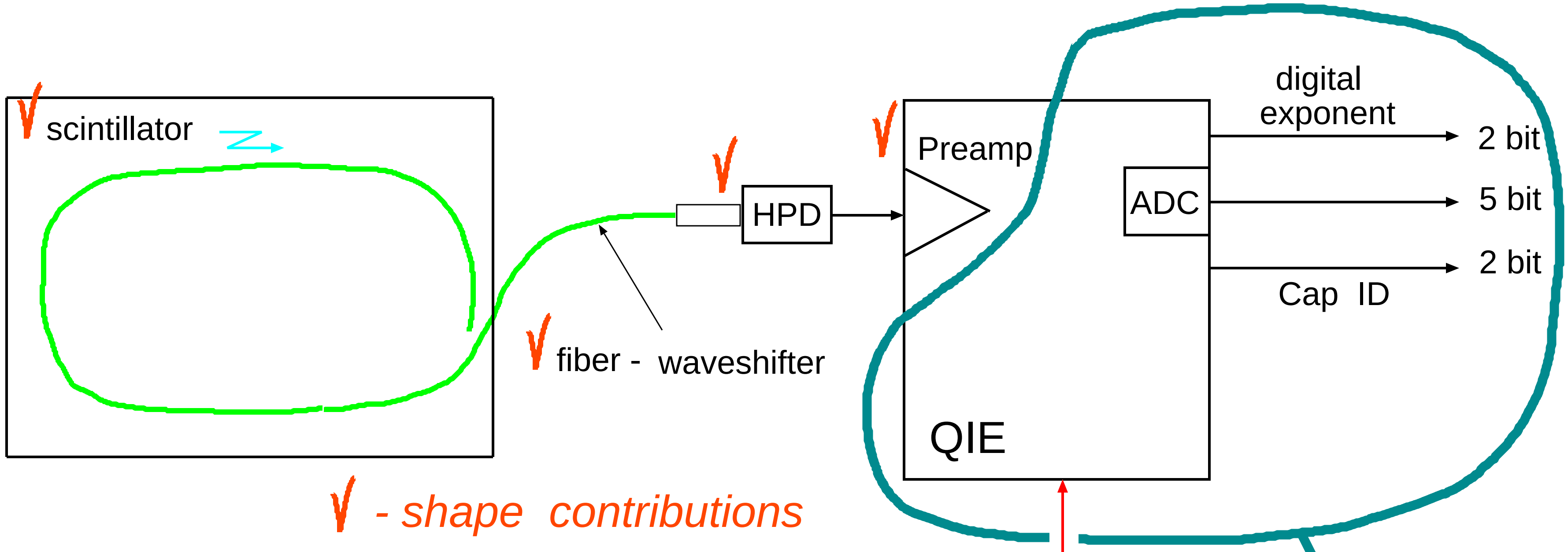
- Currently (incl. ORCA_4_6_0) an "amplitude reconstruction" using linear combination of ampitude measurements in (-3, +5) time samples is being performed ("a la" ECAL)

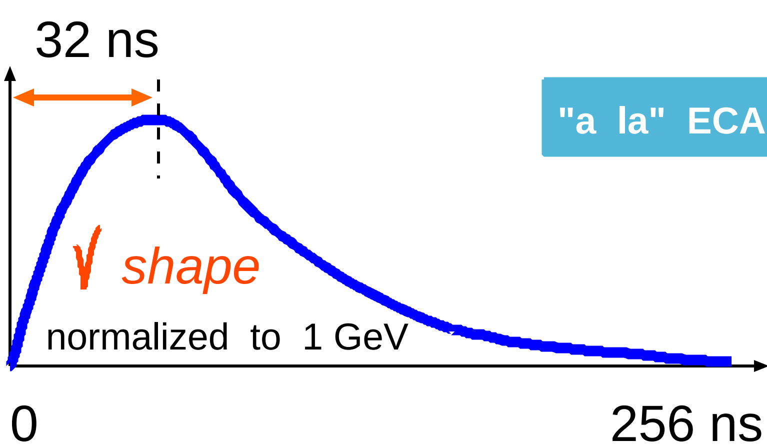
- After CMS week (March, 5-10) a completely different scheme of QIE integration (including ADC quantization) instead of amplitude sampling is tested

- Everything (noise, LSB etc.) expressed in terms of photoelectrons and probably requires some update

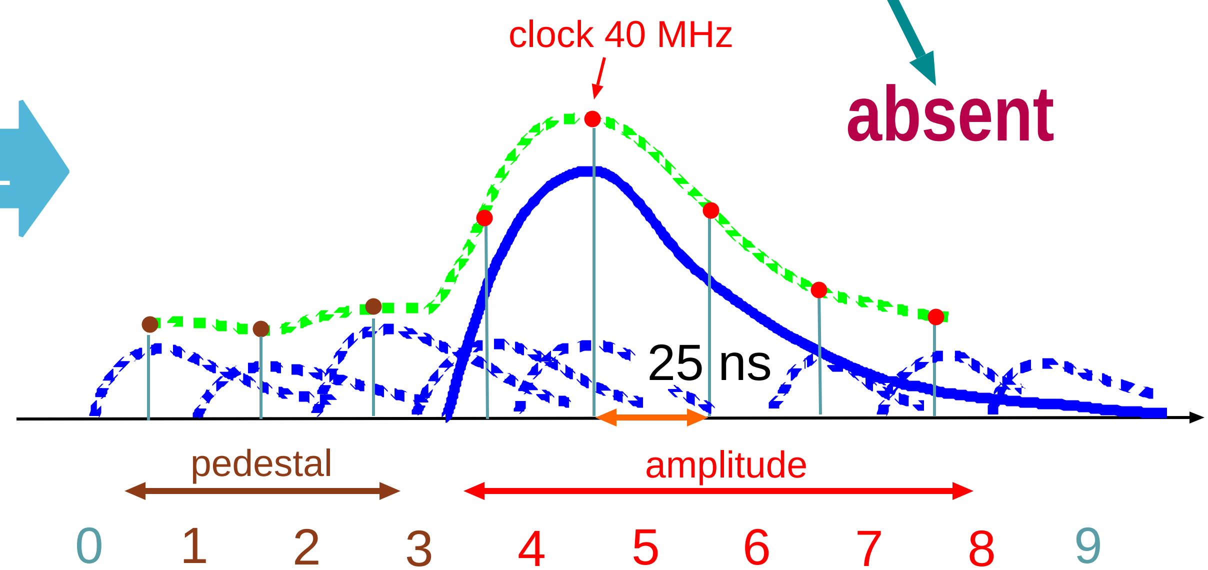
  (currently used 10 pe / GeV)

HCAL ELECTRONICS : CURRENT SITUATION





"a la" ECAL



SHAPE COMPONENTS

- **Scintillator + wave-length shifter**

  $f_d(t) = \exp(-t/\tau_s)$, $\tau_s = 11$ ns

- **HPD**

  $f_{HPD}(t) = 1.0 + (t/\tau_{HPD})$, $\tau_{HPD} = 10$ ns

- **Preamplifier**

  $f_p(t) = t * \exp(-t/\tau_p)$, $\tau_p = 25$ ns

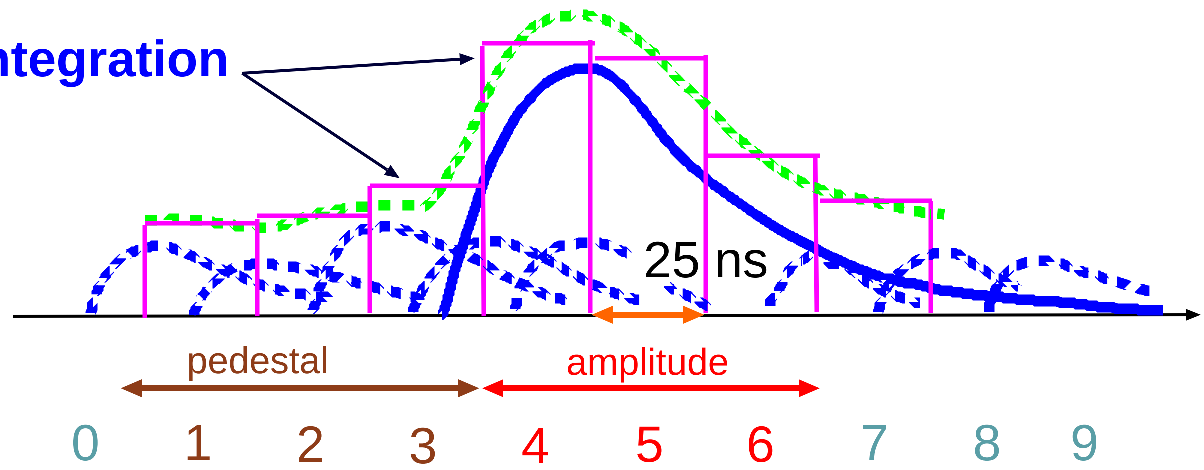
provided by Dan Green

peak time = 32 ns

- **Other contributions ?**

HCAL ELECTRONICS : MAIN CHANGES

- **QIE integration**



- **ADC quantization according to FADC table with 4 variable-size bin ranges.**

- **Photo statistics effect is implemented**

- **HB/HE : GEANT Hit jitter**
  - **HCAL Hit time step = 1 ns starting from CMSIM 118, not 10 as before !**

- **HF splitted from HB/HE**

ADC QUANTIZATION

HCAL QIE Transfer Function
QIE Data Word

MSB	6	5	4	3	2	LSB
Range #		FADC Code				

Range 1			Range 2			Range 3			Range 4		
FADC code	Bin Size	Charge	FADC code	Bin size	Charge	FADC code	Bin size	Charge	FADC code	Bin size	Charge
0	1	-1.5	32	5	•	64	25	•	96	125	•
1	1	-0.5	33	5	•	65	25	•	97	125	•
2	1	0.5	34	5	62.5	66	25	372.5	98	125	1922.5
3	1	1.5	35	5	67.5	67	25	397.5	99	125	2047.5
4	1	2.5	36	5	72.5	68	25	422.5	100	125	2172.5
5	1	3.5	37	5	77.5	69	25	447.5	101	125	2297.5
6	1	4.5	38	5	82.5	70	25	472.5	102	125	2422.5
7	1	5.5	39	5	87.5	71	25	497.5	103	125	2547.5
8	1	6.5	40	5	92.5	72	25	522.5	104	125	2672.5
9	1	7.5	41	5	97.5	73	25	547.5	105	125	2797.5
10	1	8.5	42	5	102.5	74	25	572.5	106	125	2922.5
11	1	9.5	43	5	107.5	75	25	597.5	107	125	3047.5
12	1	10.5	44	5	112.5	76	25	622.5	108	125	3172.5
13	1	11.5	45	5	117.5	77	25	647.5	109	125	3297.5
14	1	12.5	46	5	122.5	78	25	672.5	110	125	3422.5
15	1	13.5	47	5	127.5	79	25	697.5	111	125	3547.5
16	2	14.5	48	10	132.5	80	50	722.5	112	250	3672.5
17	2	16.5	49	10	142.5	81	50	772.5	113	250	3922.5
18	2	18.5	50	10	152.5	82	50	822.5	114	250	4172.5
19	2	20.5	51	10	162.5	83	50	872.5	115	250	4422.5
20	2	22.5	52	10	172.5	84	50	922.5	116	250	4672.5
21	2	24.5	53	10	182.5	85	50	972.5	117	250	4922.5
22	2	26.5	54	10	192.5	86	50	1022.5	118	250	5172.5
23	3	28.5	55	15	202.5	87	75	1072.5	119	375	5422.5
24	3	31.5	56	15	217.5	88	75	1147.5	120	375	5797.5
25	3	34.5	57	15	232.5	89	75	1222.5	121	375	6172.5
26	3	37.5	58	15	247.5	90	75	1297.5	122	375	6547.5
27	4	40.5	59	20	262.5	91	100	1372.5	123	500	6922.5
28	4	44.5	60	20	282.5	92	100	1472.5	124	500	7422.5
29	4	48.5	61	20	302.5	93	100	1572.5	125	500	7922.5
30	5	52.5	62	25	322.5	94	125	1672.5	126	625	8422.5
31	5	57.5	63	25	347.5	95	125	1797.5	127	625	9047.5

Bin Size and Charge are in fC, for HB 1fC ≈ 0.3Gev
Charge – minimum charge for the bin (low threshold)
• - These codes never occur, if charge is less than 62.5 fC we see code 31 and never see codes 32,33,64,65,96,97
If there is an occasional fluctuation at the range #1 we might see code 0.
In this table assumption is that pedestal is in bin 2 (code 1), which is probably close to what the ASIC developer is trying to achieve.

