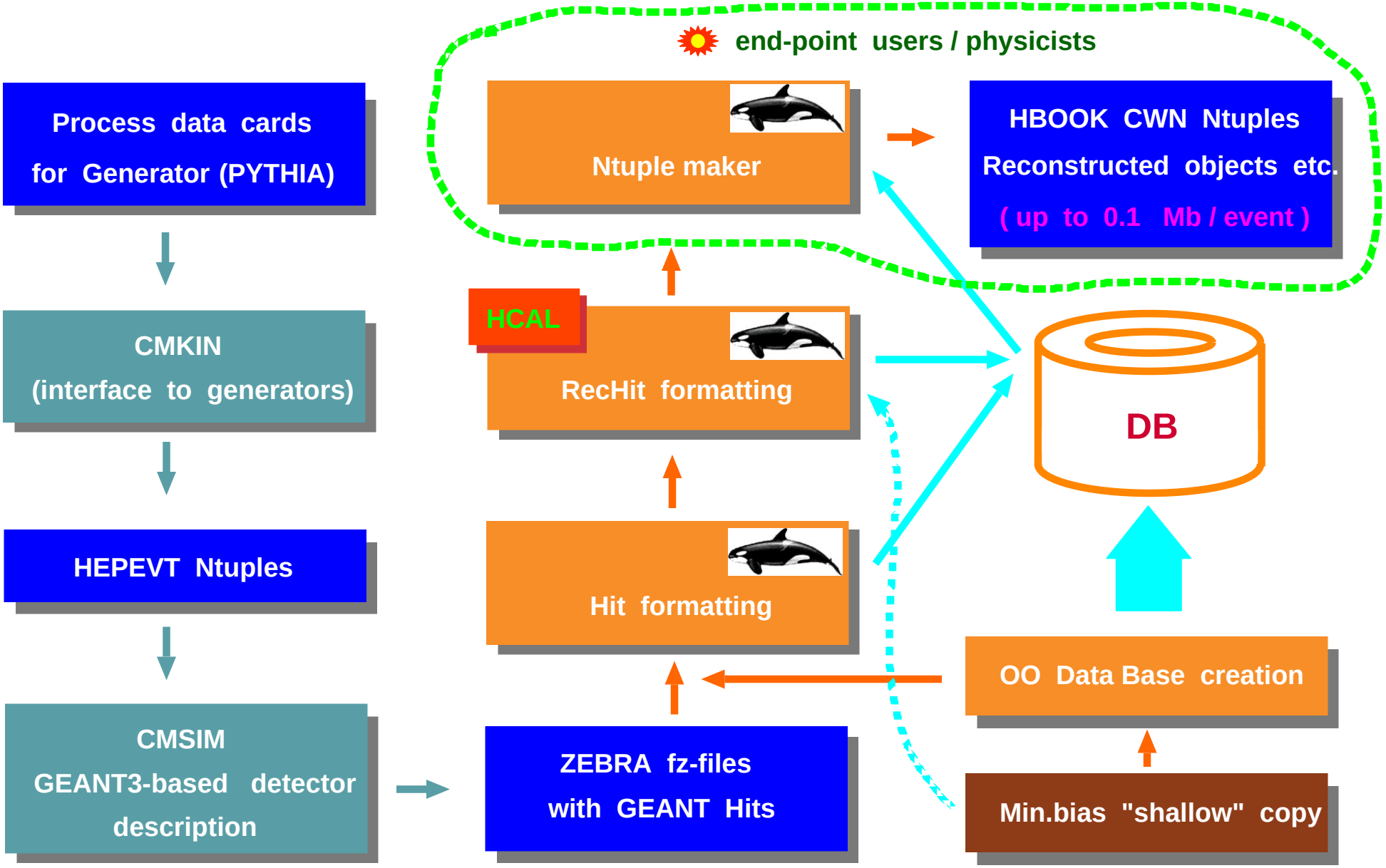
CURRENT STATUS of HCAL SIMULATION in ORCA

http://cmsdoc.cern.ch/~abdullin/jetmet/meetings/7mar01/talk.pdf

S. Abdullin, UMD

- **General scheme of simulation with ORCA**
- **CaloRecHits (Digi) reconstruction** (Chris Tully)
- **TriggerPrimitives formatting** (Chris Tully, Teresa Monteiro)
- **Recent updates**
- **Things to do**

GENERAL SCHEME of SIMULATION with ORCA



HIT RECONSTRUCTION (RecHit)

- **Input : GEANT hits from CMSIM**

- **Noise : uncorrelated Gaussian around "baseline"**
  - noise = 0.0006 GeV (~ 0.07 - 0.13 GeV in scaled energy)
  - baseline : default value = 0.3 GeV (~ 35 - 66 GeV !)

