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Calibration of HCAL with γ + jet channel

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Study of a possibility of suppression of the initial state radiation (ISR) and background by the way of the event selection and an influence of the ISR and background on the calibration.

Events with

direct photons ($\gamma + jet$) and

background ($jet + jet$)

from Spring01 production (no pile-up)

have been used.

Signal events. Samples ”1” – ”4”.

Parameter	”1”	”2”	”3”	”4”
Pt^{γ} (GeV/c)	20-40	40-100	100-200	200-300
No of events	10000	10000	10000	10000

Signal + background. Samples ”1” – ”3”.

Parameter	”1”	”2”	”3”
Pt^{γ} (GeV/c)	20-40	40-100	100-200
No of events	50000	50000	50000

Levels of study

”**PARTICLE**” – CMSJET v.4.703 without field and energy and spatial smearing;

”**FIELD**” – CMSJET with field and without energy and spatial smearing;

”**SMEAR**” – CMSJET with field and energy and spatial smearing;

”**ORCA**” – CMS121 + ORCA454

The results at ”PARTICLE”, ”FIELD” and ”SMEAR” levels are similar. Further we will present results at ”PARTICLE” and ”ORCA” levels only.

For improvement of $Pt^{\gamma} - Pt^{par}$ imbalance and for background suppression we put constraints (selection cuts) on the values:

$\Delta\phi$ – angle between ”γ” and jet,

$\mathbf{Et}_{\gamma}^{isol}$ – summarized Et in R=0.7 in the outside 7x7 crystals around of ”γ”,

$\mathbf{Et}_{jet}^{isol}$ – summarized Et in 0.7<R<1 around of jet,

$\mathbf{Et}^{miss}$ – missing Et,

$\mathbf{Et}^{jet2}$ – Et of the second leading jet,

$\mathbf{Et}^{out1}$ – vector sum of Et in the outside 7x7 crystals around of ”γ” and in the outside of cone R=0.8 around of jet,

$\mathbf{Et}_{S}^{out1}$ – scalar sum of Et in the same region,

$\mathbf{Et}^{out2}$ – vector sum of Et in the outside of cone R=0.8 around of ”γ” and in the outside of cone R=0.8 around of jet,

$\mathbf{Et}_{S}^{out2}$ – scalar sum of Et in the same region.

The errors dependent on ISR.

We consider a calibration with a reconstruction the energy of the initial parton. It means for each measured Et value of jet corressponds to the value of Pt^{par}:

$$Pt^{par}(Et^{jet}) \iff \text{mean of } Pt^{\gamma}(Et^{jet}).$$

A balance between photon and parton will be destroied by ISR:

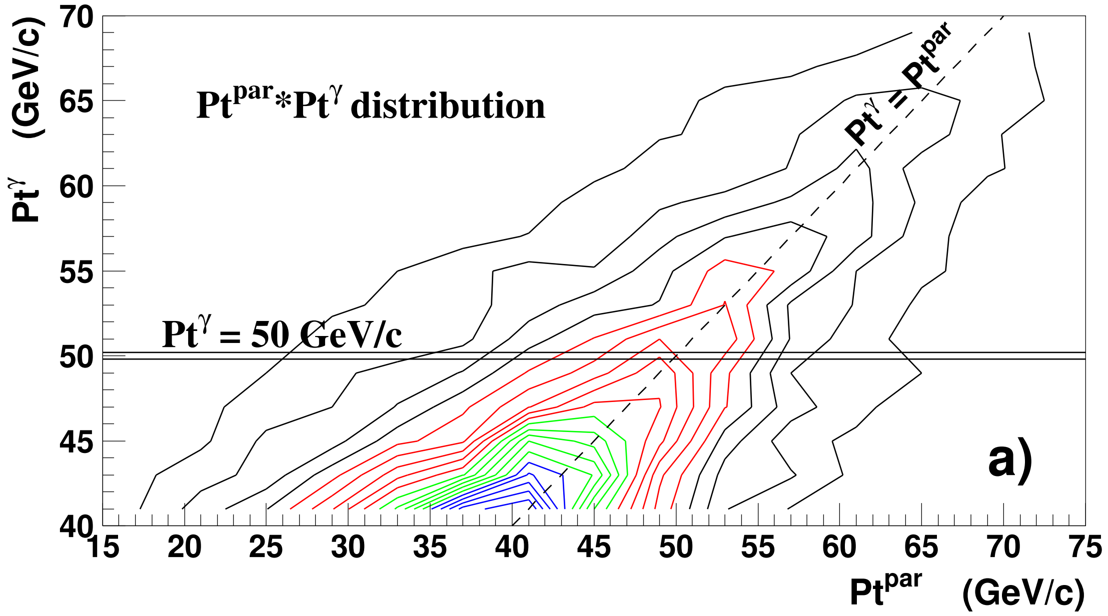
$$Pt^{par} = |\vec{Pt}^{\gamma} + \vec{Pt}^{ISR}|.$$

That leads to statistical and systematic errors of the calibration:

$$Pt^{par}(Et^{jet}) = \; <Pt^{\gamma}(Et^{jet})> + \Delta_1 - \Delta_2 \pm \sigma.$$

Δ_1 depends on correlation coefficient between Pt^{γ} and Pt^{par};

Δ_2 depends on event selection: limitation on some parameters leads to the effect that relative number of events with $Pt^{\gamma} > Pt^{par}$ or $Pt^{\gamma} < Pt^{par}$ can be increased. The energy imbalance $Pt^{\gamma} - Pt^{par}$ is shifted.