- **Currently in ORCA quantization is performed as x 100000 and : 100000, thus LSB = 1-2 MeV (~ 0)**
- **Update : 4 ranges with variable bin size to follow closer energy resolution ~ $a/\sqrt{E}$ + b behaviour**
- **LSB is taken (for a while) as 3 photoelectrons ~ 300 MeV**

ADC IN ACTION

bin No	FADC code	bin energy (MeV)	code → energy
1	0	-450 to -150	-300
2	1	-150 to 150	0*
3	2	150 to 450	300
4	3	450 to 750	600
5	4	750 to 1050	900

default baseline *

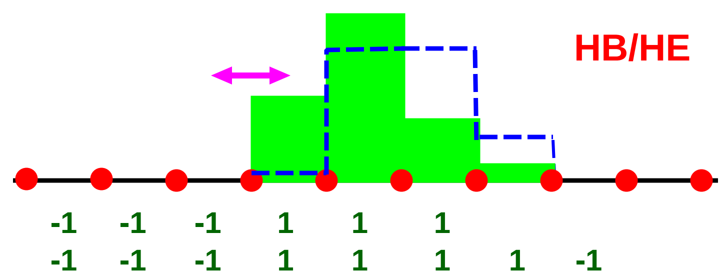
* important : results fairly slightly depend on a random baseline variation within one ADC bin

Separation is not straightforward as HF/HB/HE are all in "HCAL"

- if (MyCell().WhichSubDetector() == "HF") is required in some cases

HF and HB/HE divergencies

- photostatistics variation : already taken into account for HF in CMSIM
- noise : 2 pe (HB/HE) and 0.125 pe (HF)
- shape : short HF signal (peak time ~ 3-4 ns) and longer HB/HE one (32 ns)
- QIE integration : HF signal can be integrated within one time bucket
- hence different weights pattern for HF and HB/HE time buckets
  both in TPG and off-line (RecHit)
- QIE sensitivity : LSB = 0.43 pe for HF and 3 pe for HB/HE
- time phase tuning :
  (HF doesn't have proper GEANT time)



ORCA CODE : CHANGED PACKAGES (I)

HcalRealistic

- class HcalRealisticShapeHF added
- class HcalRealisticReadout changed

  pub. methods added Shape HF, SigmaElecNoiseHF, PeakTimeHF, PeakTimeAdjust, PeakTimeAdjustHF, GeVtoPE, PEtoGeV

  pub. methods changed HcalRealisticNoisifier
- class HcalRealisticCoder changed

  pub. methods added GetCodeFADC, GetEnergyFADC

  pub. methods changed convert

HcalRealisticRec

- class HcalRealisticAnalyser changed

  pub. methods changed evalAmplitude, computeWeights

HcalTrigPrim

- class HcalTrigAnalyser added
- class HcalTrigPrimFormatter changed

  pub. methods changed constructor, reconstruct
- class HcalTrigAnalyser changed

  pub. methods changed evalAmplitude, computeWeights

CaloReadout

not HCAL-specific

- class CaloFrontEndResponse changed
  pub. members changed samplecache
  pub. methods changed getCache -> getSampleCache, constructor, lazyUpDate

- class CellReadout changed
  pub. methods added Calibration (returns rscale)
  pub. methods changed constructor (DepthGain*Factor -> private member rscale)

- class CaloScaler changed
  pub. methods changed Scale

- class CaloDataFrame changed
  pub. methods added getTriggerEnergy, setTriggerEnergy,
  getPUinTimeEnergy, setPUinTimeEnergy,

- class CaloTimeSample changed
  pub. methods added getTriggerEnergy, setTriggerEnergy,
  getPUinTimeEnergy, setPUinTimeEnergy,

ORCA CODE : CHANGED PACKAGES (III)

CaloRecHit

- class CaloRecHitFormatter changed
  pub. methods changed reconstruct ← not HCAL-specific

CaloTrigRec

- class CaloTrigRecSetup changed

CaloDetector

- class CellID changed
  pub. methods added getUniqueNum, setUniqueNum
- class CellProperties changed
  pub. methods added getNum, setNum

LIST of NEW SimpleConfigurables

Hcal:DoADC = 1	bool	ADC simulation switch
Hcal:TakeGeantHitTime = 1	bool	GEANT Hit time switch
Hcal:FADCcalibration = 3.	real	LSB (photo electrons) for HB/HE
Hcal:FADCcalibrationHF = 0.43	real	LSB (photo electrons) for HF
Hcal:noiseHF = 0.125	real	noise sigma for HF (photo electrons)
Hcal:enoise = 0.0006	real	old noise sigma (DoADC = 0) in GeV
Hcal:CollectionFactor = 1.11	double	RecHit correction for 2-bucket coll.
HcalTrig:CollectionFactor = 1.11	double	TrigPrim correction for 2-bucket coll.
Hcal:TimePhaseAdjust = 23.	real	tunable time phase for signal collection

Hcal:photostatHB1 = 0.00085	real	GEANT Hit energy (GeV) per photo electron in various HB/HE layers
Hcal:photostatHB2 = 0.00068	real	
Hcal:photostatHB3 = 0.00045	real	
Hcal:photostatHB4 = 0.00067	real	
Hcal:photostatHE1 = 0.00064	real	
Hcal:photostatHE2 = 0.00045	real	
Hcal:photostatHE3 = 0.00045	real	

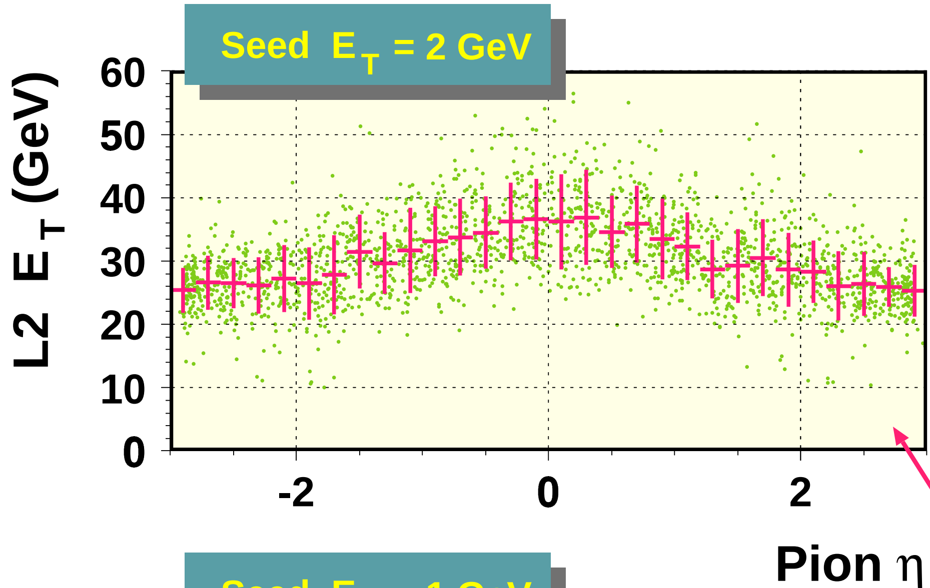
CODE : OLD -> NEW SMOOTH TRANSITION ?

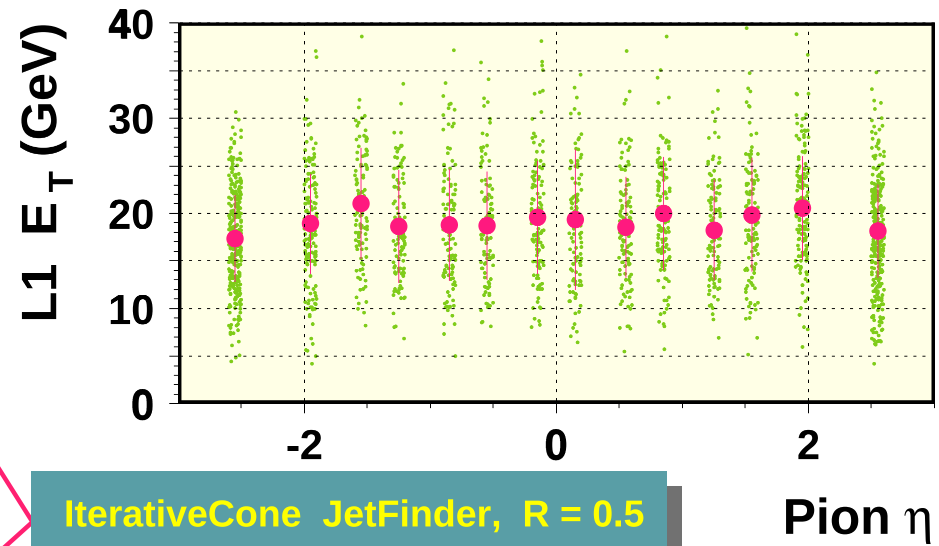
- **The plan was (~ 0.5 year ago) to change ORCA code to make it close to the hardware design and then to study the performance with some adjustment of the off-line signal evaluation (pileup subtraction etc.)**

- **This plan has migrated to the side of the hardware (first of all TPG) optimization as we don't yet precisely know some characteristics of the hardware componets**
  - **ADC baseline position and stability (fast/slow time components)**
  - **Noise value**
  - **Optimal signal evaluation (incl. pedestal subtraction) and BCID (bunch-crossing identification) in TPG w/wo pileup**

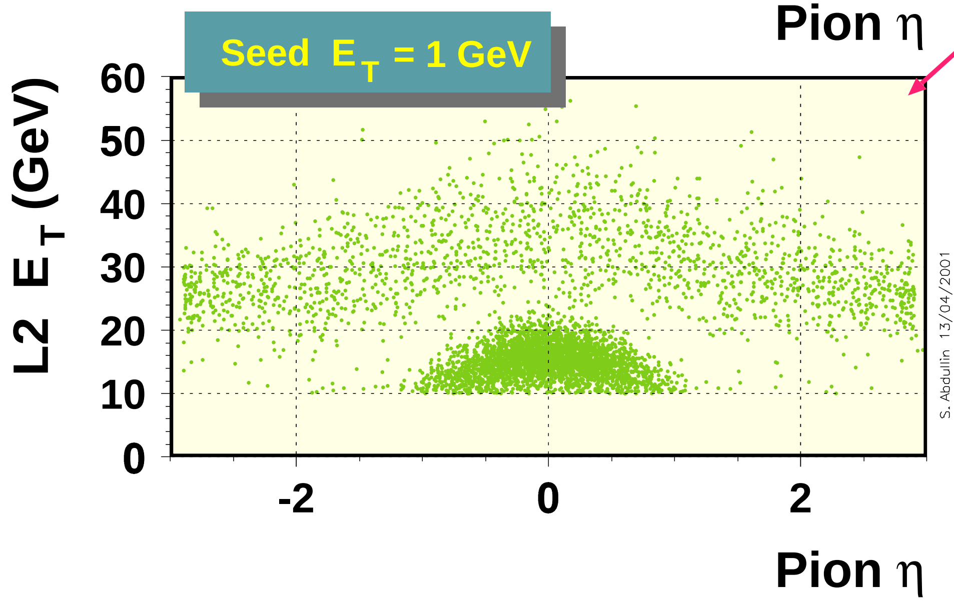
as many of them are not yet commited and their development is under way