- **Shape : defined by a few effective time constants**
  - sintillation tile + wave-lenght shifter
  - HPD
  - Binkley preamplifier

- **Coming Soon!**
  - photostatistics effect in HB/HE

    HB1 : 0.0004486
    HB2 : 0.0006803
    HE1 : 0.0004491
    HE2 : 0.0000679

    GEANT hit Energy (GeV) / photoelectron
  - QIE integration+quantization

HIT RECONSTRUCTION : SHAPE

- **Scintillator + wave-length shifter**

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

- **HPD**

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

- **Preamplifier**

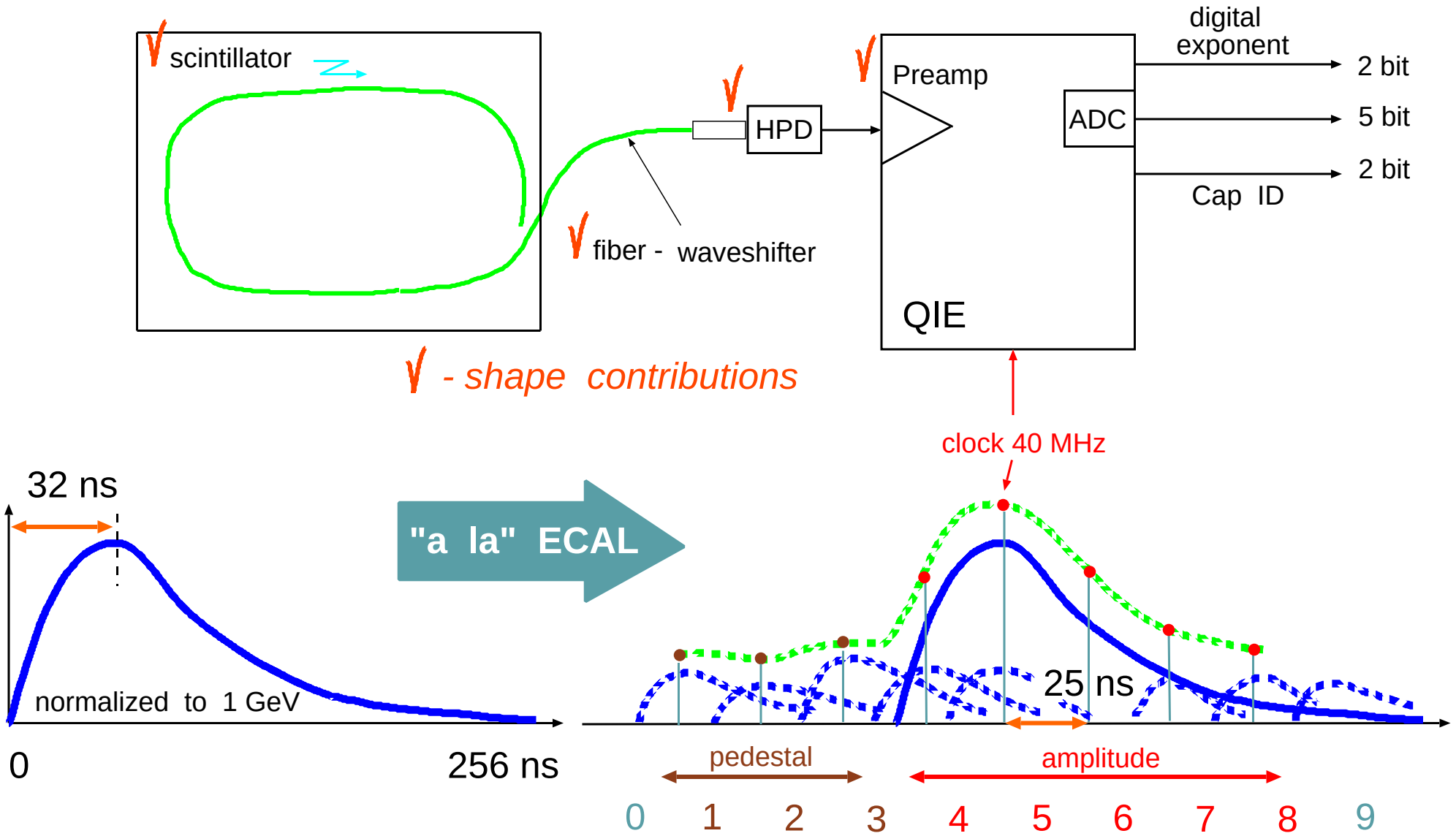
  $f_p(t) = t * \exp(-t/\tau_p), \qquad \tau_p = 25\ ns$

provided by Dan Green

peak time = 32 ns

- **Other contributions ?**

HIT RECONSTRUCTION : SAMPLING



HIT RECONSTRUCTION : ADC → AMPLITUDE → ENERGY

- **P. Bevington, *"Data Reduction and Error Analysisfor the Physical Sciences"*, McGrow-Hill, New York, 1992.**

vector of weights

- $$E = \frac{\vec{p}^{\,T}\mathbf{W}\vec{p}\,[\vec{f}(\phi)^T\mathbf{W}] - \vec{f}(\phi)^T\mathbf{W}\vec{p}\,[\vec{p}^{\,T}\mathbf{W}]}{\vec{f}(\phi)^T\mathbf{W}\vec{f}(\phi)\,[\vec{p}^{\,T}\mathbf{W}\vec{p}] - \vec{p}^{\,T}\mathbf{W}\vec{f}(\phi)\,[\vec{f}(\phi)^T\mathbf{W}\vec{p}]} \cdot \vec{y}$$

- Pedestal = ...
- χ^2 = ...
- Energy (deposited) = E · scale (depth gain factor)

W - **weight matrix : the inverse of the noise correlation matrix, in case of uncorrelated Gaussian noise (σ)** $W_{ii} = 1/\sigma^2$;

$\vec{y}$ - **measured time samples;** $\vec{p}$ - **unit pedestal ($\vec{=1}$);**

$\vec{f}(\phi)$ - **unit pulse shape;** ϕ - **40 MHz clock phase;**

This method of amplitude reconstruction seems to be adequate for low luminosity (electronic noise only) while for high luminosity (pileup) it's not so clear.

