Use of ECAL Time in physics analyses at CMS

Livia Soffi

Universita' Sapienza Roma – INFN Roma

IFAE, Cagliari, 04.04.2013

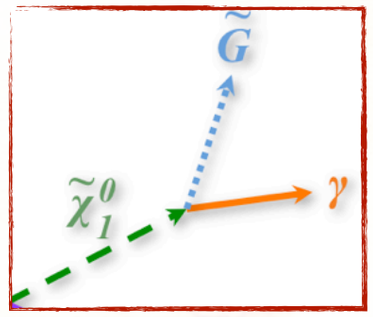
Outline

ECAL

Detection of the $H \to \gamma\gamma$ decay enhanced by the **good energy resolution**

Fast scintillation timescale of PBWO4: >80% of the light emitted in about 25 ns

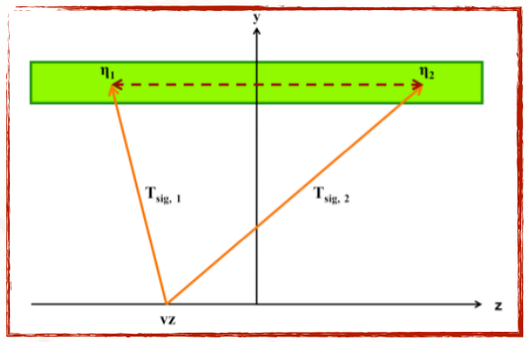
Search for exotic physics with long-lived particles →



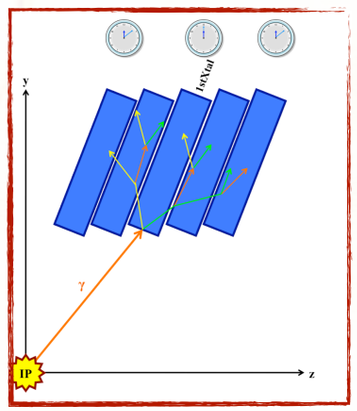
arXiv:1212.1838v1

Time of flight measurement

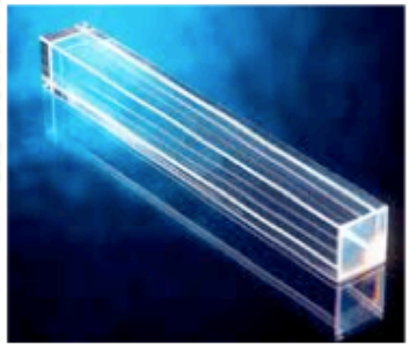
→ Identification of the primary vertex in events with low track multiplicity (e.g. $H \to \gamma\gamma$) →