SOME SIMPLE TESTS : NOISE IS AN ISSUE





IterativeCone JetFinder, R = 0.5

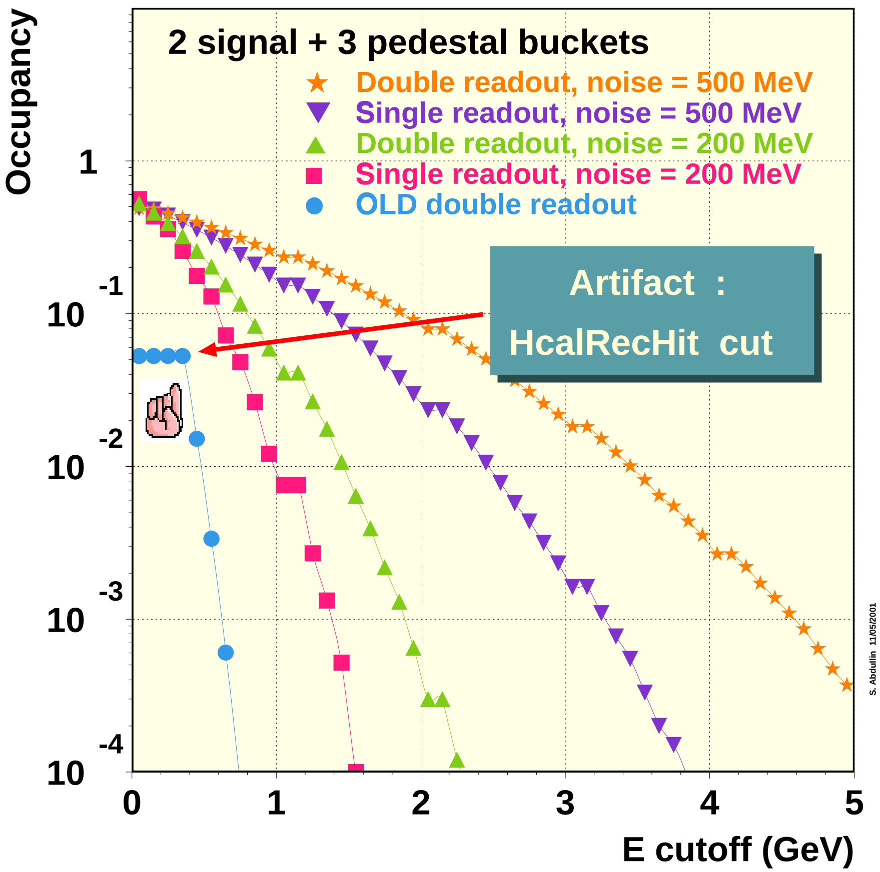


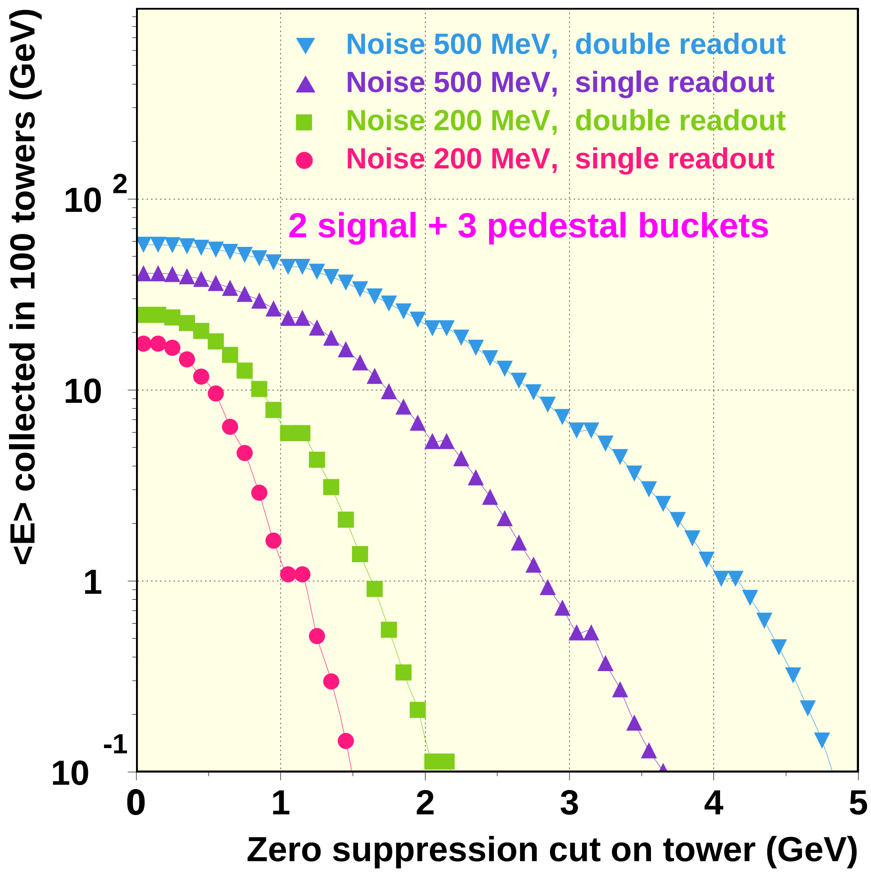
- 3 signal + 3 pedestal buckets (weights : -1,-1,-1, 1,1,1)

some ("dirty") tricks : (i) code = 0 ignored

(ii) ADC scale shifted by -1/2 channel

NOISE LOOKS WORRISOME





- **"Double readout" stands for (trigger) tower consisted from 2 layers (thus 2 readouts)**
- **Baseline in the 6th ADC channel**

ONE LAYER INSTEAD of FORMER TWO in HB/HE

2 readouts -> 1

- **Saves money and reduces the noise**
  - noise : per readout per time bucket

- **GEANT (CMSIM) or ORCA to change ?**
  - GEANT geometry description update looks more natural
  - HcalBase (unfortunately not only it) contains too many "hardwared" "dirty tricks" (yuck !) - to increase their numbers ?

- STOP **Requires HCAL re-calibration anyway**
  - preferably with fairly low-pt pions (10-20 GeV)

ORCA TODO LIST

2 -> 1 layer transition

- minimal changes if CMSIM takes it into account
- more elaborate (and less "natural") if ORCA needs to accomodate the things (but possible)

Pedestal subtraction scheme (under study)

- current code architecture is designed for the sequential time buckets treatment, e.g. 3 pedestal ("pre-samples") + 2 signal ("post-samples")
- a deviation, such as "parallel pedestal calculation" requires some (substantial ?) work

A number of minor improvements

FE TOY SIMULATION

Motivation : fast simulation of various signal + pedestal evaluation schemes etc.

- "test bed" for ORCA, as we didn't fully understand FE response for various parameters

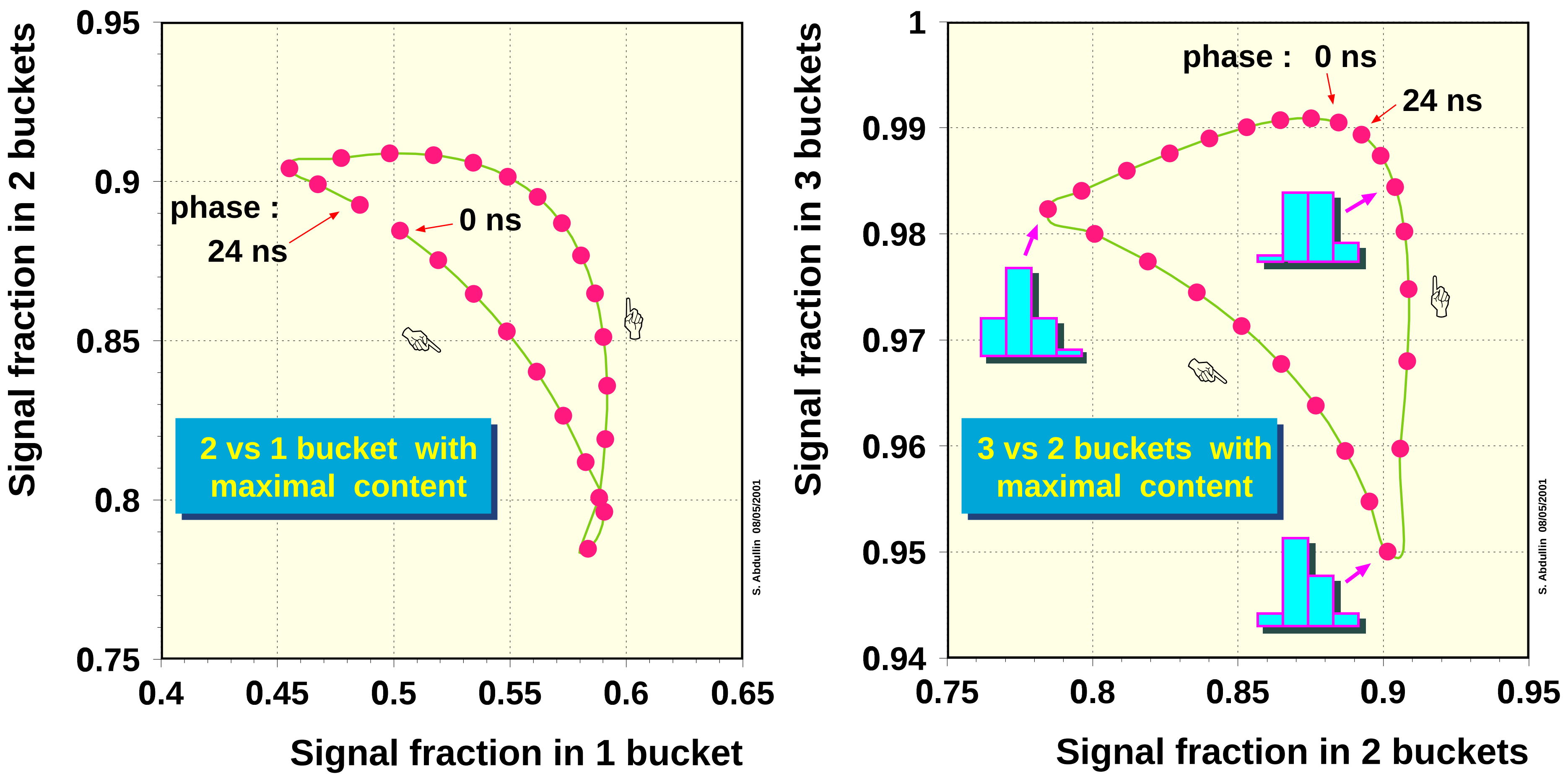
Preserves basic ORCA FE functionality :

- the same noise simulation
- the same time bucket series (TimeSample & DataFrame)
- the same shape parametrization
- the same ADC quantization

Misses GEANT hit arrival time jitter

- typically small (2-3 ns for relatively high signals)
- proper time phase adjustment makes the effect smaller as the signal fraction collected in 2(3) time buckets has a good stability within a few ns range (see later on).

SIGNAL COLLECTION



- parameterased signal shape = f(t) : convolution of 3 shape components (p.4)
- t = time_of_maximum(32 ns) - tuning phase

NOISE : CALCULATIONAL DETAILS

- **Single readout is considered**

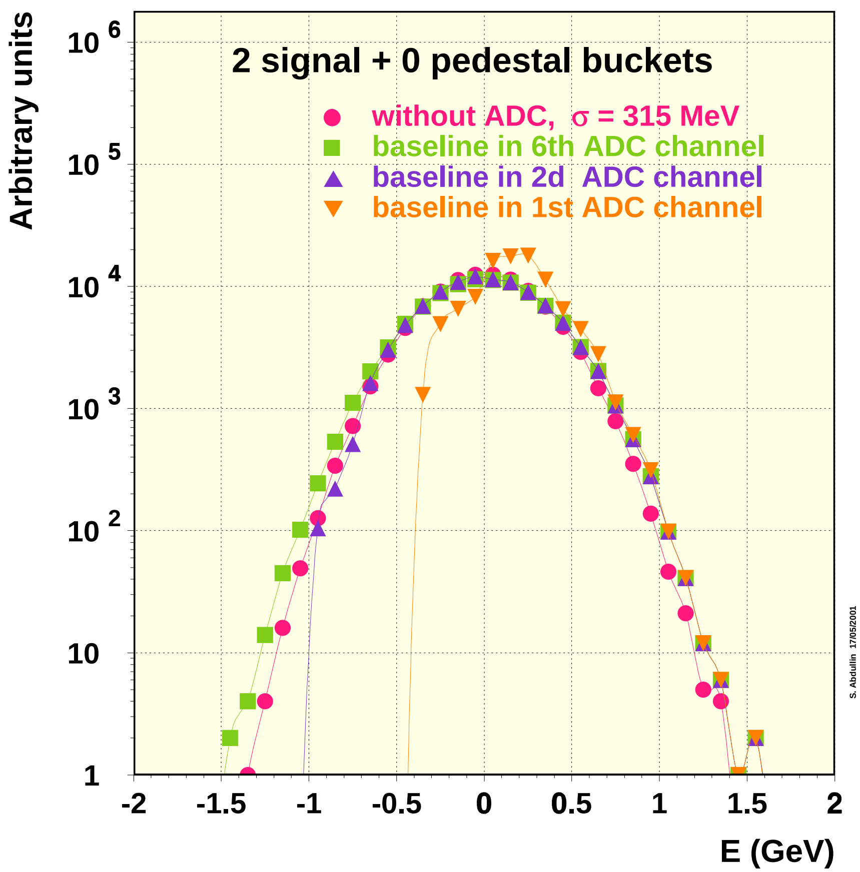
- **Gaussian noise with σ = 200 MeV (equivalent of 2pe) contributes to each time bucket (might be bigger ?)**