HCAL TIME SAMPLE WEIGHTS

Amplitude reconstruction "a la" ECAL

Time Sample	Unit Pulse Shape	Energy Weight	Pedestal Weight
1	0.0000	0.0000	0.0000
2	0.0000	-0.2077	0.1625
3	0.0000	-0.2077	0.1625
4	0.0000	-0.2077	0.1625
5	0.0602	-0.1384	0.1500
6	1.0000	0.9423	-0.0452
7	0.3545	0.2006	0.0888
8	0.0289	-0.1744	0.1565
9	0.0005	-0.2070	0.1624
10	0.0000	0.0000	0.0000

HCAL OCCUPANCY (I)

Low lumi :

- PYTHIA 6.152 + CMSIM 120 + ORCA_4_4_0
- jet0300.boot , jm_nimbias, jetHit120_2D_CERN
- $< N_{ev} > = 1.73$ per bunch crossing

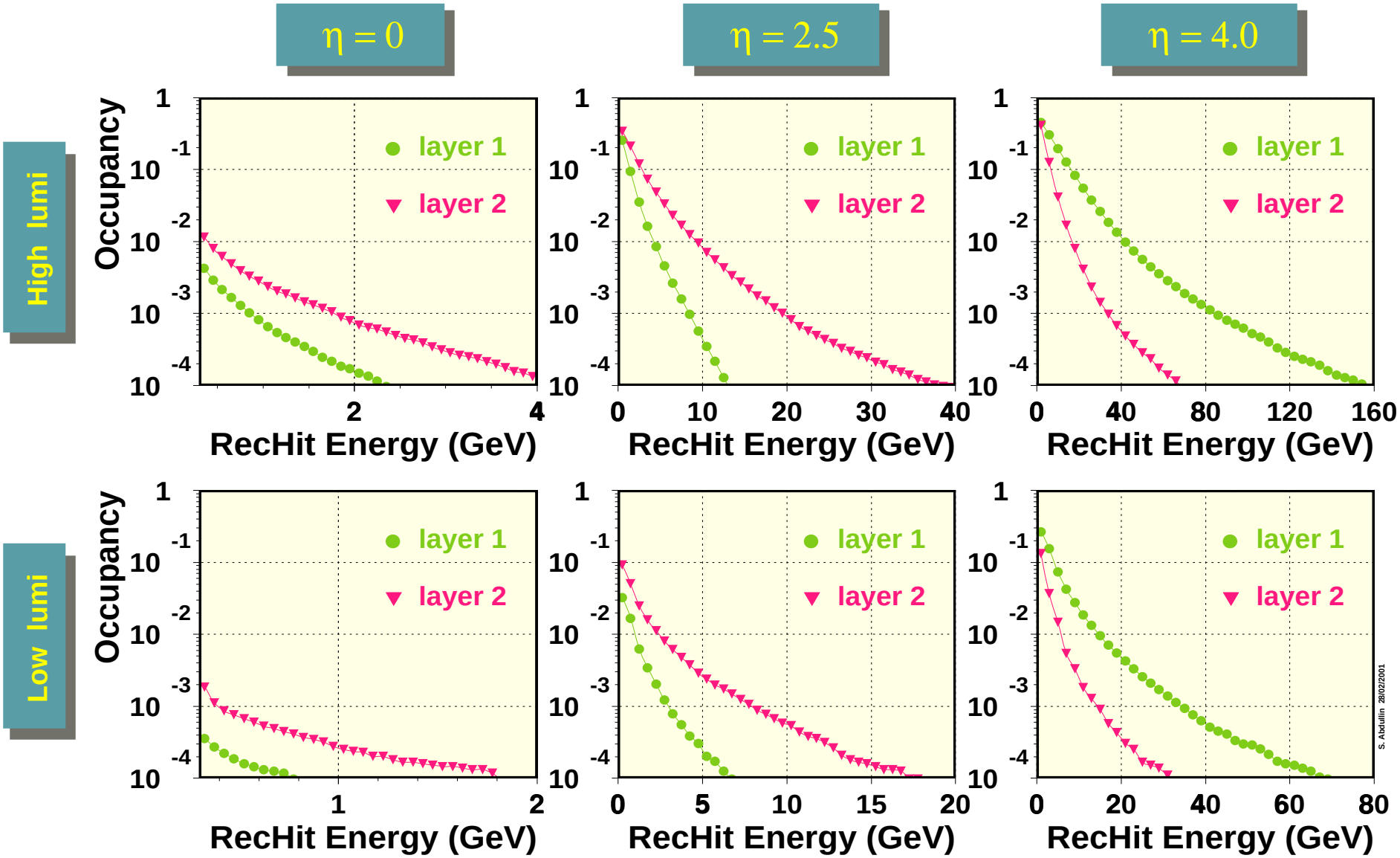
High lumi :

- PYTHIA 5.73 + CMSIM 116 + ORCA_4_2_0
- jet0900.boot, filt_minbias2k, 1034PurePileup
- $< N_{ev} > = 17.3$ per bunch crossing

Default ORCA parameters used

- Old gain factors
- No quantization etc.