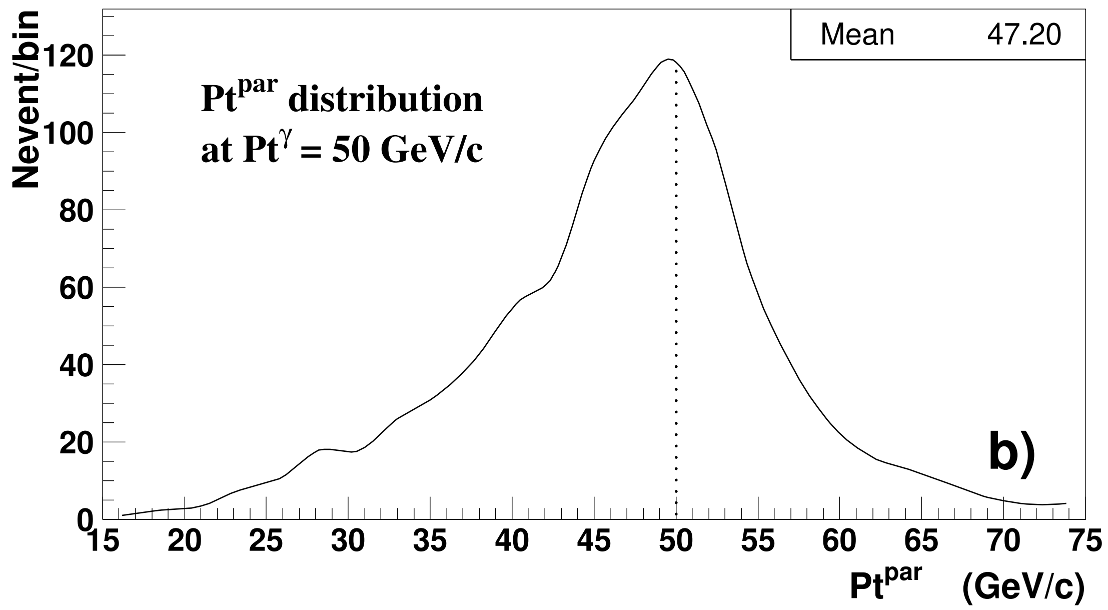
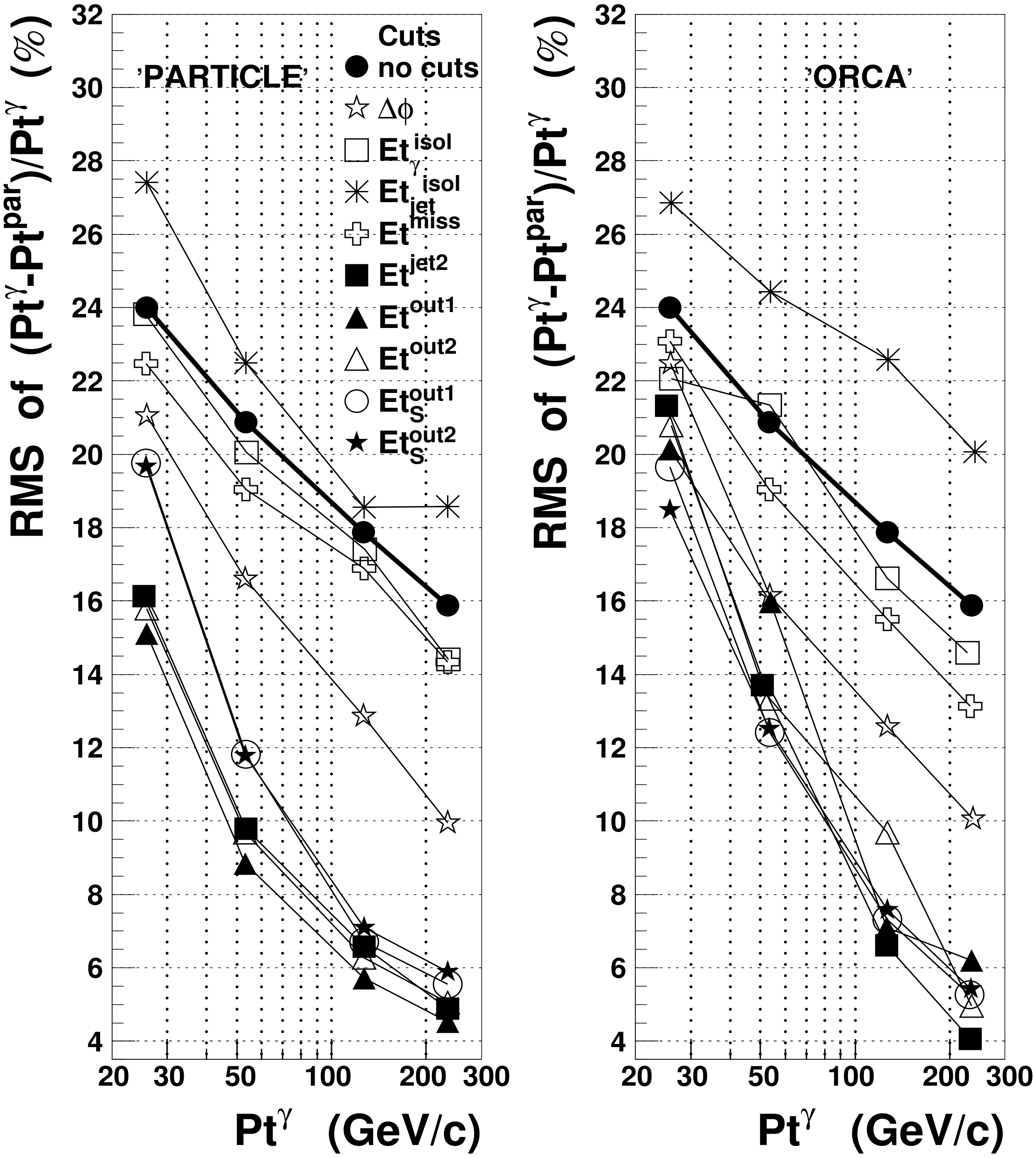


Illustration for Δ_1. $Pt^{\gamma} \times Pt^{par}$ distribution (a) and Pt^{par} distribution for fixed Pt^{γ} (b).

We have imbalance

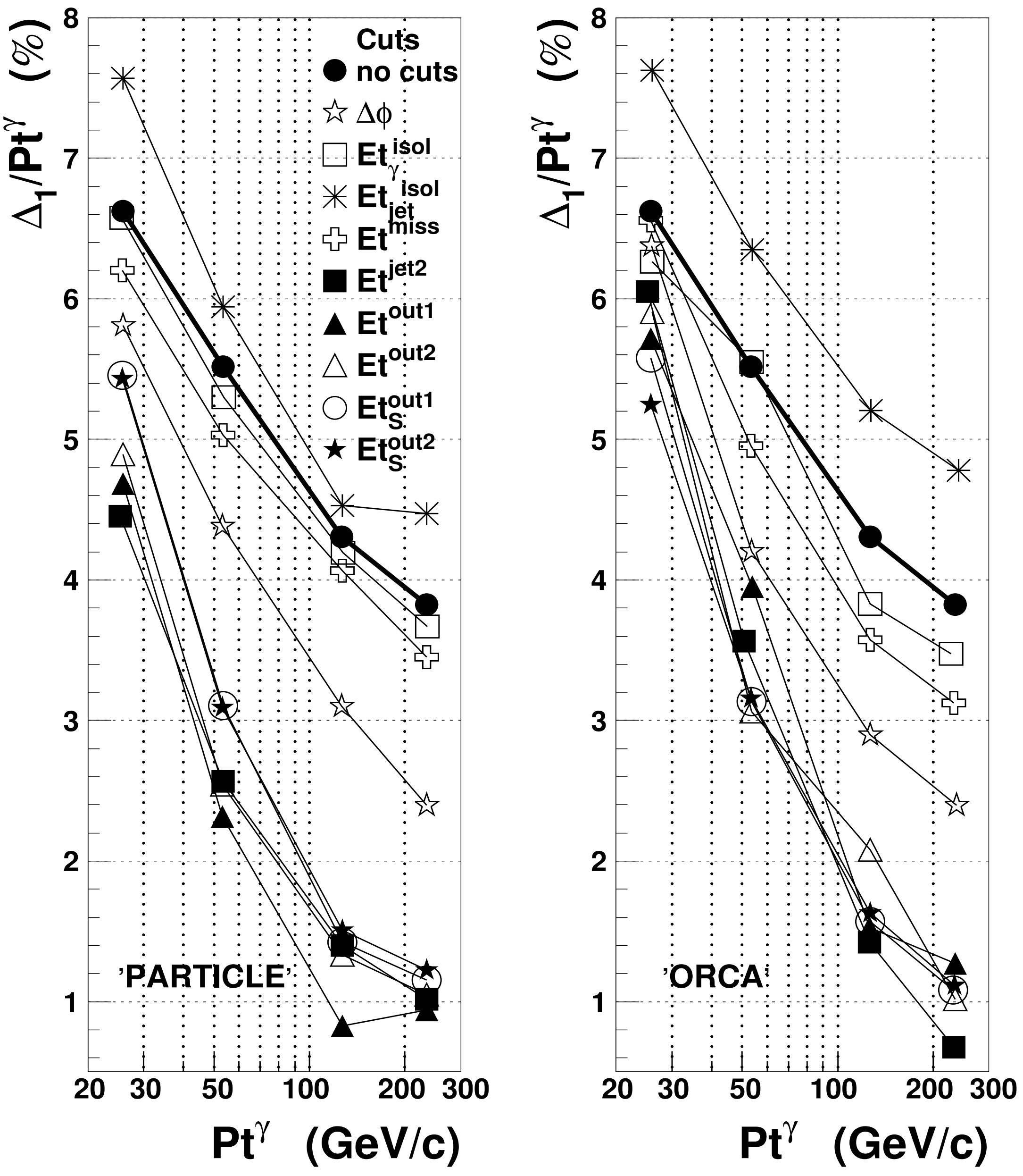
$$\Delta_1 = Pt^{\gamma} - <Pt^{par}(Pt^{\gamma})> = 2.8\, GeV/c$$

for $Pt^{\gamma} = 50\, GeV/c$.