Time development of electromagnetic shower → Photon Identification →

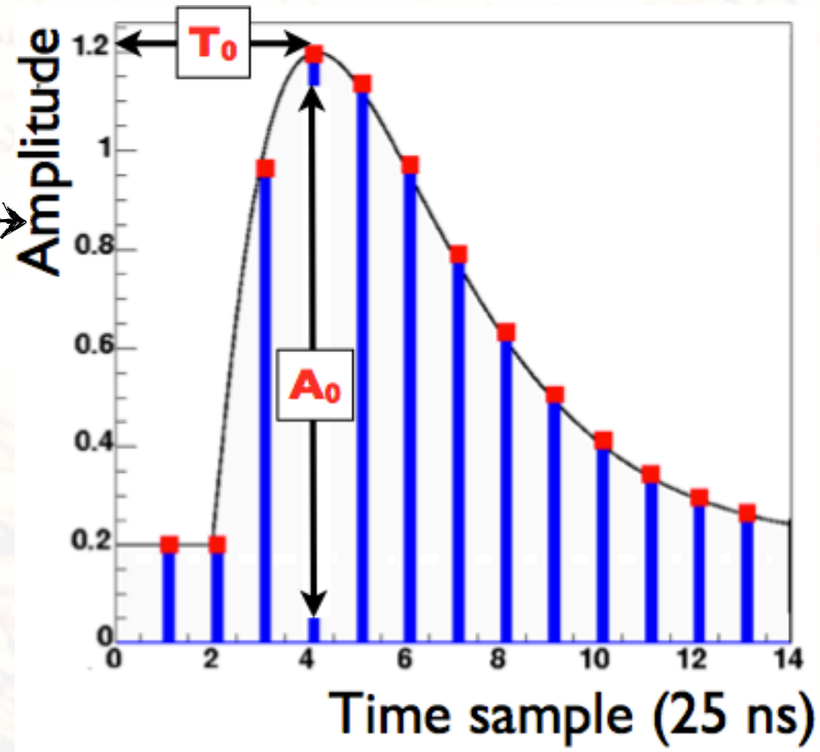


ECAL Time Measurement

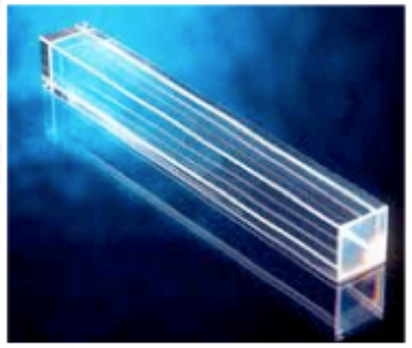


Photodetector Front End electronics

$$E_{xtal} \propto A_0$$
$$T_{xtal} \propto T_0$$