HCAL OCCUPANCY (II)



TRIGGER PRIMITIVES (TrigPrim) FORMATTING

- **Data Frames (~ ADC output) are joined in groups corresponding to a fixed map (of hardware modules)**

  E.g. in barrel : HcalTrigPrim = Hcal tower (0.087 x 0.087)
  EcalTrigPrim = 5 x 5 matrix (0.087 x 0.087)

- **Transverse "energy" (appropriately scaled in case of HCAL) is summed over all TrigPrim constituents**

- **An amplitude reconstruction is then performed similar to that for individual readouts (RecHits)**

- **5 weights instead of currently used 8 !**

BUNCH ID

A kind of simple peakfinder exists in ORCA

- Energy calculation is applied to the TimeFrame with the weights shifted by -1, 0, 1 bunch
- RecHit time is set to -25, 0, 25 ns (jitter) depending on which shift gives the maximal amplitude.
- Included in Ecal/Hcal RecHits, Trigger Primitives
- RecHits : no filtering applied, stored with its jitter value as well as χ^2 for subsequent analysis
- ECAL experience : $P(\chi^2)$ can be slightly better than a simple peakfinder (by ~10 %) for low energy RecHits without pile up
- Trigger Primitives : E_T is calculated both taking into account bunch ID (default) and ignoring it (supplementary value)
- Some algorithm of the sort is to be implemented in L1

READOUT QUANTIZATION (I)

S.Los HCAL/CMS 12/14/00

Default ORCA option :

- **Readout simulation :**

  DataFrame = int (TimeFrame x 100 000)

- **Hit reconstruction :**

  TimeFrame = real (DataFrame) / 100 000.

  LSB corresponds to ~ 1-2 MeV (negligible)

First attempt to simulate ADC quantization effect (still "a la" ECAL)

- **tabulated ADC counts as a function of charge**
- **requires some scale :**

  Energy deposited in scintillator / 1 femtoCoulomb

  (fairly arbitrary set to 0.004 GeV for all readouts)

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.

READOUT QUANTIZATION (II)

Noise

- one of the most important issues for a signal reconstruction
- 0.0006 GeV (in terms of GEANT Hits energy) - kept the same as before

  (0.07 - 0.13 GeV in terms of scaled reconstructed energy)

Pedestal

- corresponds (in GeV) to QIE charge (or ADC channel) in the absence of calo signal
- 0.004 (~0.45 - 0.9) - means the middle of the 3d ADC channel, not critical,