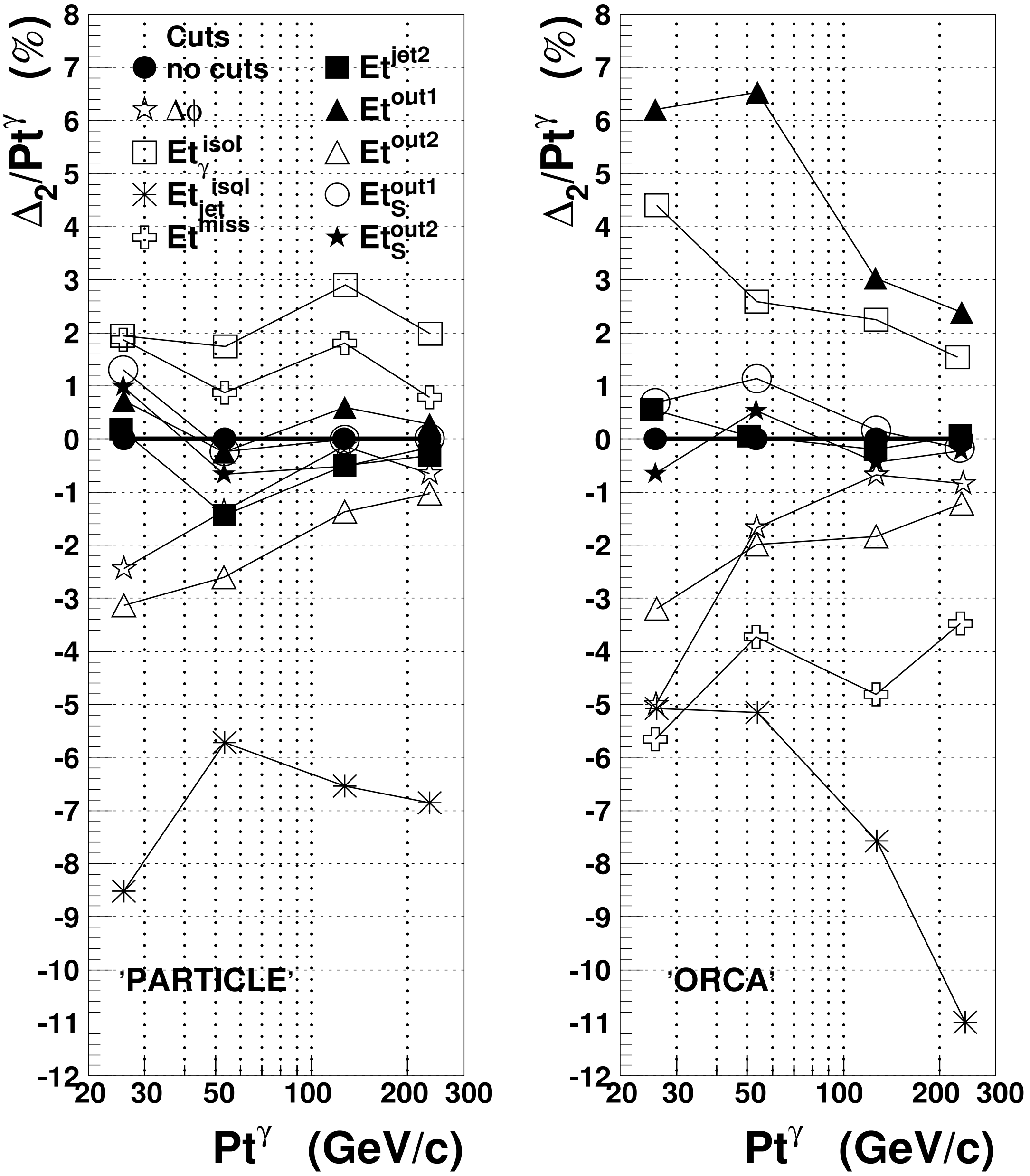
Pt^{γ} dependence of RMS of Pt^{γ}-Pt^{par} imbalance for different selection cuts at efficiency of signal suppresion Eff$= 5\%$ ("PARTICLE" and "ORCA"-levels).

More better suppression of RMS we are getting by use cuts on second jet and Et^{out}, Et^{out}_{S}. Cuts on isolation of jet increases of RMS.



Values of systematic error Δ_1 for different Pt^{γ} at efficiency of signal suppresion Eff$= 5\%$.

The Pt^{γ} dependence is similar to previous one.
Cuts on second jet and Et^{out}, Et^{out}_{S} reduces Δ_1
from 7$\%$ (no cuts) to 6$\%$ at $Pt^{\gamma} = 20\,GeV/c$,
from 4$\%$ (no cuts) to 1$\%$ at $Pt^{\gamma} = 200\,GeV/c$.



Values of systematic error Δ_2 at Eff=5%.

When we put the restriction for isolation of jet, missing Et, Et^{out1} and isolation of gamma we have significantly errors:

- by limitation Et^{out1} and isolation of gamma relative number of events with $Pt^{\gamma} > Pt^{par}$ will be increased,
- by limitation isolation of jet and missing Et relative number of events with $Pt^{\gamma} > Pt^{par}$ will be decreased.

The errors dependent on background.

We have different values of imbalances:

$\Delta_S = \langle Et^{\gamma} - Et^{jet} \rangle_S$ – a case of signal events;