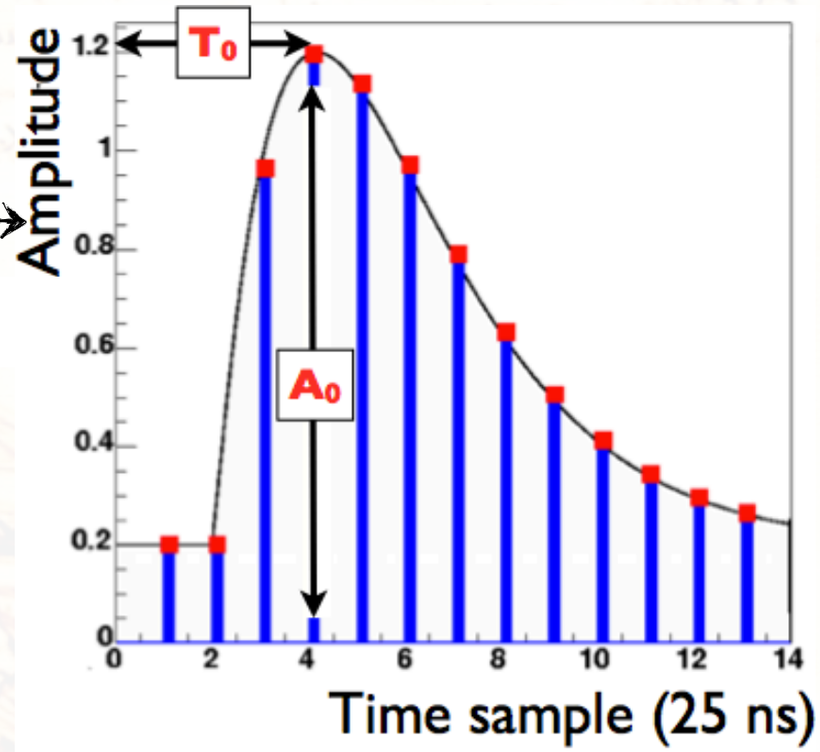


ECAL Time Measurement

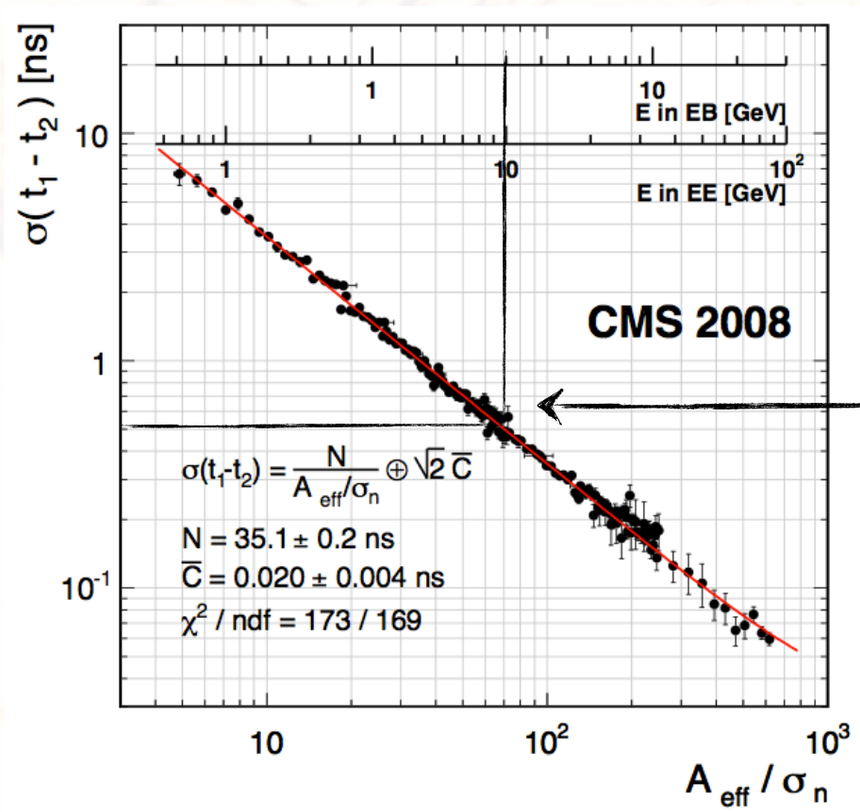


Photodetector Front End electronics

$$E_{xtal} \propto A_0$$
$$T_{xtal} \propto T_0$$



Time resolution @TestBeam

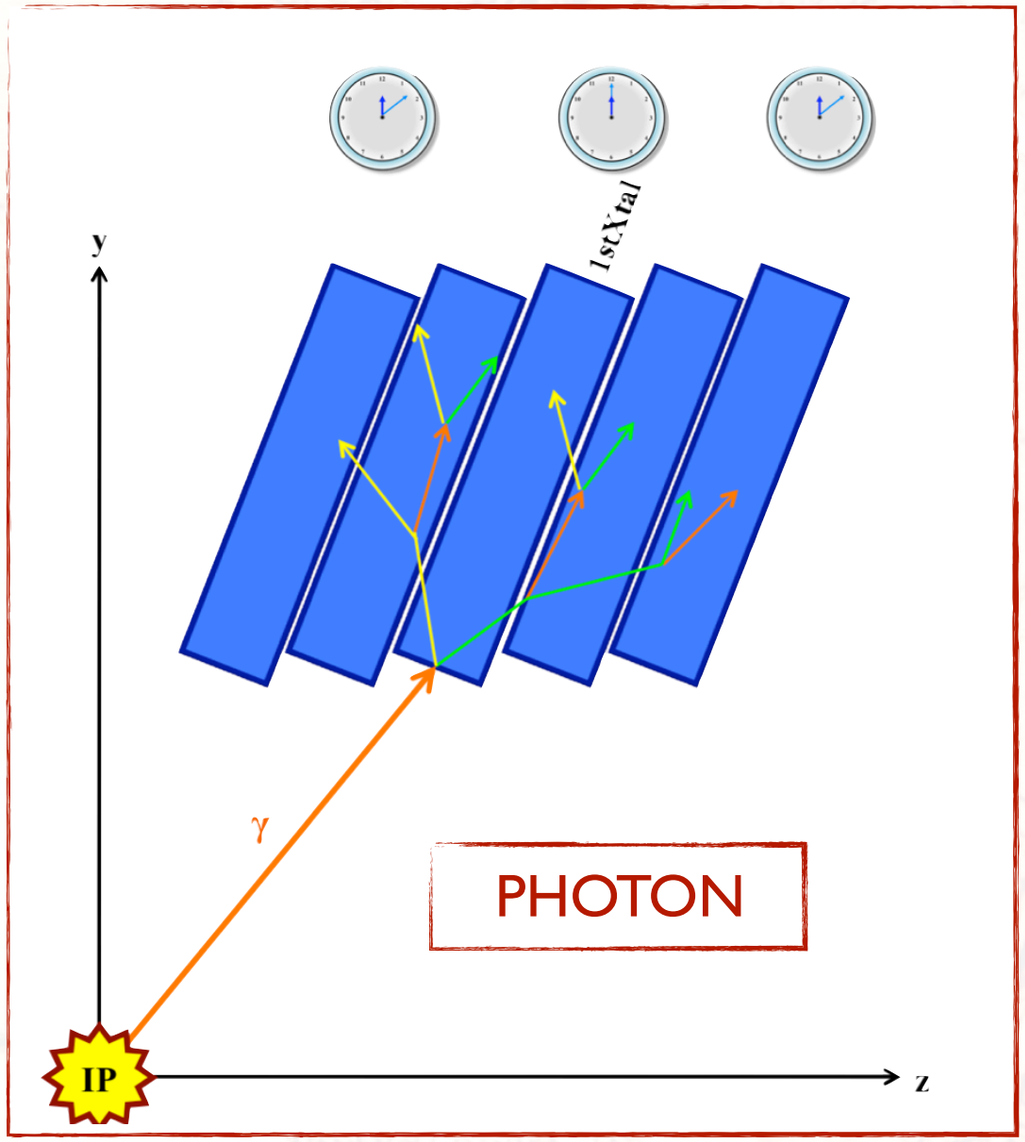