  but unlikely as high as 0.3 (~ 35 - 66) in the current version of HCAL in ORCA

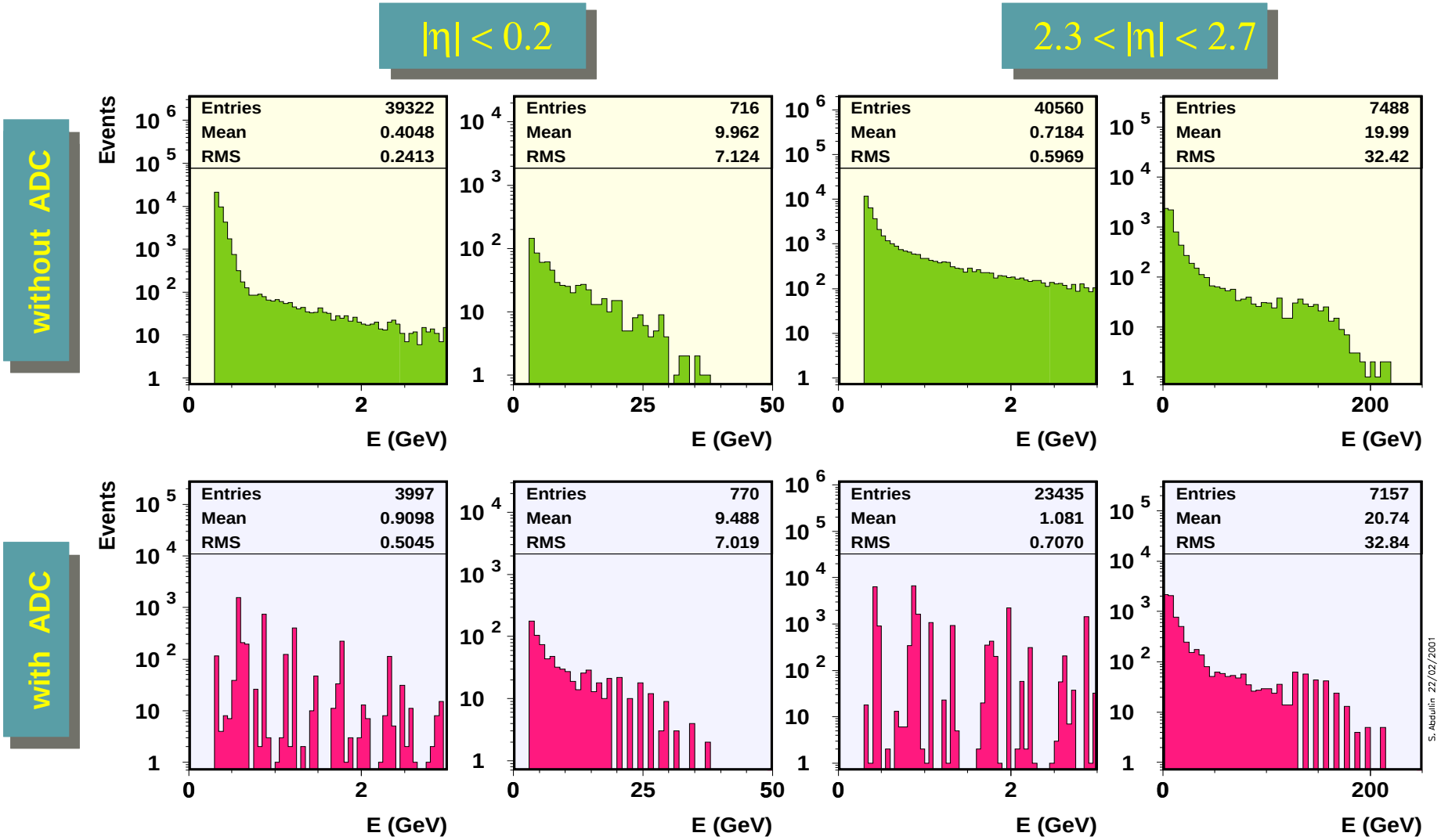
Charge / Energy

- the entire system scint. -> shifter -> HPD -> pream. -> QIE will be calibrated in reality (?)
- for the time being a reasonable guess is required as ORCA deals with GEANT Hits energy
- 1 femtoCoulomb / 0.004 GeV

READOUT QUANTIZATION (III)

Energy of HCAL RecHit (DIGI) with/without ADC

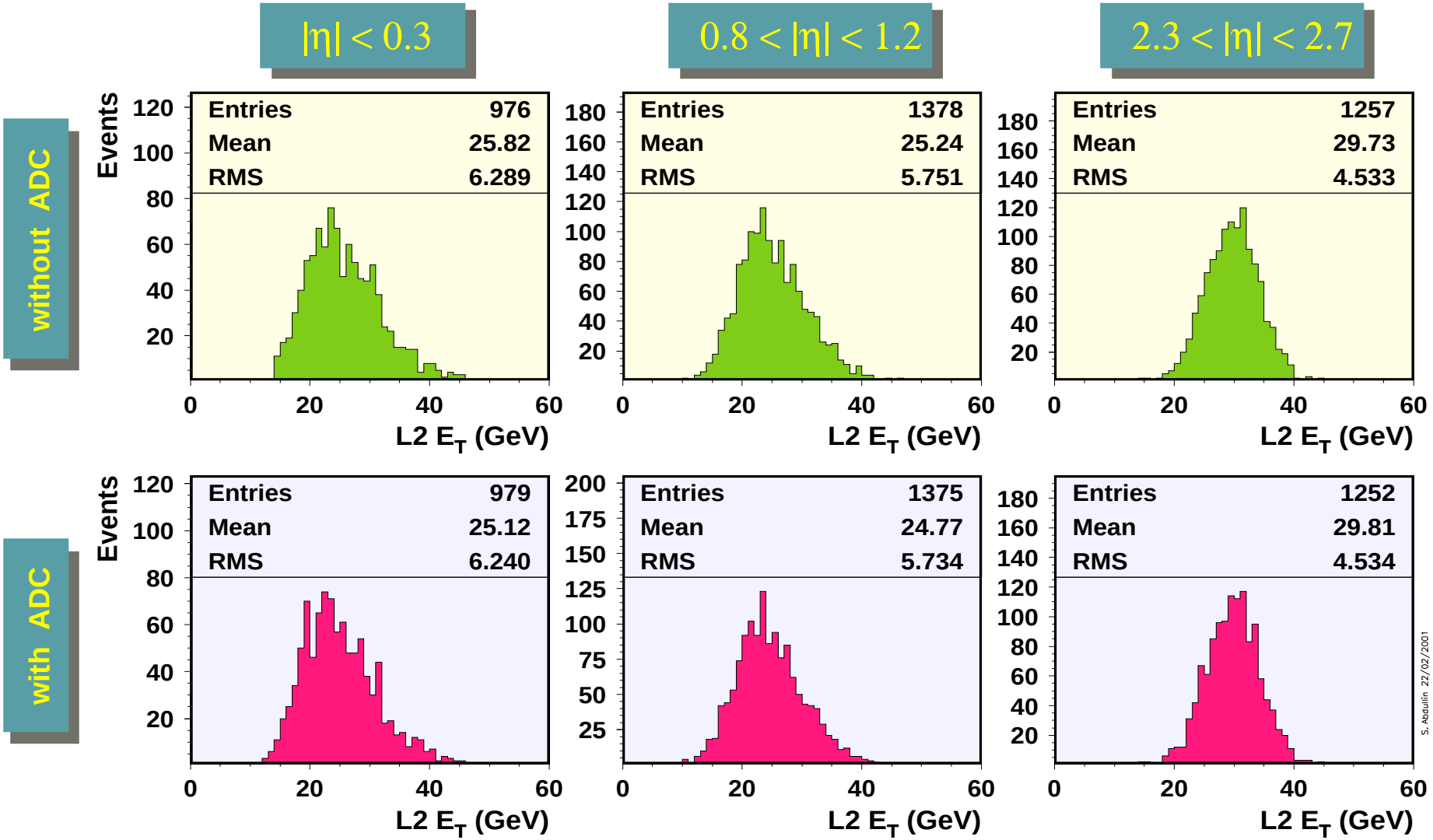
single pions with p_T = 30 GeV



READOUT QUANTIZATION (IV)

E_T of L2 jet (R=0.5) with/without ADC

single pions with p_T = 30 GeV



READOUT QUANTIZATION (V)