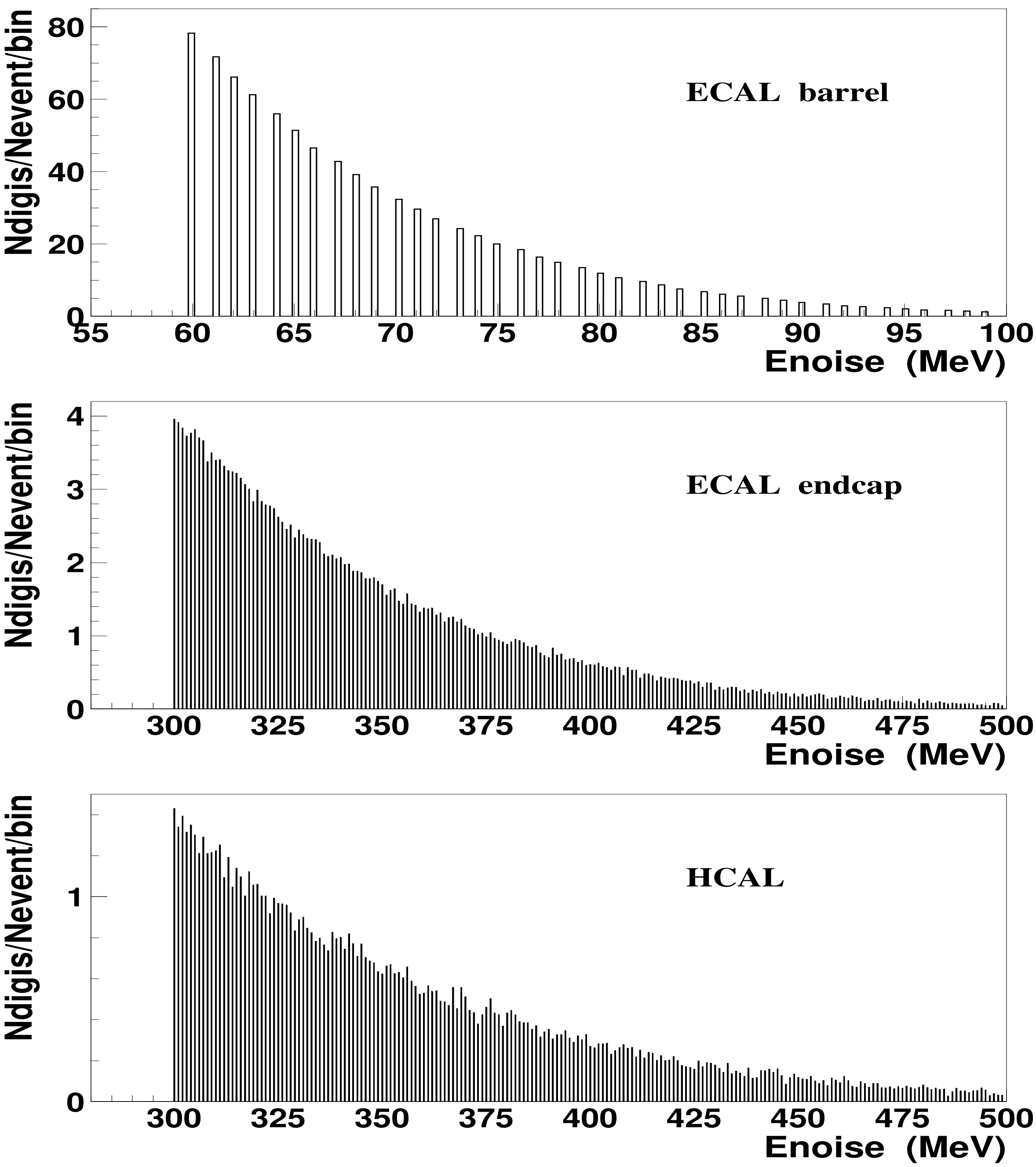
$\Delta_{S+B} = \langle Et^{\gamma} - Et^{jet} \rangle_{S+B}$ – a case of signal + background.

Thus background causes an error into the calibration:

$$\Delta_{S+B} - \Delta_S$$

Further we shall characterize backgrounds by:

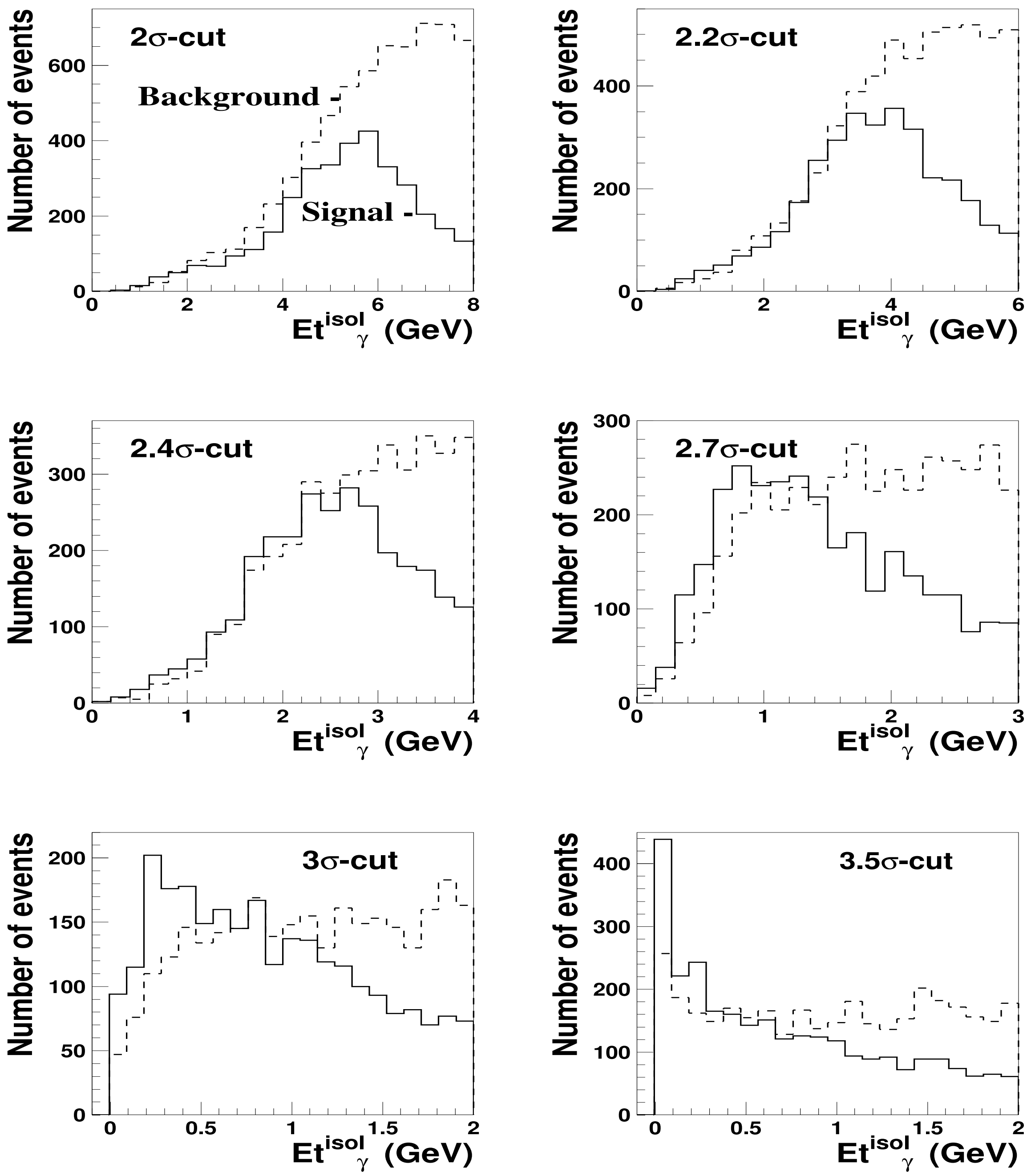
- **S/B (a ratio of number of signal events to number of background events);**
- **an errors** $\delta_{S+B} - \delta_S = (\Delta_{S+B} - \Delta_S)/Et^{\gamma}$**;**
- **yan difference** $\sigma_{S+B} - \sigma_S$ **(**σ **= RMS of** Et^{γ}**-**Et^{jet}**).**



Distributions of the E noise in the cells of EB, EE and HCAL after to 2σ cuts.

We have used ORCA 454, which differs from CMSJET and CMSIM in digitization, i.e. noise is included.
The noise have influence in particularly over isolation of "γ".