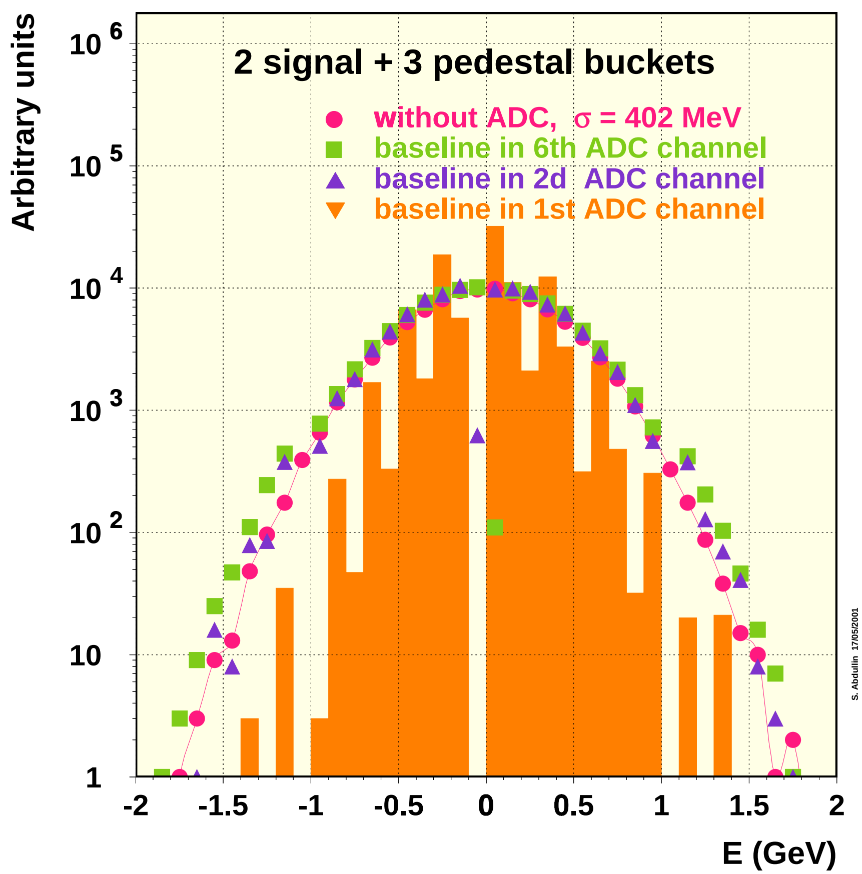
- **"0 pedestal" buckets case corresponds to an assumption that the baseline is known precisely (from Maxwell's daemon ?)**

- **Baseline is randomly smeared within given ADC bin for each new series of time buckets for every single signal evaluation**

- **LSB = 300 MeV**

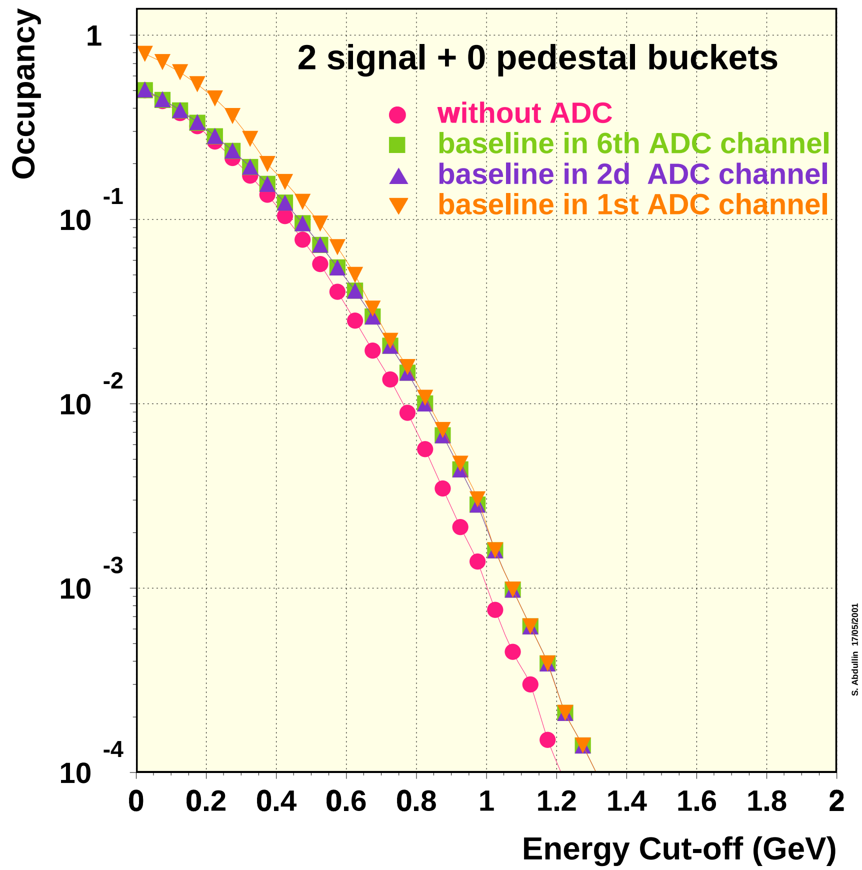
BASELINE POSITION (I)

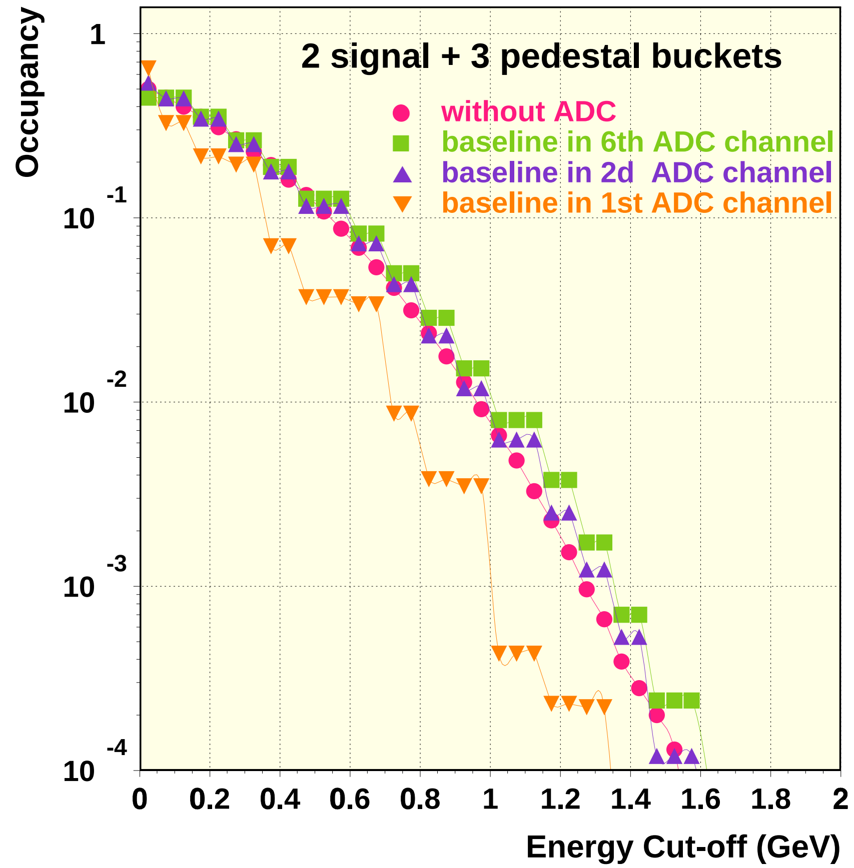




- **Quantization effect is smeared, as "floating" baseline is assumed to be precisely measured and subtracted**
- **Quantization effect is clearly seen, as pedestal is evaluated together with signal**

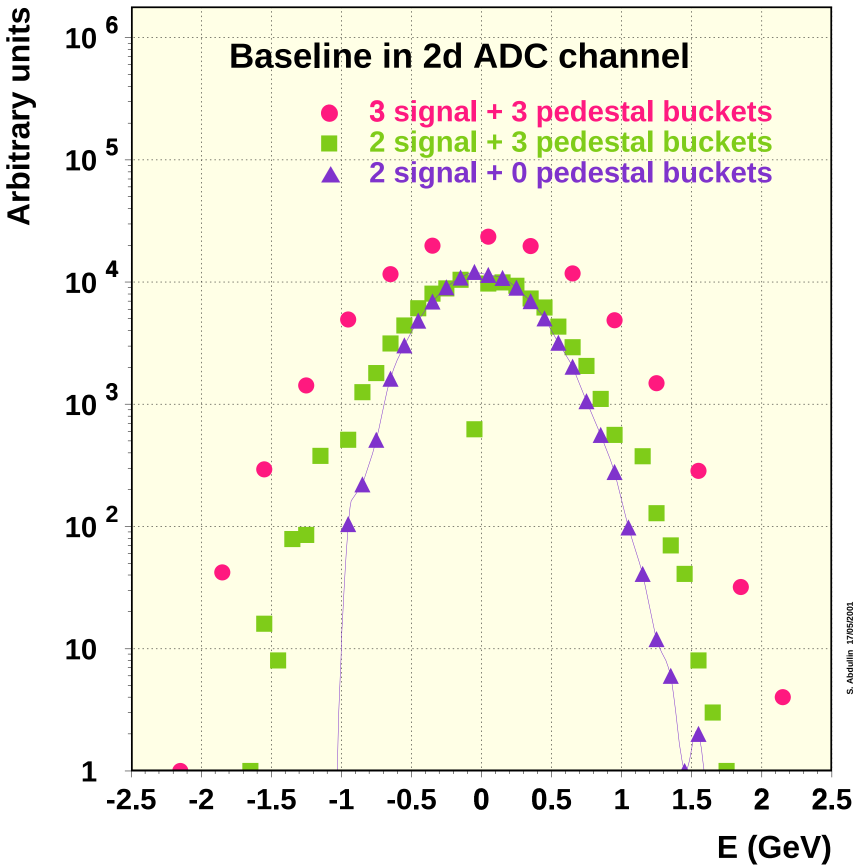
BASELINE POSITION (II)