Effect of the HCAL ADC implementation

- **Noise RecHits are suppressed**

- **Sizeable LSB creates "spectrum lines" in RecHits energy distribution**

LSB (GeV) depends on the depth gain factor :

RecHit Energy (GeV)	HB layer=1	HE layer=2
0 - 6	~ 0.4	~ 0.9
30 - 50	~ 2	~ 4.5
300 - 400	~ 20	~ 45

LSB values are given for 0.004 GeV / 1 femtoCoulomb of ADC "calibration"

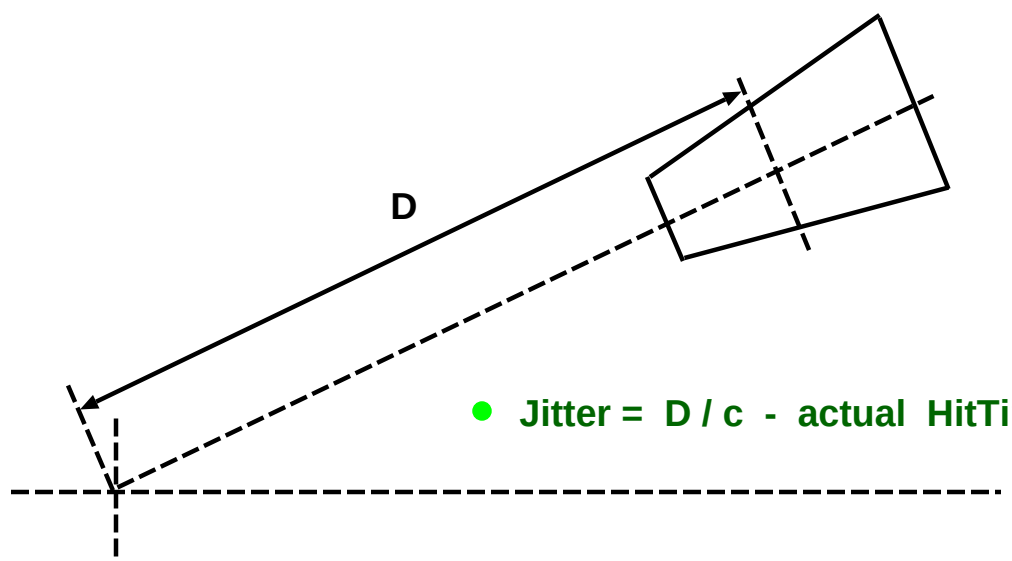
- **Resulting effect on a singe pion resolution seems to be insignificant**

HIT JITTER (I)

- In CMSIM before version 118 HCAL GEANT hit timing has 10 ns bin/step (from Chris Tully)

- Now it's 1 ns and GEANT hit time can be taken into account to calculate hit time arrival jitter