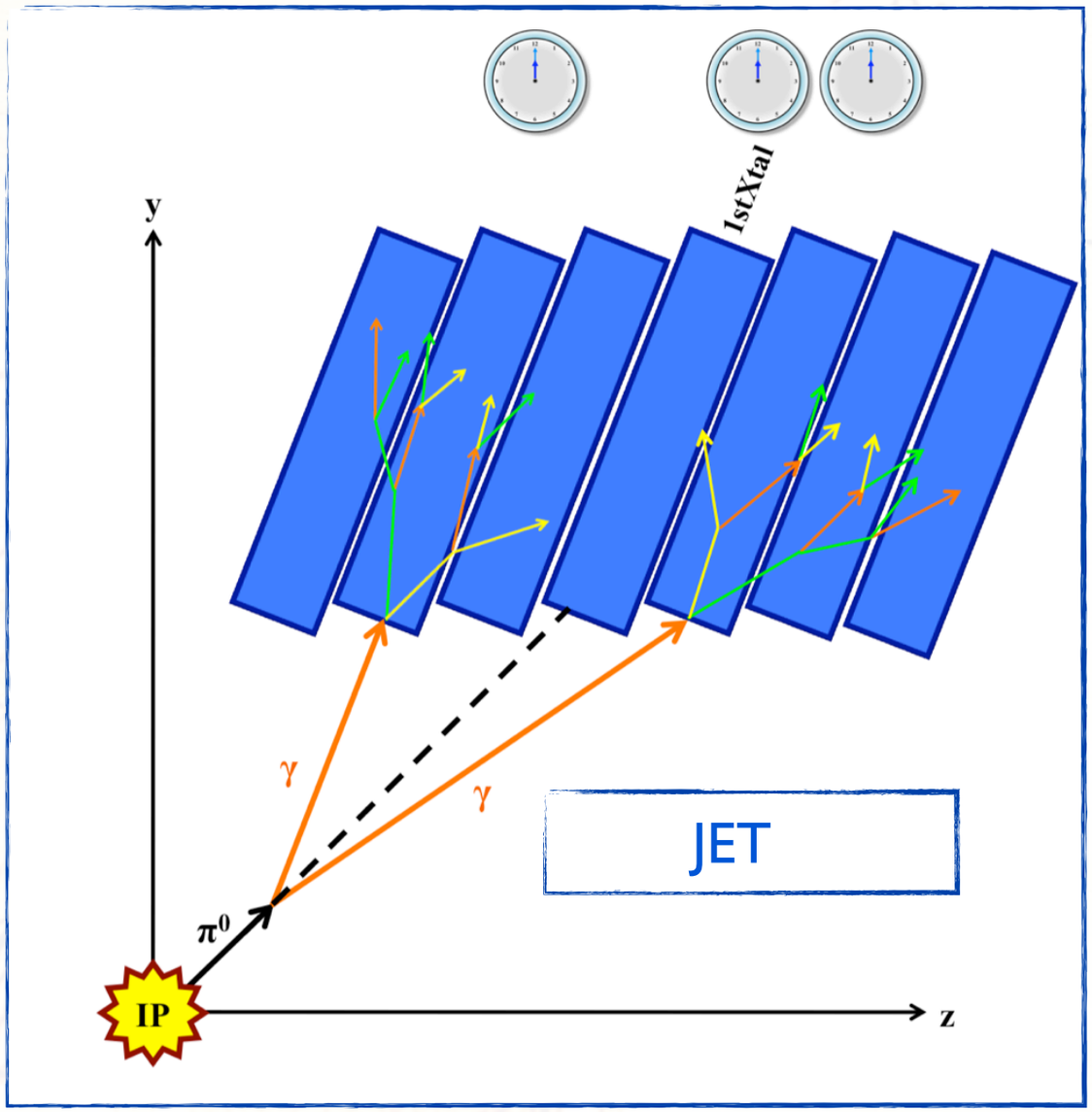
E_{xtal} > 3 GeV (barrel)

E_{xtal} >10 GeV (endcap)

$\sigma_{xtal,i}$<1 ns

Time development of a shower





PHOTON

Single shower - development from the impact point (seed) to the peripherical crystals