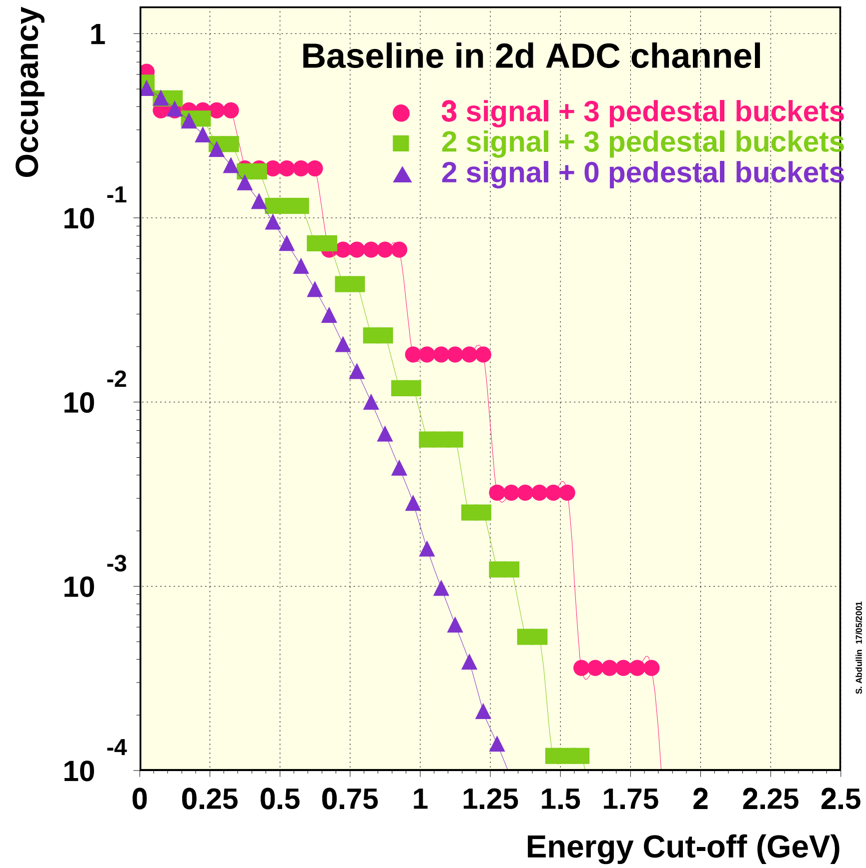




- **Just another representation of the previous transparency**

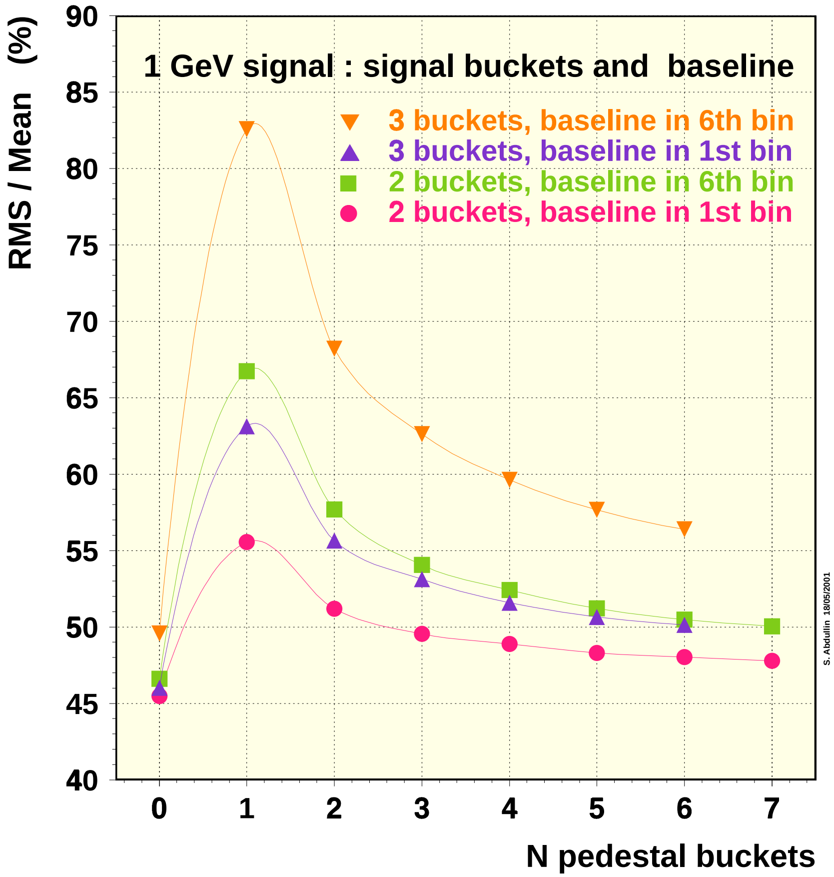
NOISE IN VARIOUS SIGNAL COLLECTION MODES

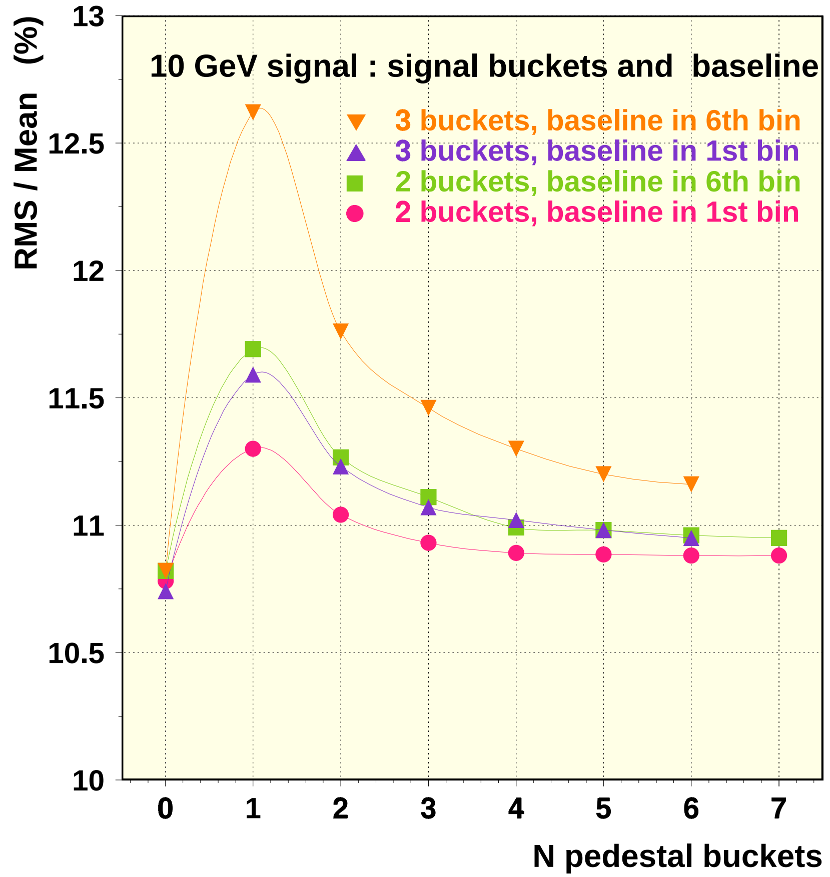




- **Both differential and "integrated" noise representation**

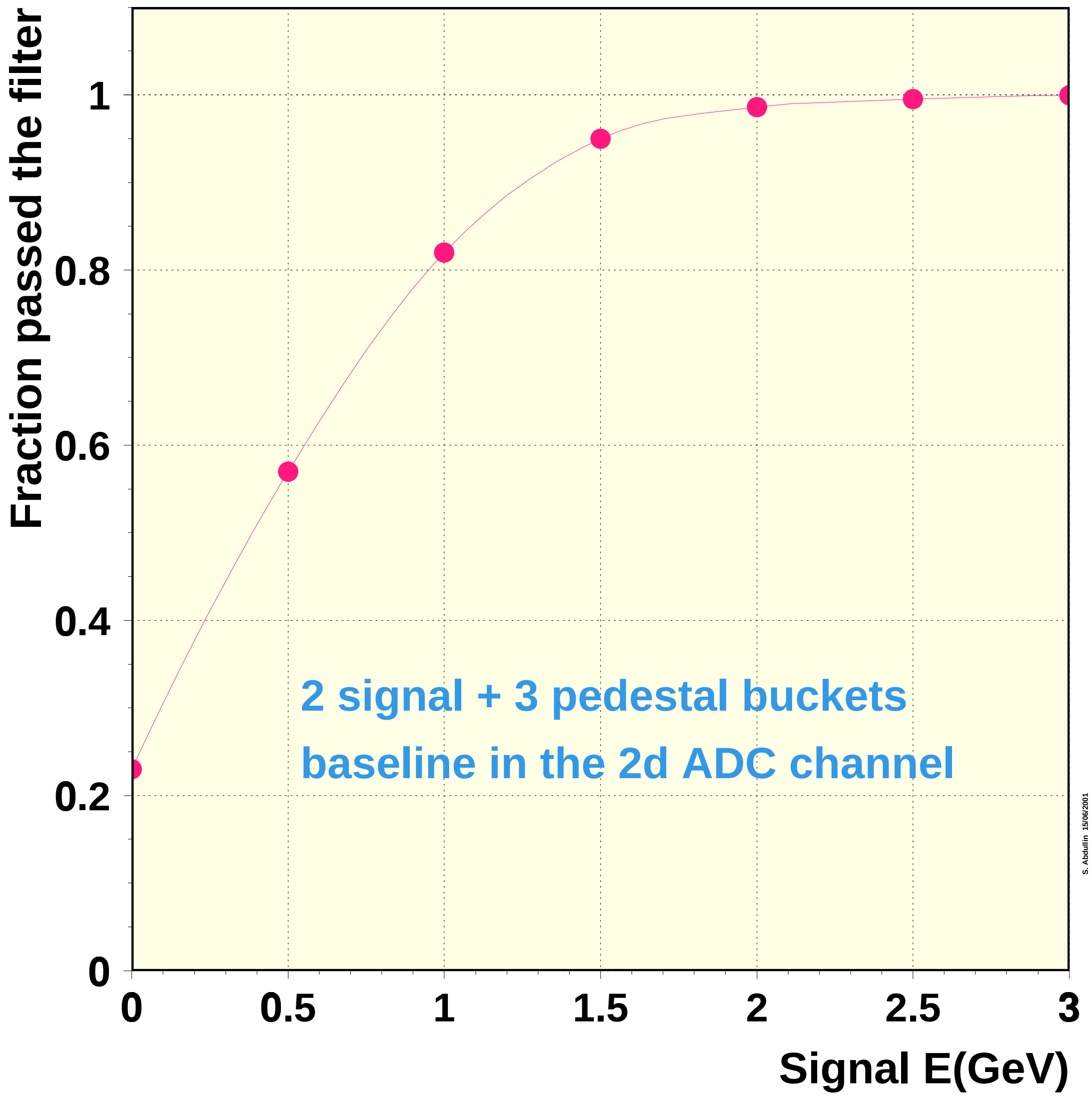
SIGNAL RESOLUTION FOR VARIOUS MODES



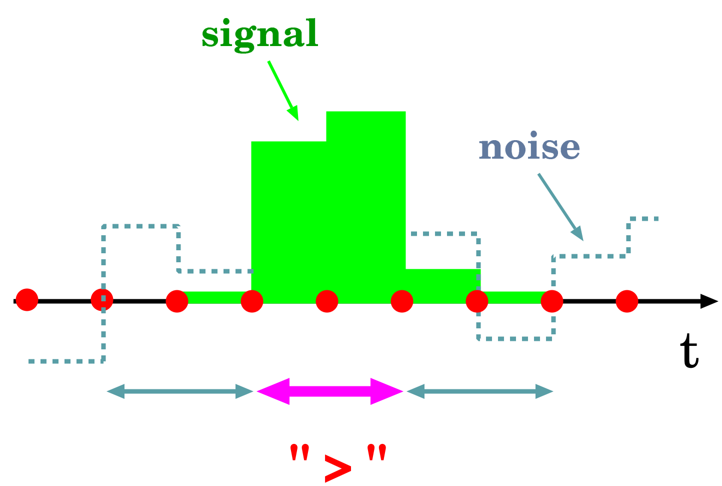


- **Ideal baseline knowledge doesn't much improve resolution**
- **2 signal buckets collection mode looks slightly better than 3 one**
- **1st ADC channel as a baseline position is a bit better than others**

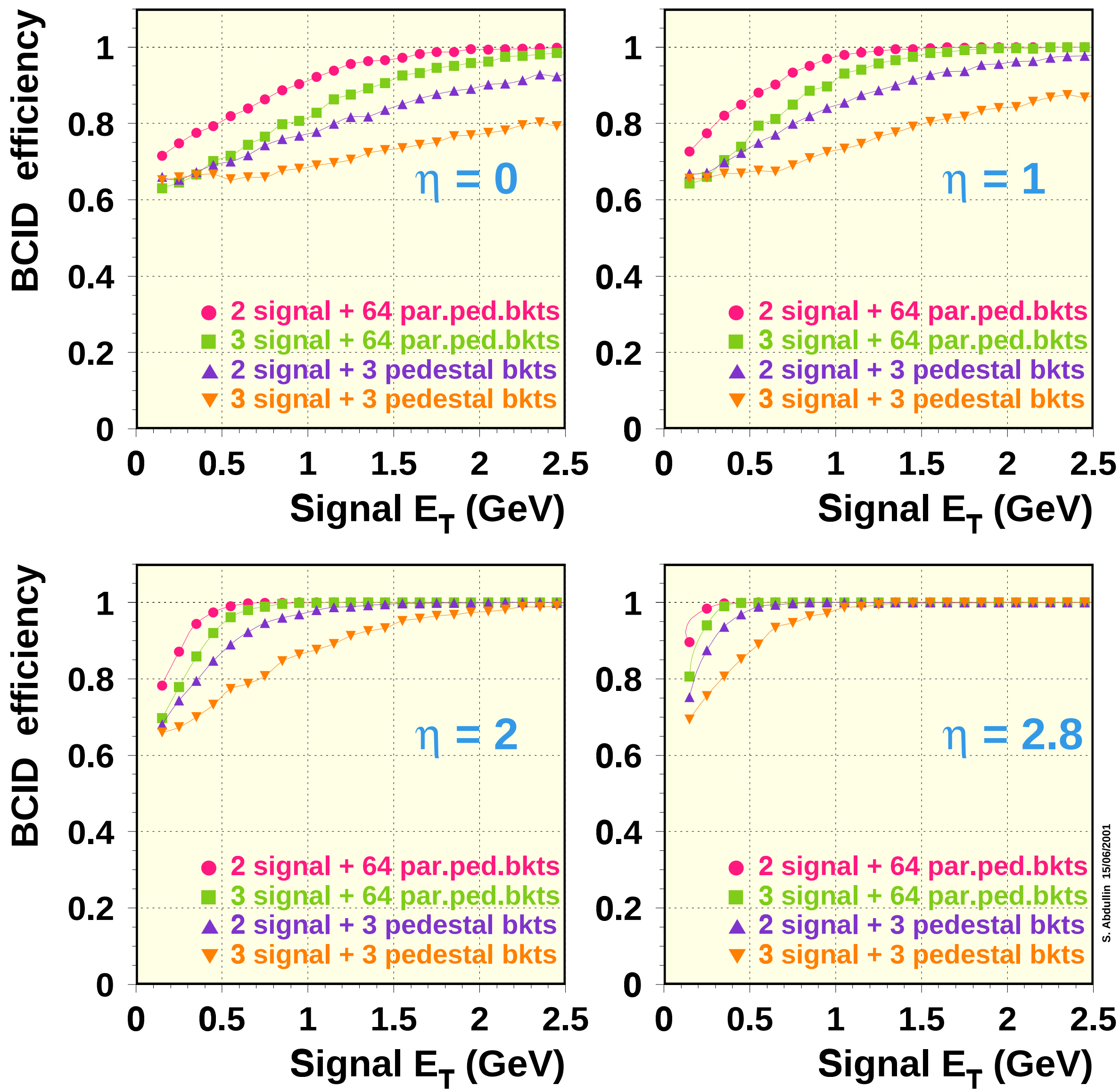
NOISE (SHAPE) FILTER ?