- Running ahead : the effect is small

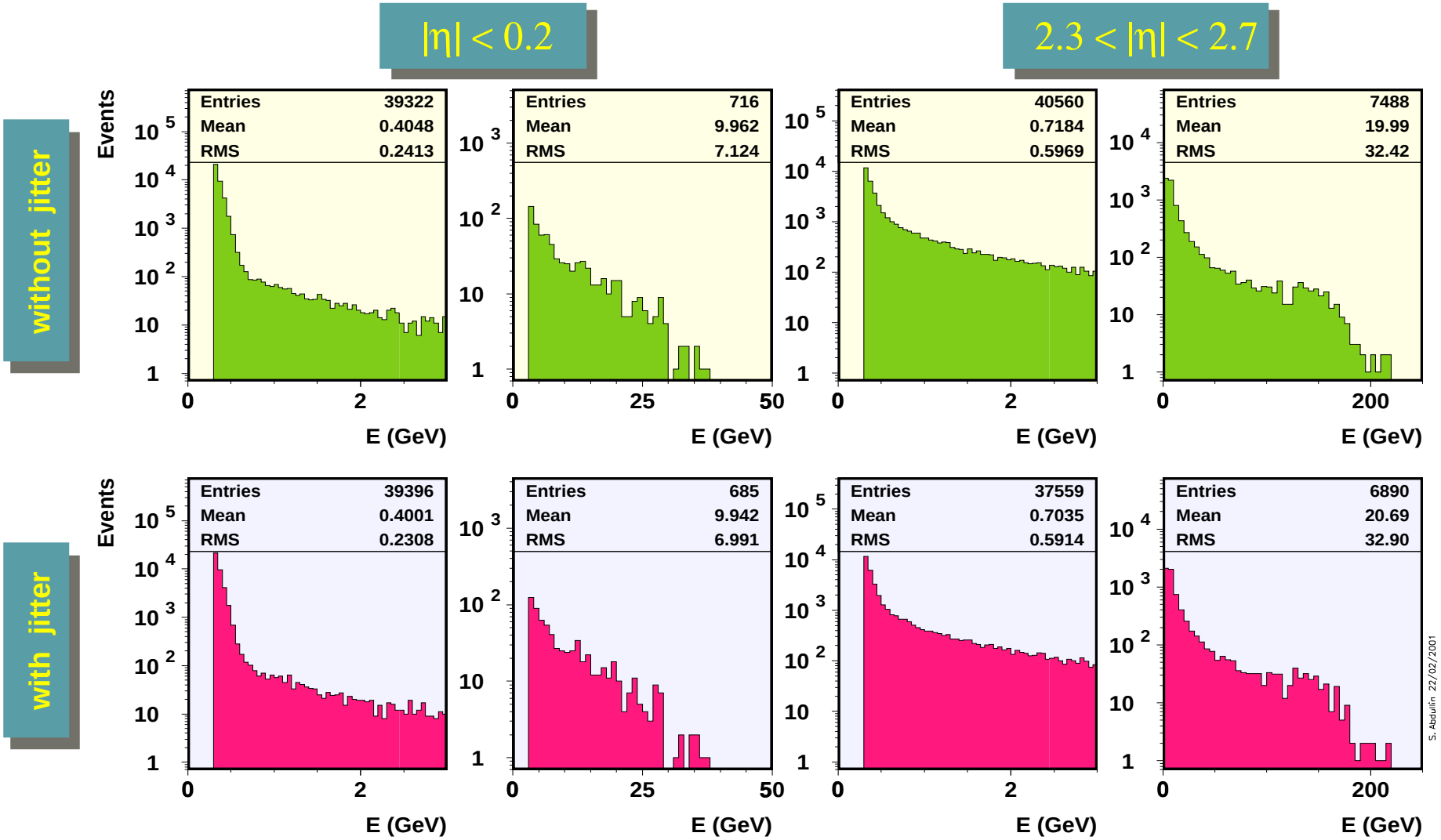


- Jitter = D / c - actual HitTime

HIT JITTER (II)

Energy of HCAL RecHit (DIGI) with/without proper hit time (jitter)

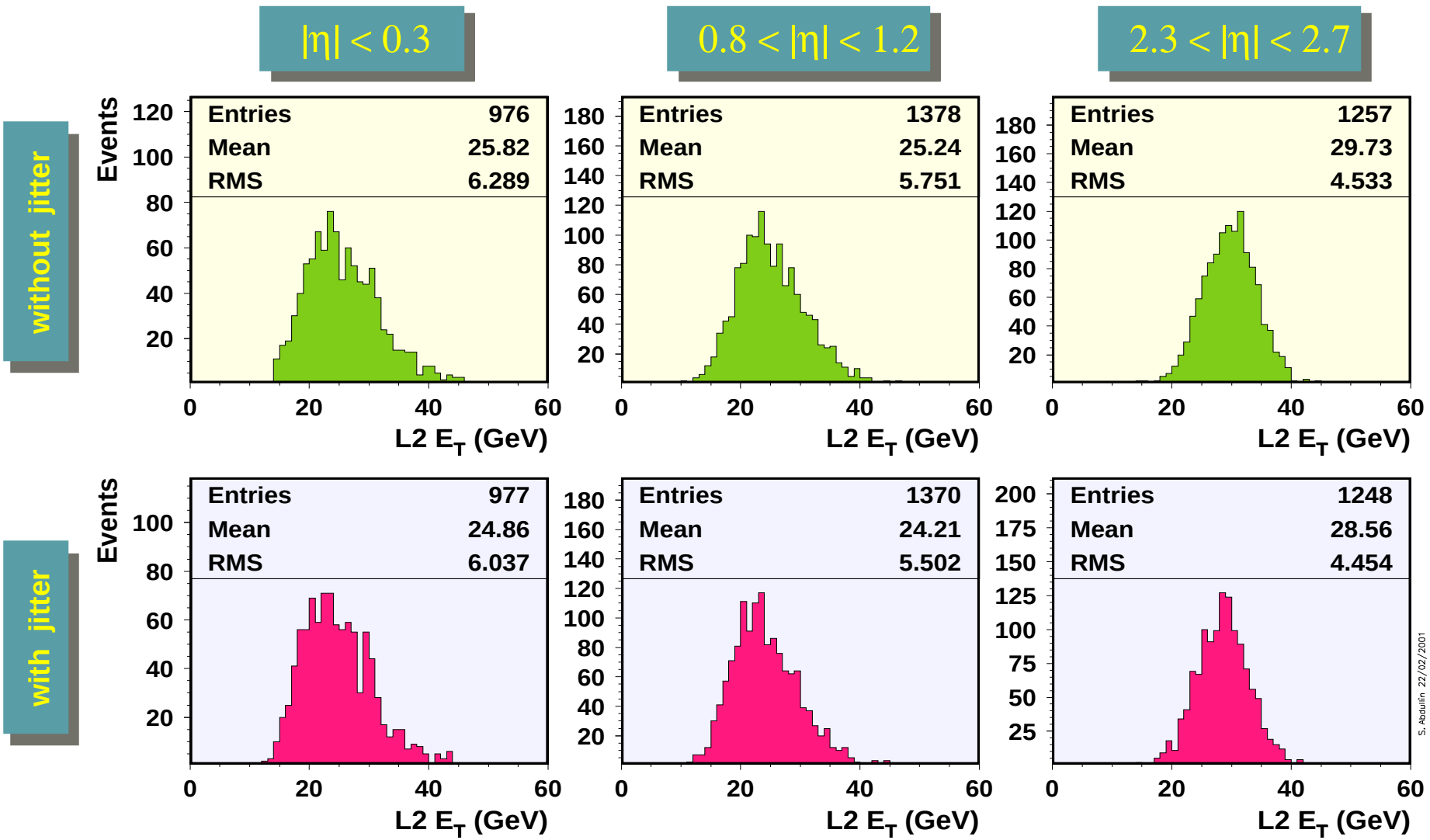
single pions with p_T = 30 GeV



HIT JITTER (III)