JET

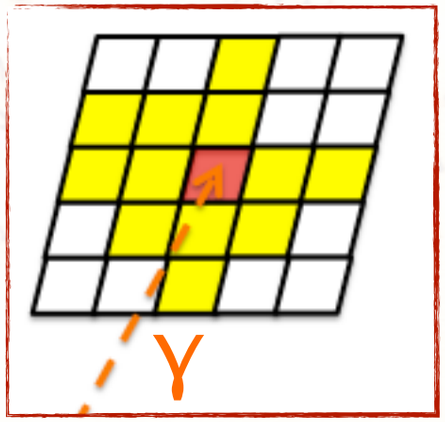
Multiple showers - not compatible with a single photon – **energy deposits almost synchronous**

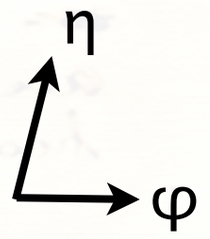
Signal and Background Discrimination

$T_{xtal,i}$ ⟶ Time of the single **xtal in the cluster**

T_{seed} ⟶ Time of the **seed of the cluster**

Study of $\Delta T_i = T_{xtal,i} - T_{seed}$ vs the distance along η and φ



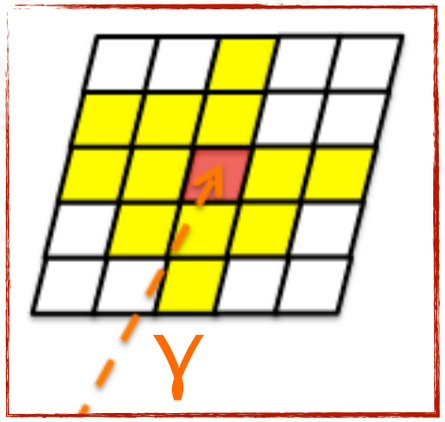


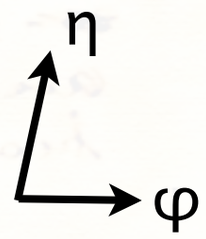
Signal and Background Discrimination

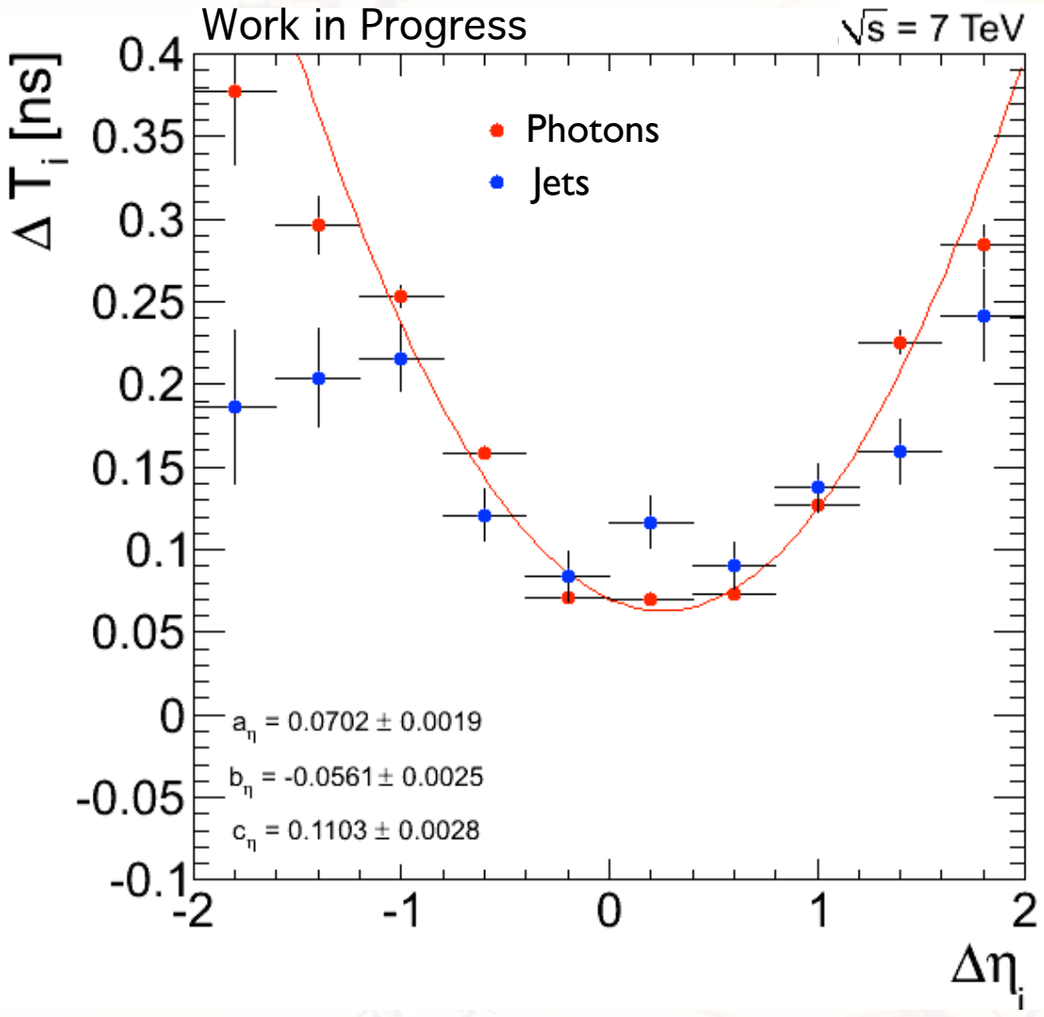
$T_{xtal,i}$ ⟶ Time of the single **xtal in the cluster**