- **The simplest shape filter**
  - **no zero suppression**
  - **"effective" zero suppression**



BCID versus SIGNAL E_T without PILEUP



BCID procedure :

- Signal is evaluated with weights corresponding to the collection modes in "true" time
- Only positive values are considered (zero suppression first)
- Signal is also evaluated with weights pattern shifted by +1, -1 time bucket
- If signal is maximal (≥) with zero shift - BCID is OK

NOISE + PILEUP : CALCULATIONAL DETAILS

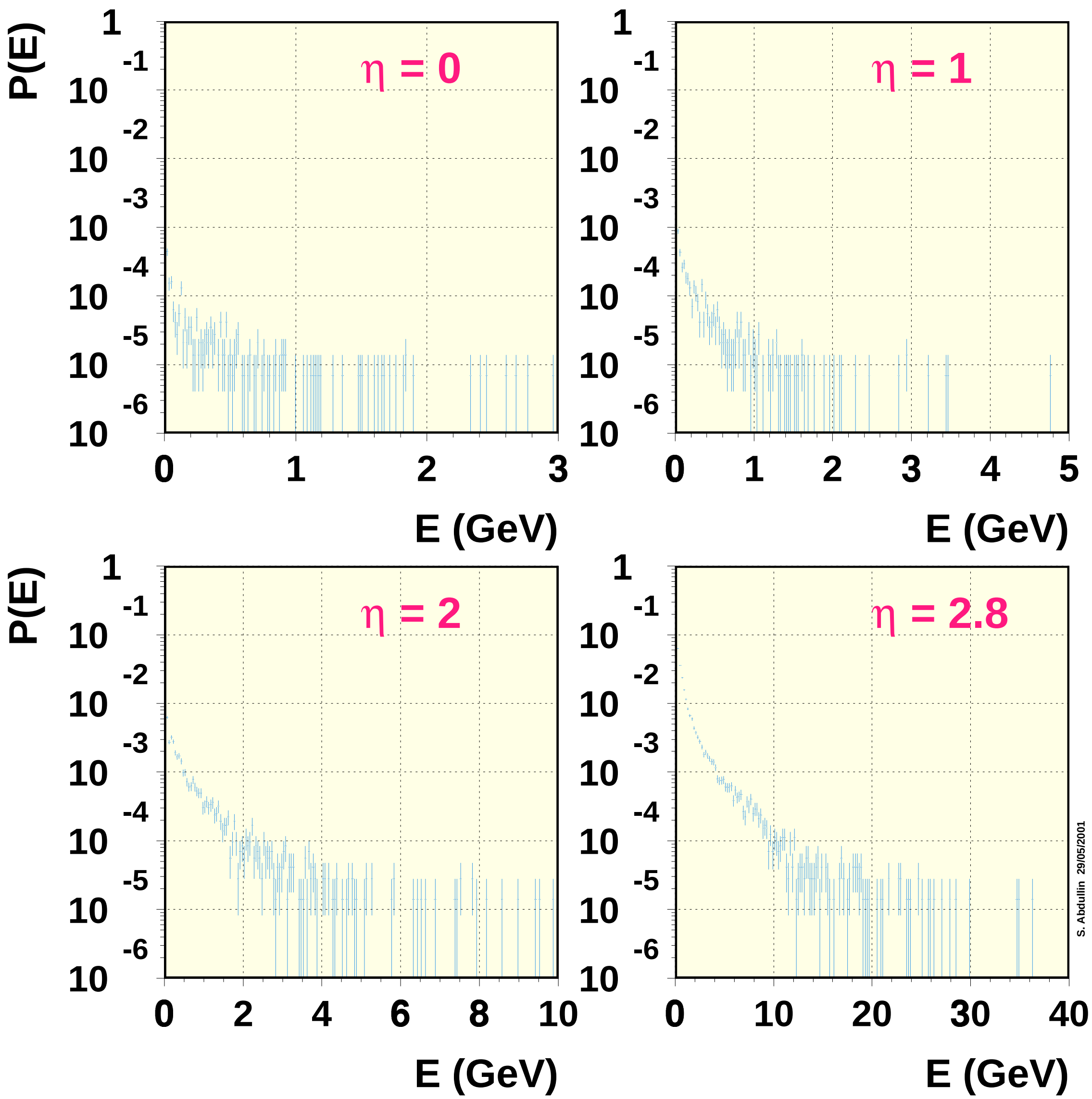
- Baseline is set in the 2d ADC channel unless another position is explicitly indicated

- "+ 64 p.ped. bkts" means pedestal is calculated as an average of independent "parallel" series of 64 digitized time buckets measuremens excluding 2(3) signal buckets

- Baseline is randomized within ADC channels (same way as for noise simulation)

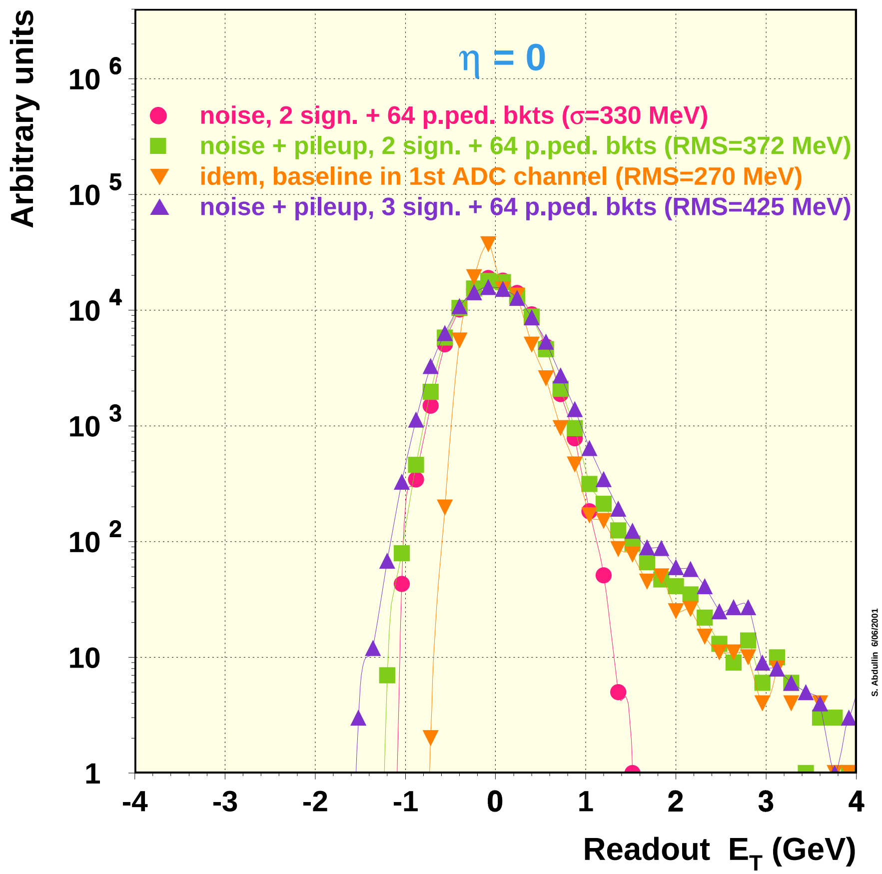
- Min.bias P(E) distributions are obtained with ORCA_4_5_0 by digitizing min.bias ooHits with noise = 0 and RecHits threshold = 0

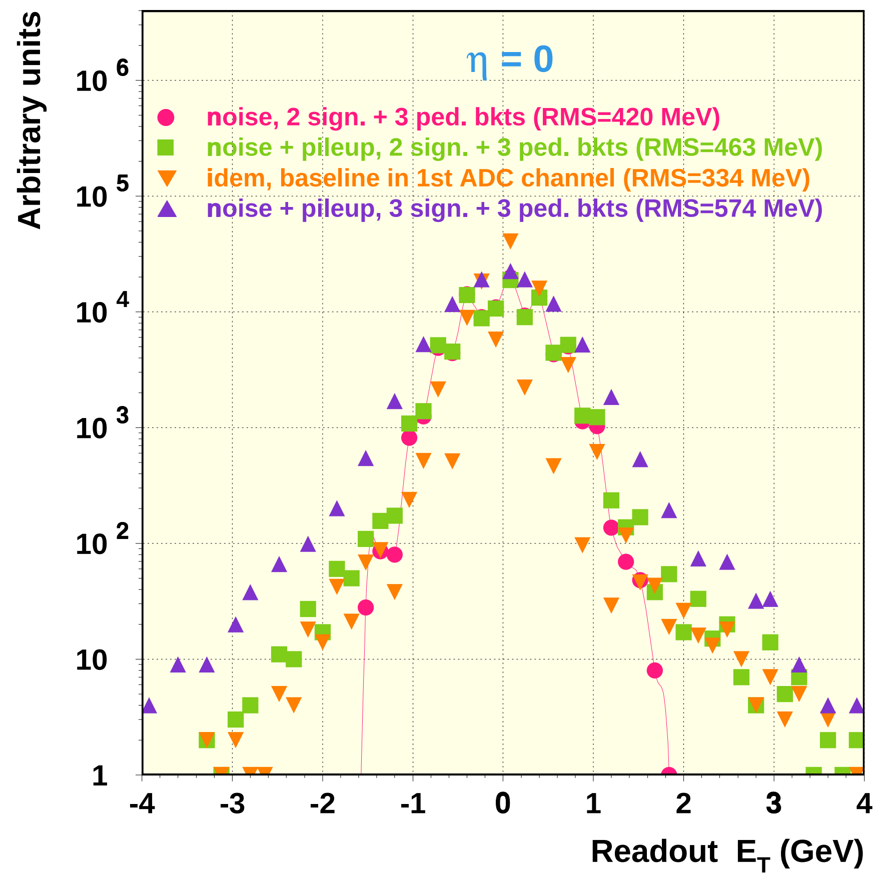
SINGLE MIN.BIAS P(E) DISTRIBUTIONS -> PILE UP



- **Single readout :**
  - energy summed up over 2 depth layers
- **Pileup in toy MC :**
  - Poisson distribution
  - <17.3> min.bias events per time bucket added synchronously
  - Resulting energy is smeared according to Poisson (E-> photoelectrons)
  - Energy is distributed over time buckets according to the parameterized shape
  - Time phase is adjusted against the collection mode (2 or 3 signal buckets)

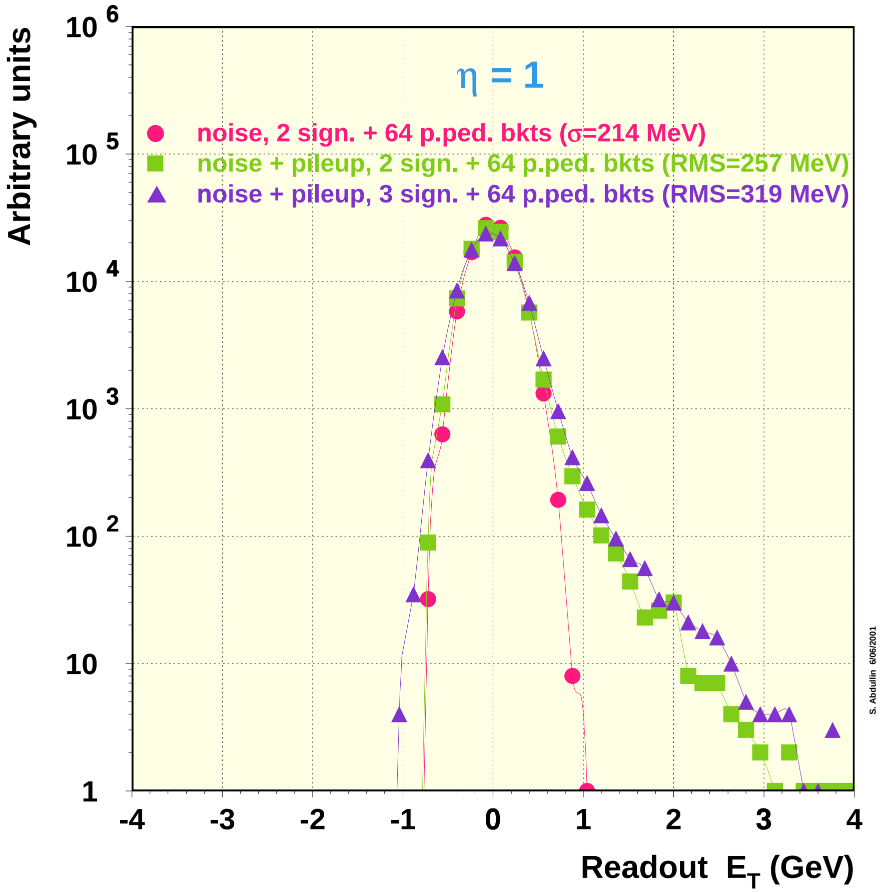
NOISE + PILEUP ET DISTRIBUTIONS (I)