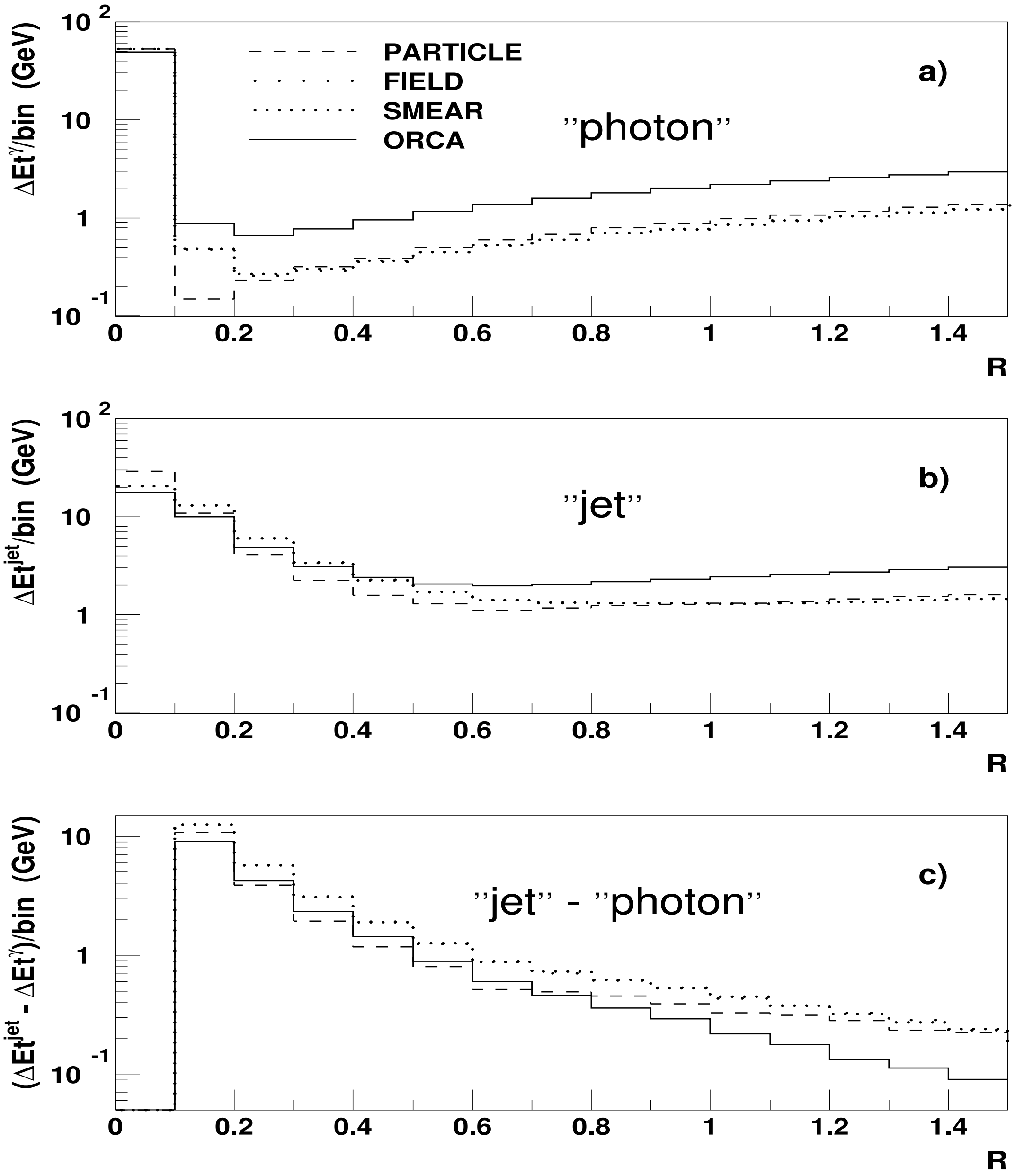
Case $40 < Et^{\gamma} < 100\,GeV$.



The $\mathbf{Et}_{\gamma}^{isol}$ distributions for both signal and background at ORCA levels with different E cuts to cell.

We can see that the signal and background separation is incoming a good at $\approx 3\sigma$ cut.

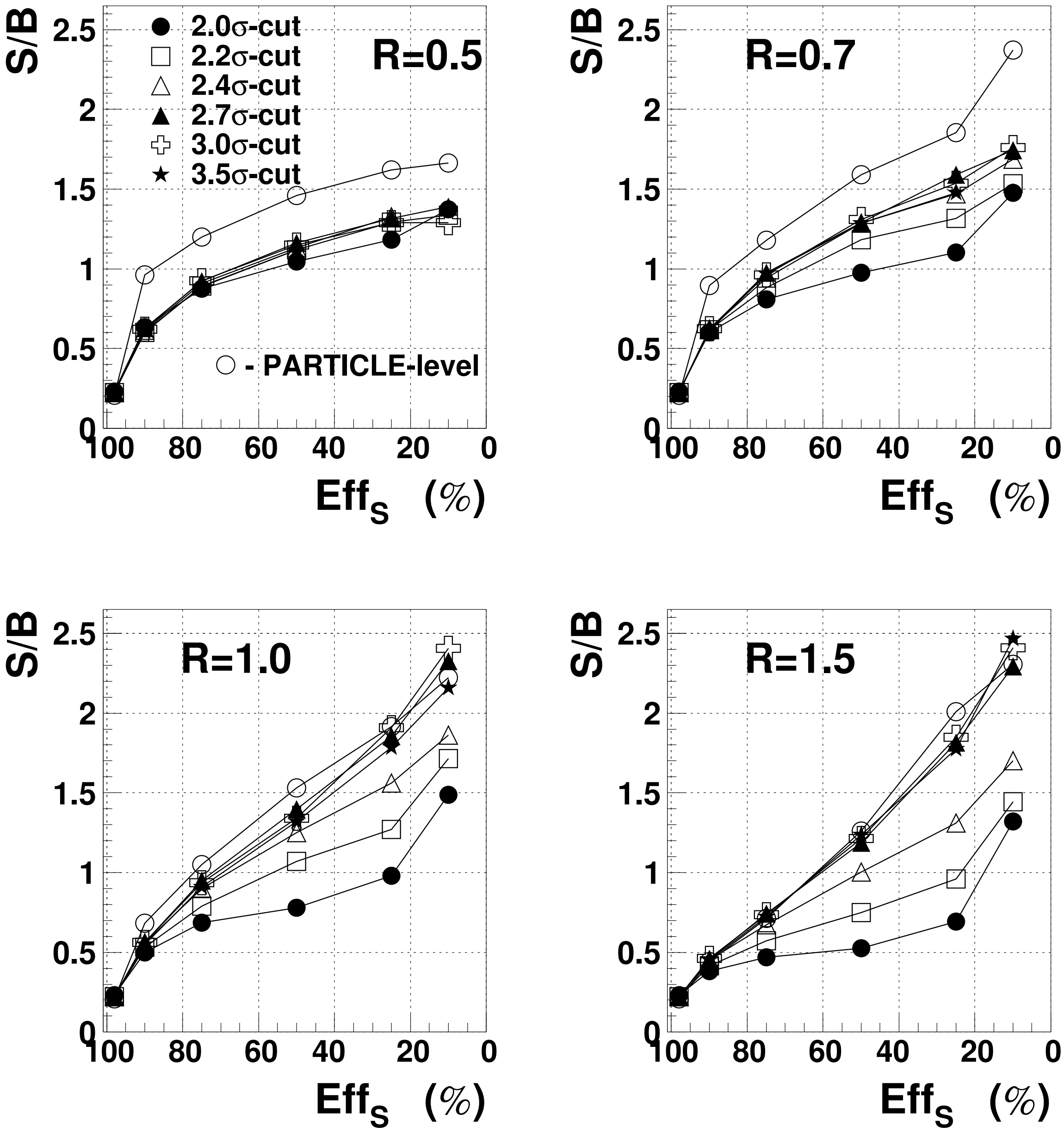
Case $40 < Et^{\gamma} < 100\,GeV$.