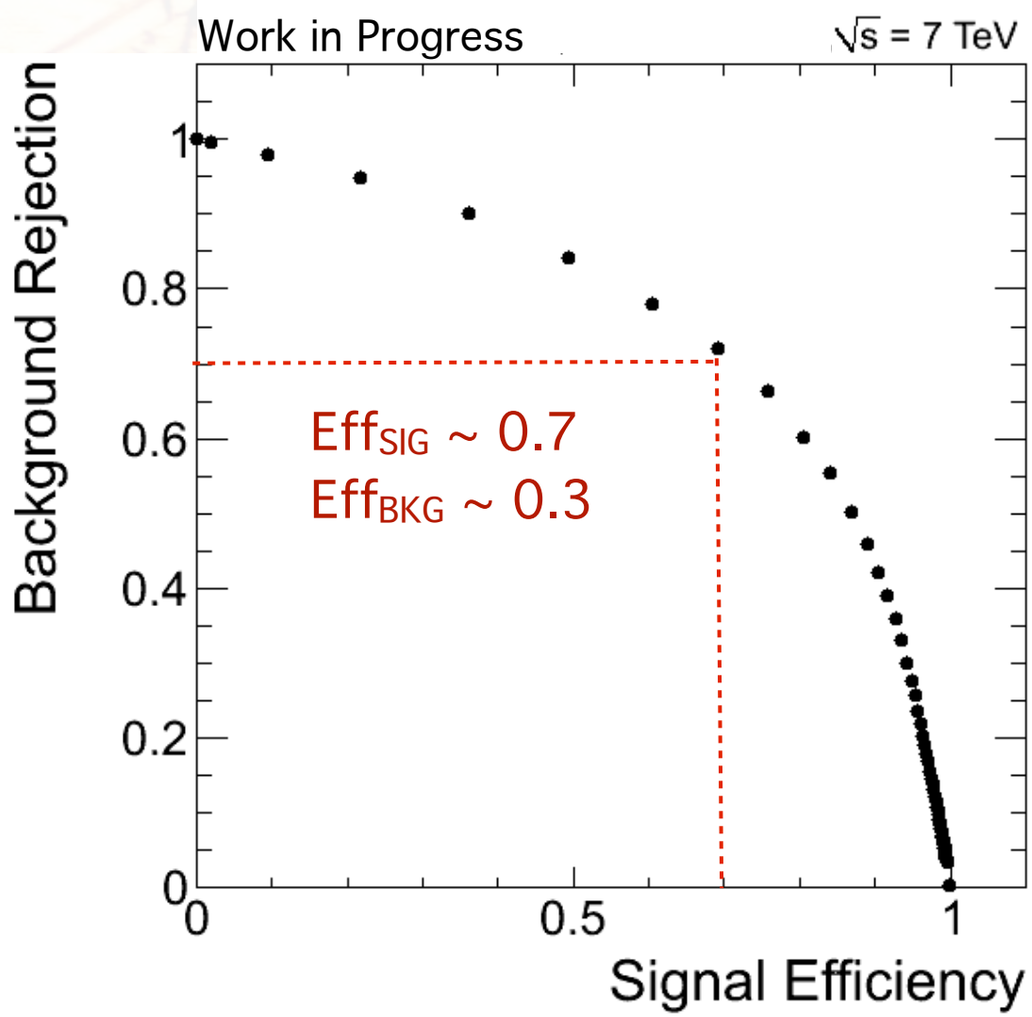
T_{seed} ⟶ Time of the **seed of the cluster**