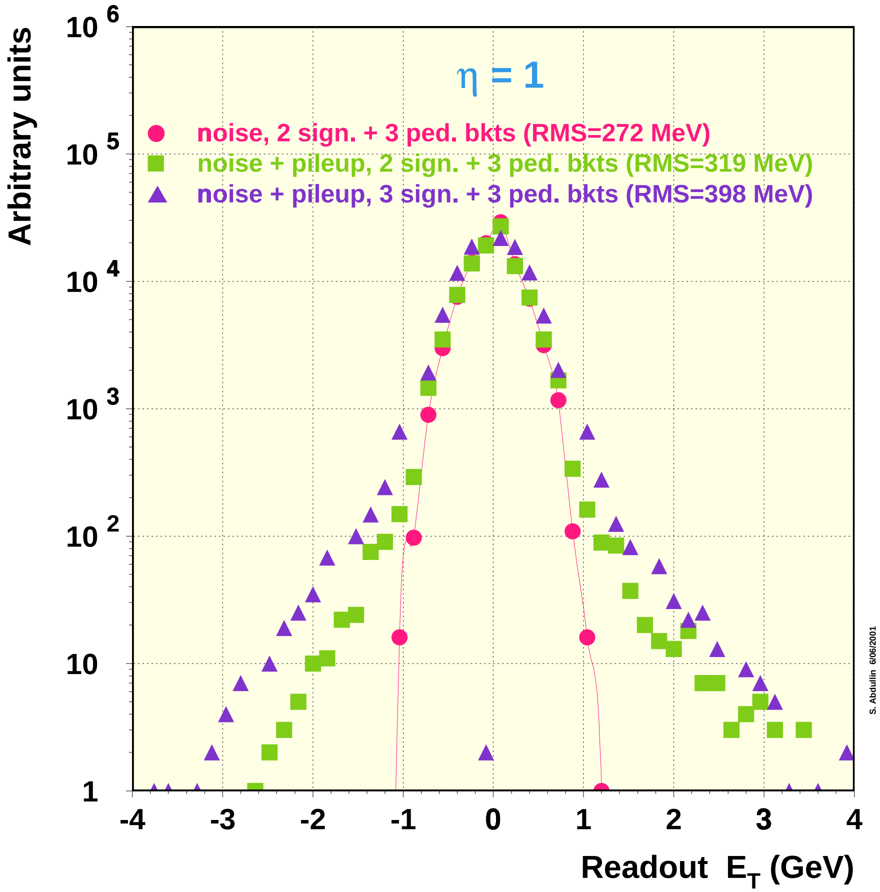




- In the central region noise > pileup
- Baseline in the 1st ADC channel is slightly better than in 2d
- 2 signal buckets collection mode looks better than 3-mode

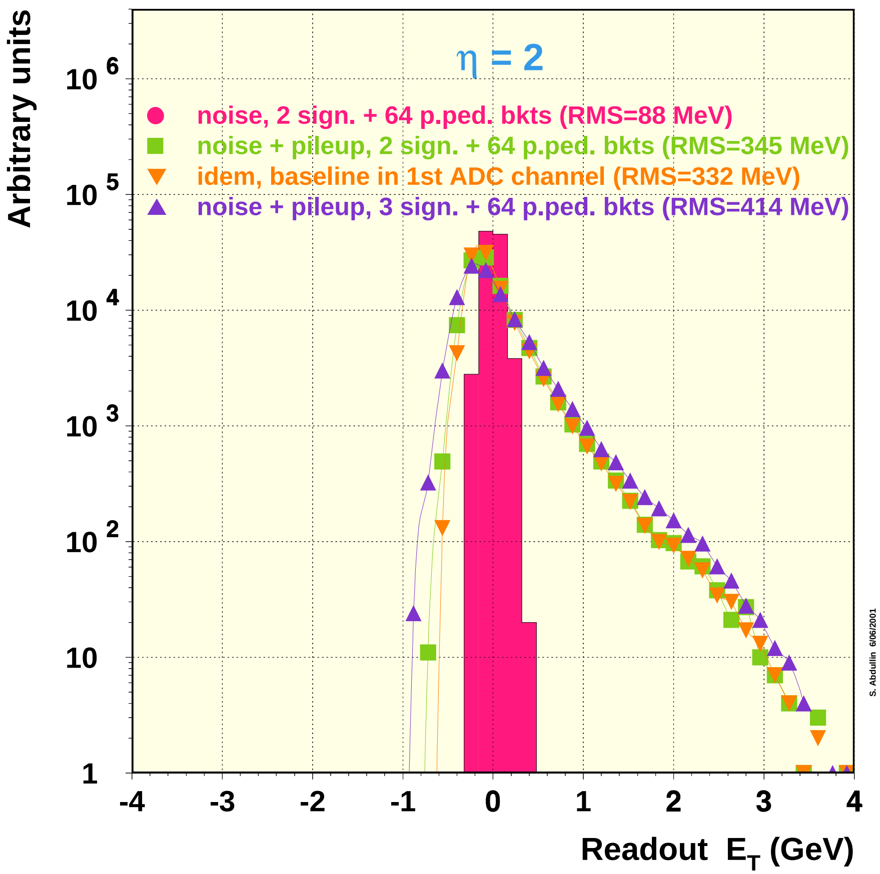
NOISE + PILEUP ET DISTRIBUTIONS (II)

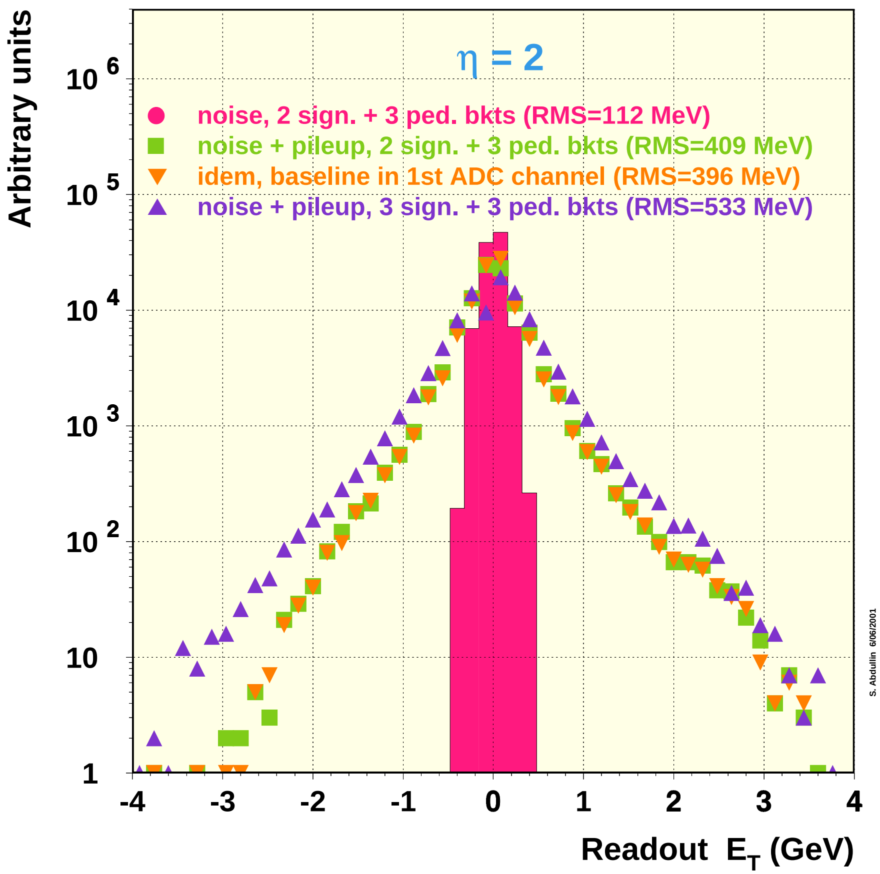




- Similar to previous transparency
- Some eta suppression of the widths

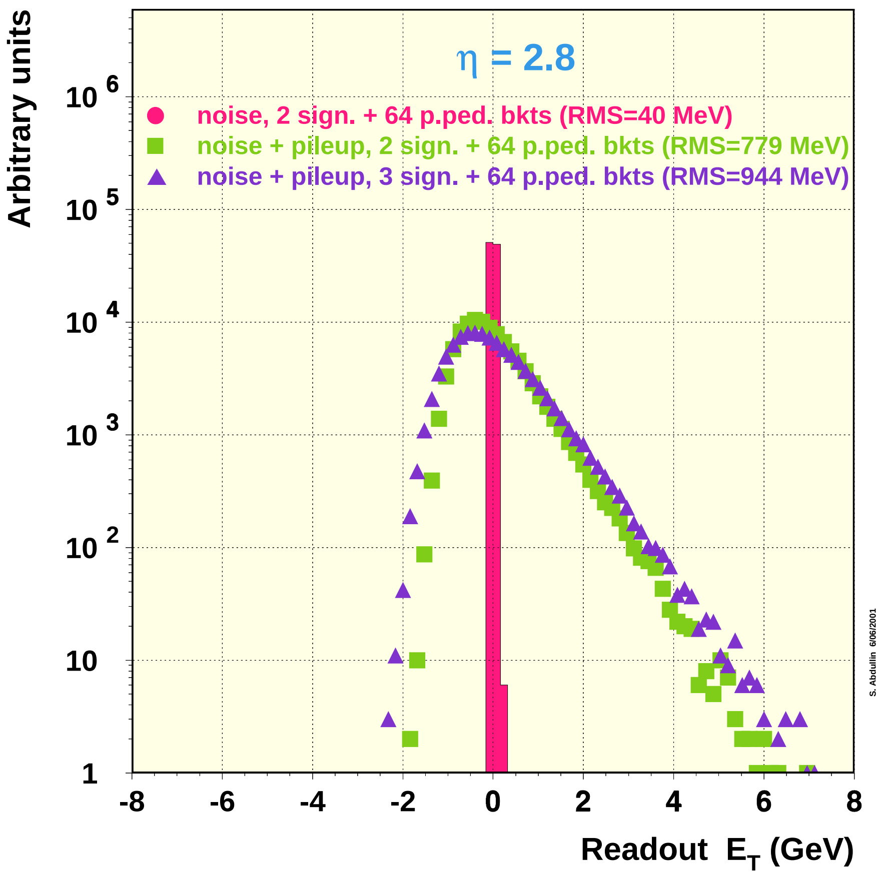
NOISE + PILEUP ET DISTRIBUTIONS (III)