An average value of the ΔEt^{γ} and ΔEt^{jet} at the ring around of the direct photon (a) and jets (b) and the difference $\Delta Et^{jet} - \Delta Et^{\gamma}$ (c).

Jets are smeared over $R = 1.5$. It should be taken into account when we are separating the direct photon from jet photons.

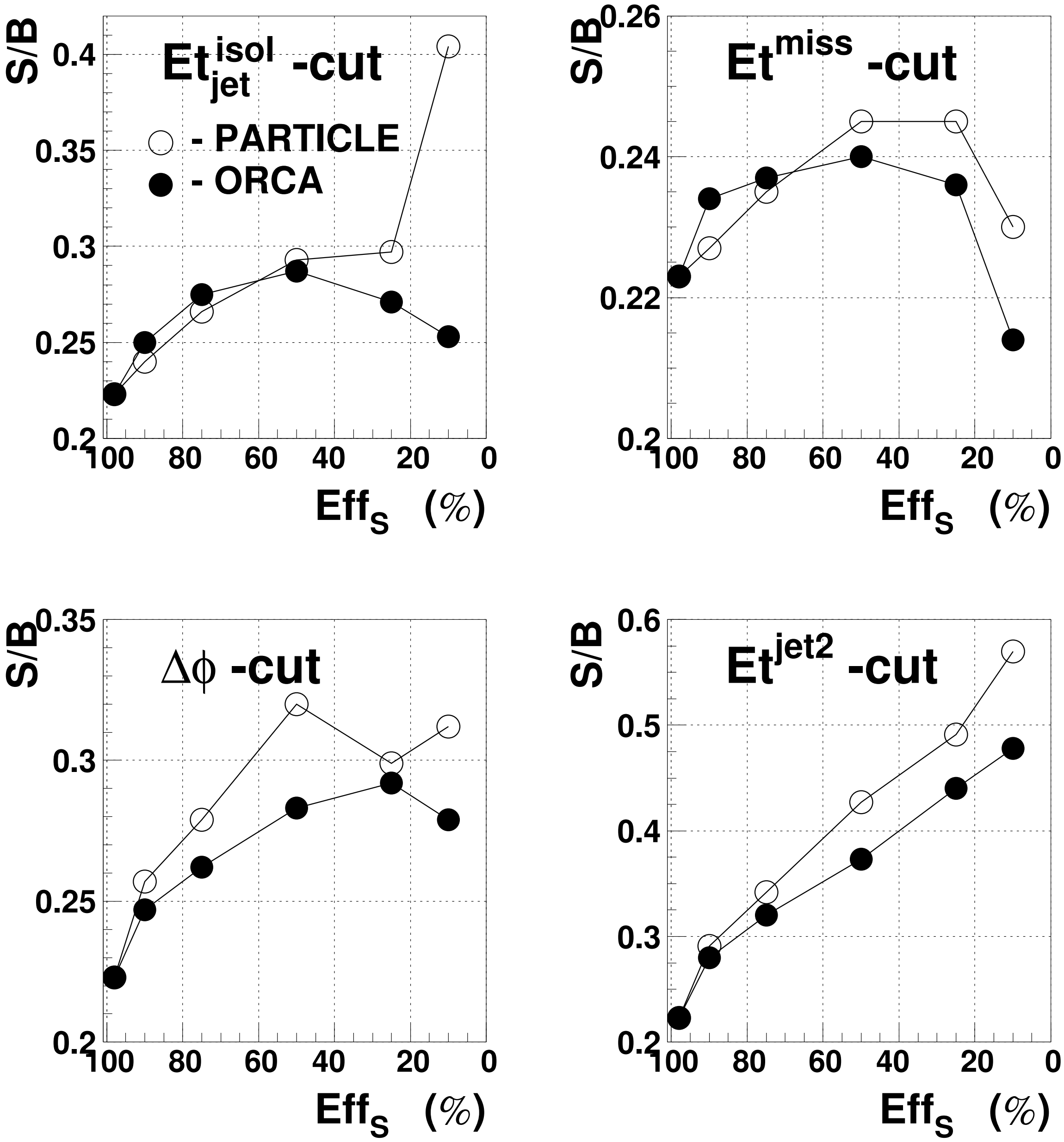
Case $40 < Et^{\gamma} < 100\,GeV$.



Eff$_S$ dependents of S/B for cuts to the summarized Et in R=0.5, 0.7, 1, and 1.5 around "γ" (Et_{γ}^{isol}-cuts) and for different E cuts of the cell.

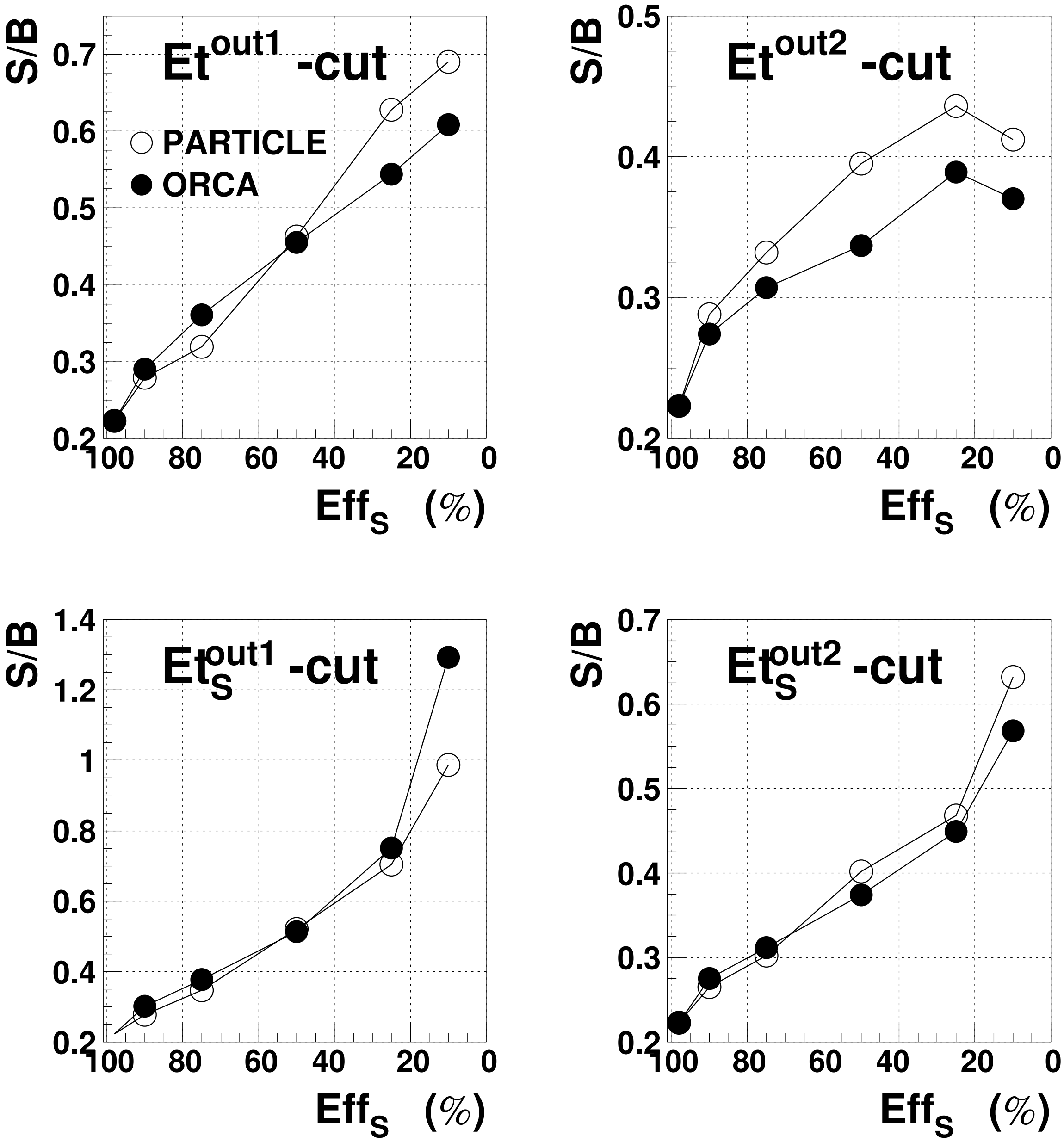
We have the best suppression of the background at $0.7 \leq$ R ≤ 1.5 and $\approx 3\sigma$ cuts on E cell. Further we will used Et_{γ}^{isol} in cone R=0.7, 1., and 1.5 at 3σ cut to cell.