Study of $\Delta T_i = T_{xtal,i} - T_{seed}$ vs the distance along η and φ





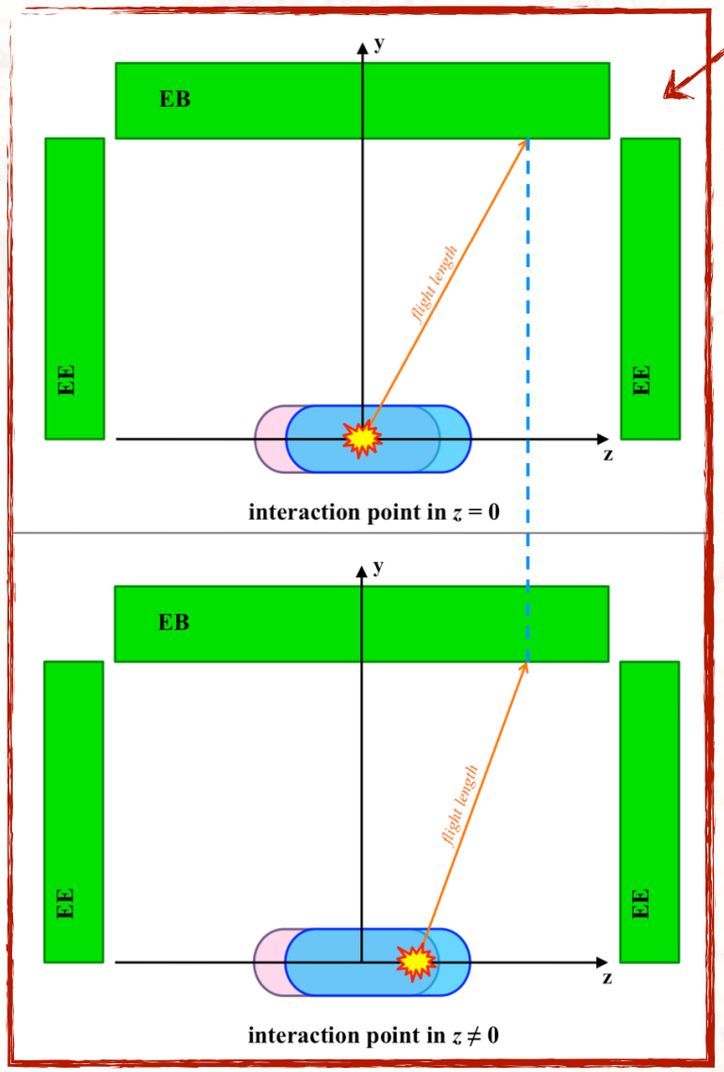


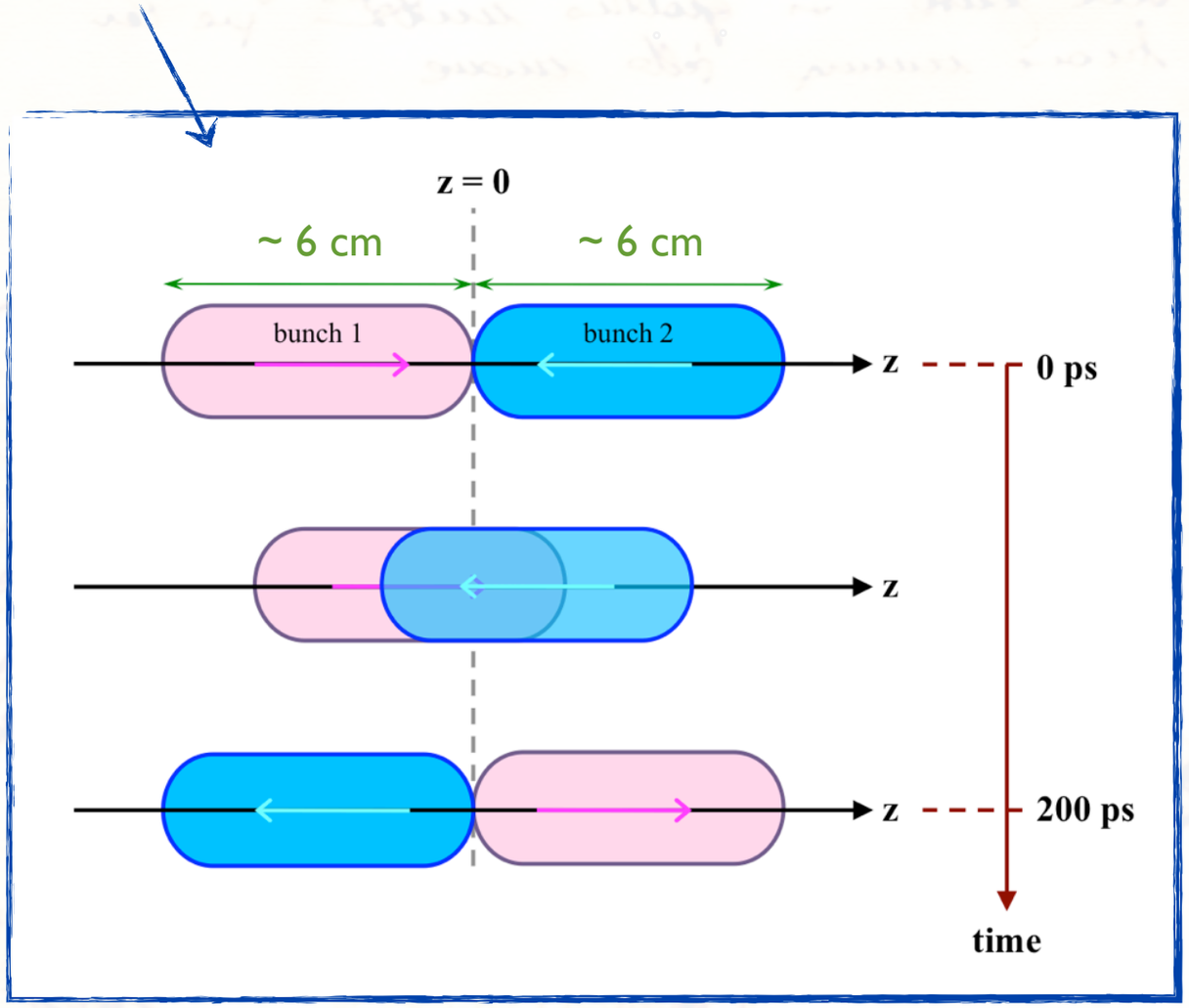


Vertex Identification