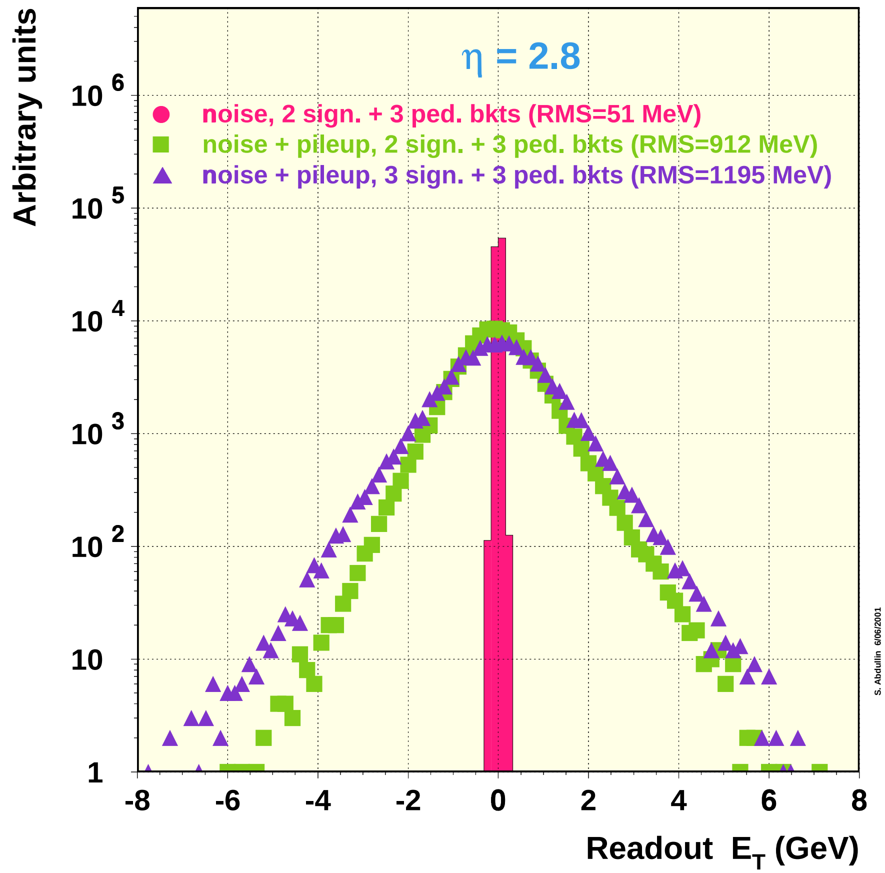




- **Pileup > noise**
- **Baseline position becomes irrelevant**

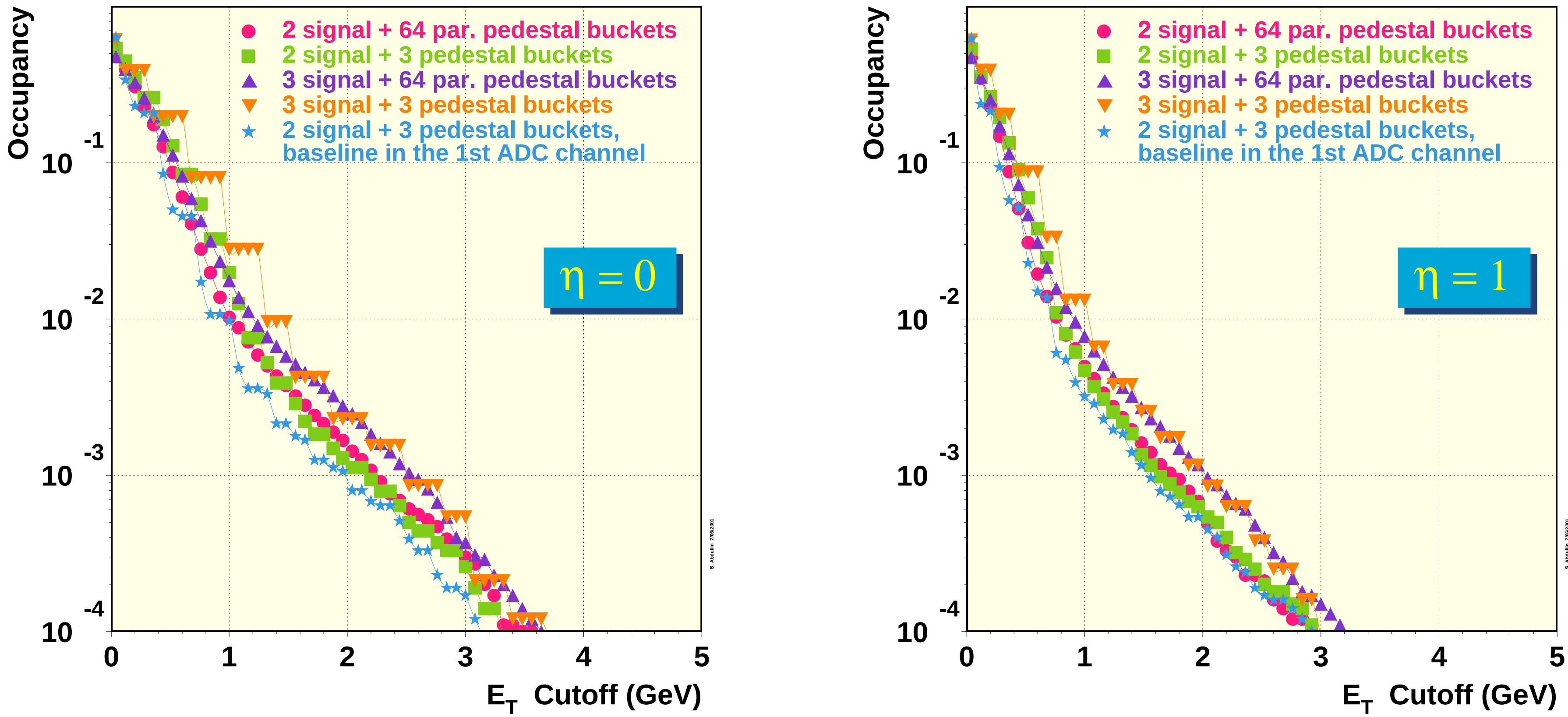
NOISE + PILEUP ET DISTRIBUTIONS (IV)





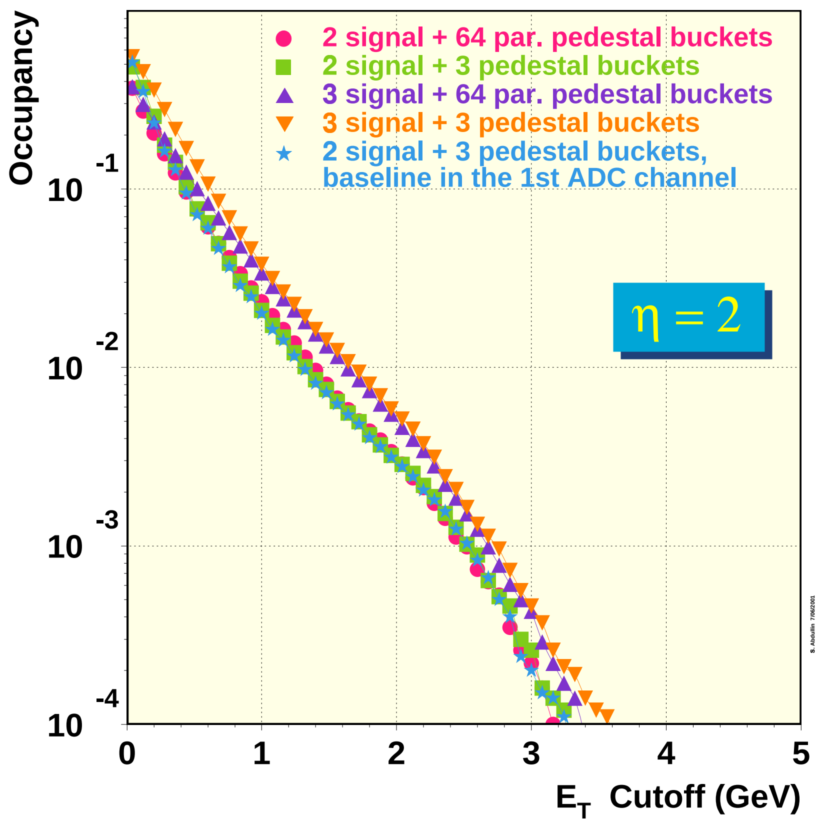
- **More explicit than the previous transparency**

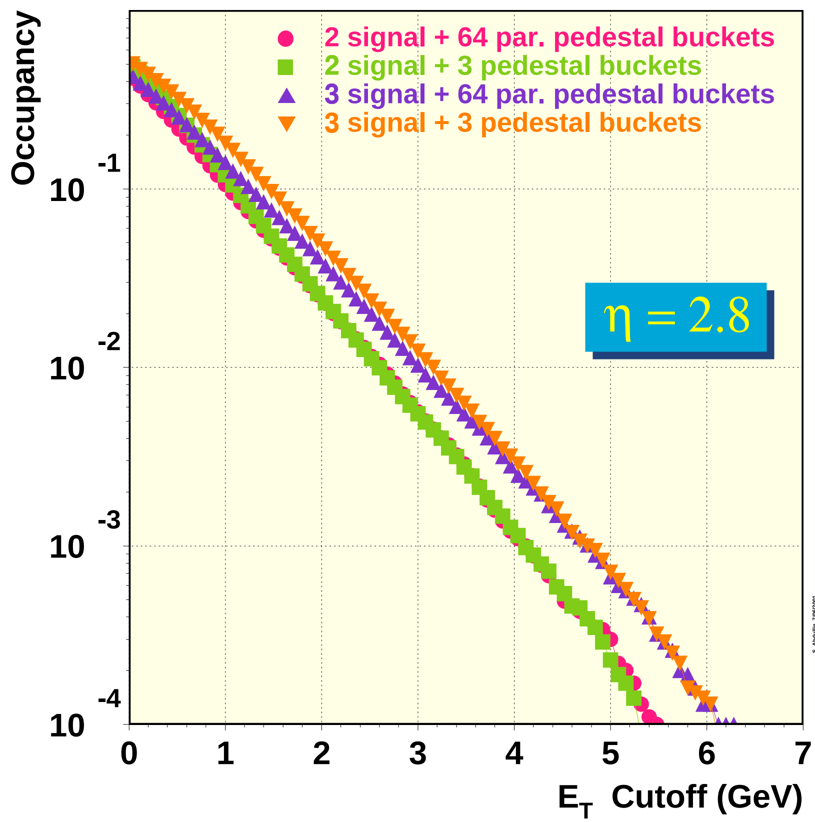
OCCUPANCY from NOISE + PILEUP (I)



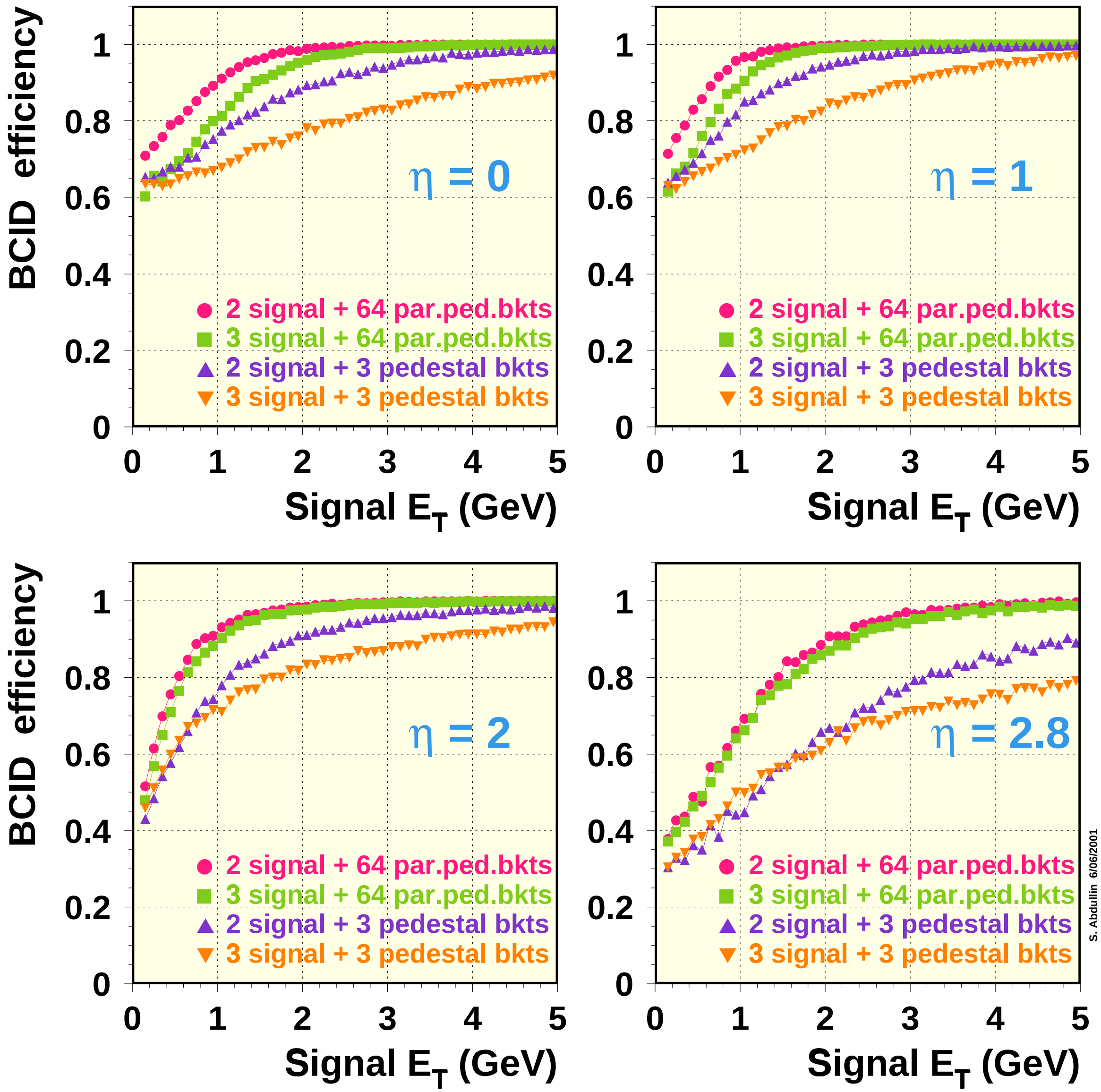
- **"Integrated" presentation of previous plots**

OCCUPANCY from NOISE + PILEUP (II)





BCID versus SIGNAL E_T at HIGH LUMINOSITY



BCID procedure :

- Signal is evaluated with weights corresponding to the collection modes in "true" time
- Only positive values are considered
- Signal is also evaluated with weights pattern shifted by +1, -1 time bucket
- If signal is maximal with zero shift - BCID is OK

CONCLUSIONS

- **FE simulation code in ORCA is updated (as well as some other code) though some more work will be required to implement one-readout TP formatting and to optimize pedestal subtraction scheme**
- **Test bed toy simulations without pile up**
  - **properly tuned time phase enables one to collect the signal in 2(3) time buckets with stable (within ~1 %) content during time range of 4-5 ns**
  - **2 signal buckets collection mode looks slightly better than 3-buckets one**
  - **baseline position in the 1st ADC channel helps a bit to improve signal resolution, though causes some non-linearity**
  - **No substantial difference between (ideal) case with precise knowledge of the baseleline and realistic case of its estimate in 3-4 pedestal buckets**
- **Toy simulations with pile up**
  - **in HB (noise > pile up) the situation is similar to no-pile up case**
  - **in HE still 2-buckets collection mode is slightly better than 3-buckets one; baseline position becomes irrelevant; pedestal estimate in ("infinite") 64 time buckets doesn't look better than just in 3 ones**
  - **the simplest BCID turn-on curves are better for "parallel" pedestal calculation**