Case $40 < Et^{\gamma} < 100\, GeV$.



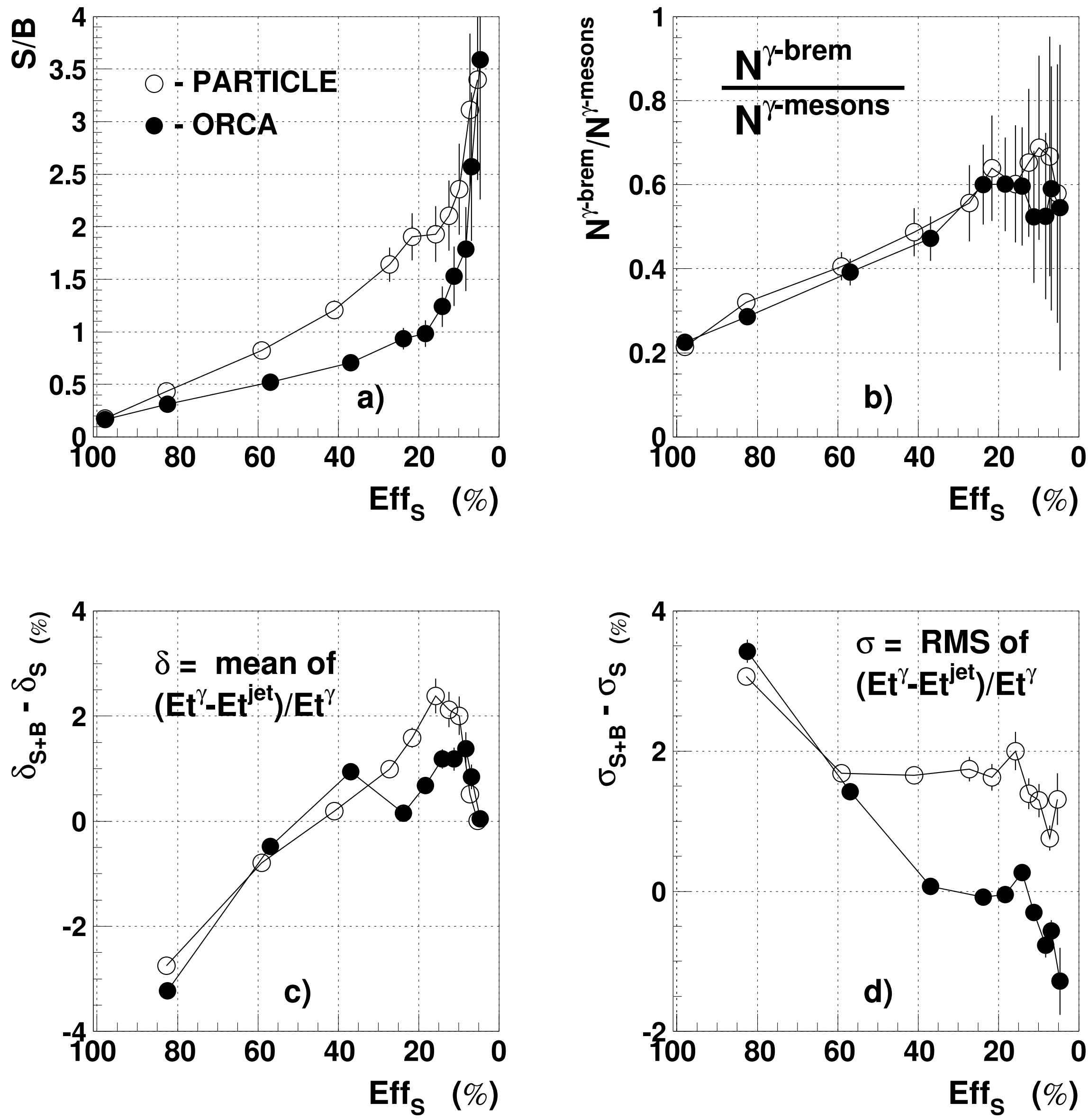
We observe some improvements of the S/B when we put the restriction for isolation of jet, missing Et, and an angle between "γ" and Et of the second jet.

Case $40 < Et^{\gamma} < 100 GeV$.



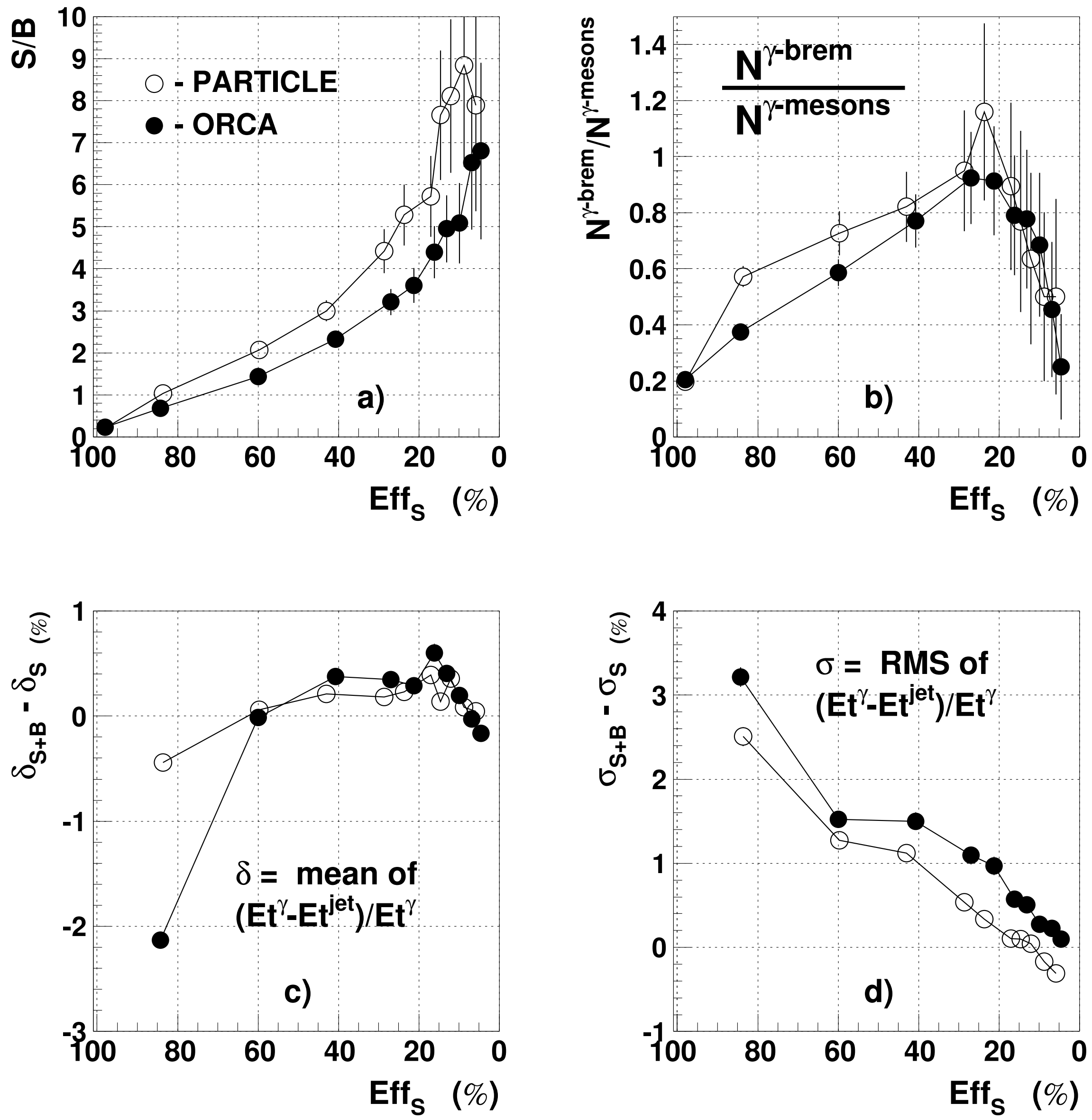
Also we get improvements of ratio S/B when we put the restriction for vector and scalar sum of Et around "γ" and jet.