E_T of L2 jets (R=0.5) with/without proper hit time (jitter)

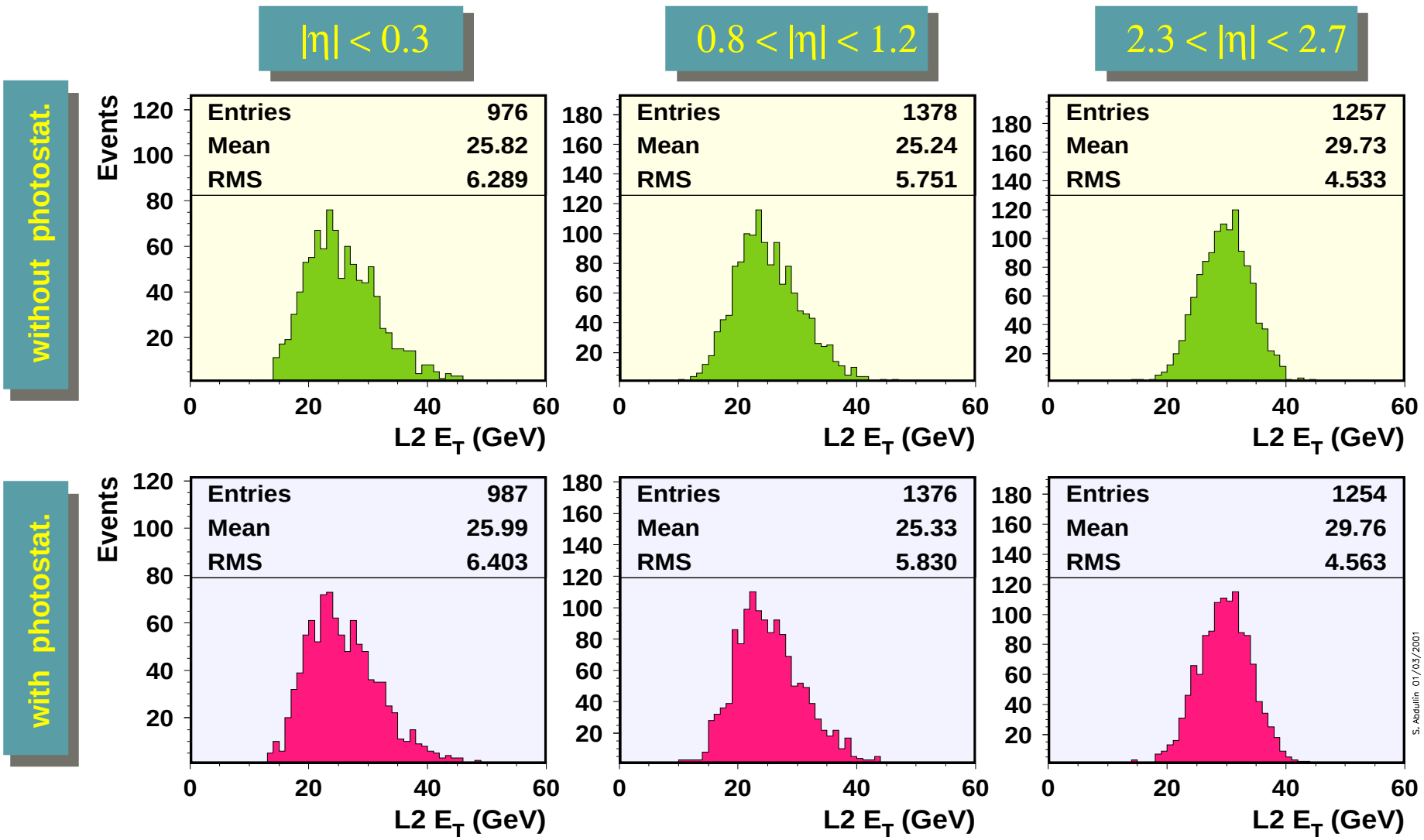
single pions with p_T = 30 GeV



PHOTOSTATISTICS EFFECT

E_T of L2 jets (R=0.5) with/without photostatistics effect

single pions with p_T = 30 GeV



THINGS to IMPROVE in ORCA (I)

(general issues not related to HCAL electronics)

- **Speed up simulation of sampling**
  - add unique sequential integer number of cell in CellID
  - create permanent address (index) field for CaloTimeSample cache
- **"Pure" GEANT energy to save**
  - 2 quantities (both from trigger event and from all in-time ones) to add to Objy-stored CaloRecHits (requires update of Objy schema)
- **Out-of-time energy suppression**
- **Number of time buckets and weights(?) in case of pileup**
- **Optimization of readout thresholds**
  - from the point of view of resolution

THINGS to IMPROVE in ORCA (II)

(issues specific for HCAL electronics)

- QIE charge integration + quantization
- Time jitter
- Photostatistics effect in HB/HE

} Coming Soon!

- HF to separate from HB/HE
  - short signal can be integrated within 1 time bucket (25 ns) - "no shape"
  - photostatistics effect is included in HF GEANT Hits (for a while ?)
- TrigPrim formatting (L1)
  - 4-5 time buckets with simplified weights (HB/HE)
  - Bunch ID ("peak finder")
- Additional contributions to the signal shape (?)
  - single photoelectron shape ?
- 5-6 time buckets in HB/HE RecHit evaluation (L2 ?)