Case $20 < Et^{\gamma} < 40\,GeV$.



Selection of the events with Et_{γ}^{isol} cut and other cuts we have amount of S/B ratio about $>$3.5 at Eff$_S < 5\%$ (fig.a). The background leads to systematic and statistical errors of a calibration $<2\%$ at Eff$_S < 60\%$ (fig.c, d). In background events the photons from decays of mesons ("γ-mesons") dominate in comparison to the photons which one emitted from quarks ("γ-brem").

Case $40 < Et^{\gamma} < 100\,GeV$.

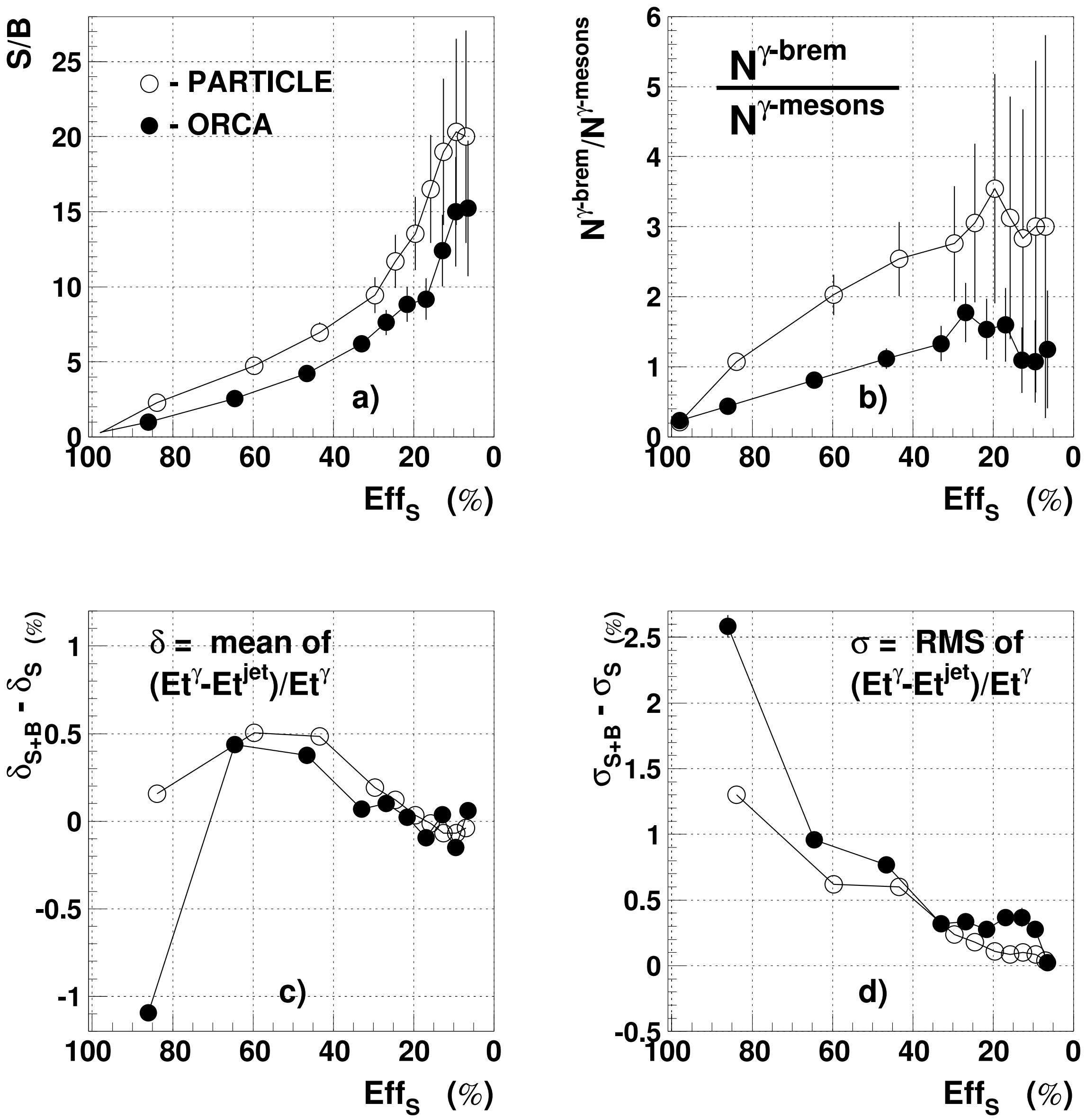


The situation with background is much better by increasing of the Et$^{\gamma}$:

S/B=7 at Eff$_S = 5\%$ (fig.a, ORCA level)

systematic error $< 0.5\%$ at Eff$_S < 60\%$ (fig.c).

Case $100 < Et^{\gamma} < 200\, GeV$.



Ratio S/B=15 at Eff$_S = 5\%$ (fig.a, ORCA level).

Systematic error $< 0.5\%$ at Eff$_S < 60\%$ (fig.c).

At Eff$_S$ $<50\%$ in background events the bremsstrahlung photons dominate by compare to the photons from mesons (fig.b).

Conclusions

- ISR is not the only source of statistical errors of the calibration but it also leads to the systematic errors.
- A limitation of the some physical parameters of events leads to essential systematic errors.
- By using of the event selection, essentially suppression of the background events can be reached.
- At signal suppresion less then in to 2 times, the background leads to calibration errors less then 1-2$\%$.
- The magnetic field effect, energy and spatial smearing ("FIELD" and "SMEAR" levels) does not practically influence to the results. Results has been determined by effects of "PARTICLE" and "ORCA" levels.
- Situation with γ in EB and γ in EE is similar.

Next step of the calibration errors study is taking into account pile-up, γ-trigger, jetfinder and π^0 rejection.