Exploit the geometrical relationship between V_z and the **Time of flight** of the photon

Measured time affected by **WHERE** and **WHEN** the collision occurs

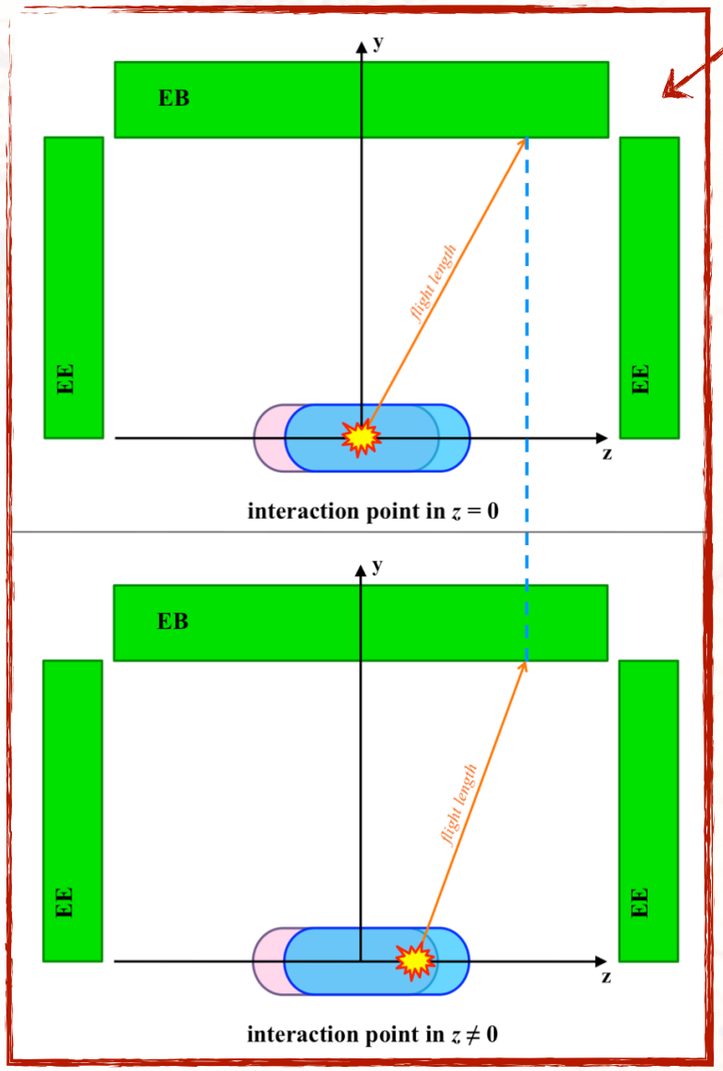


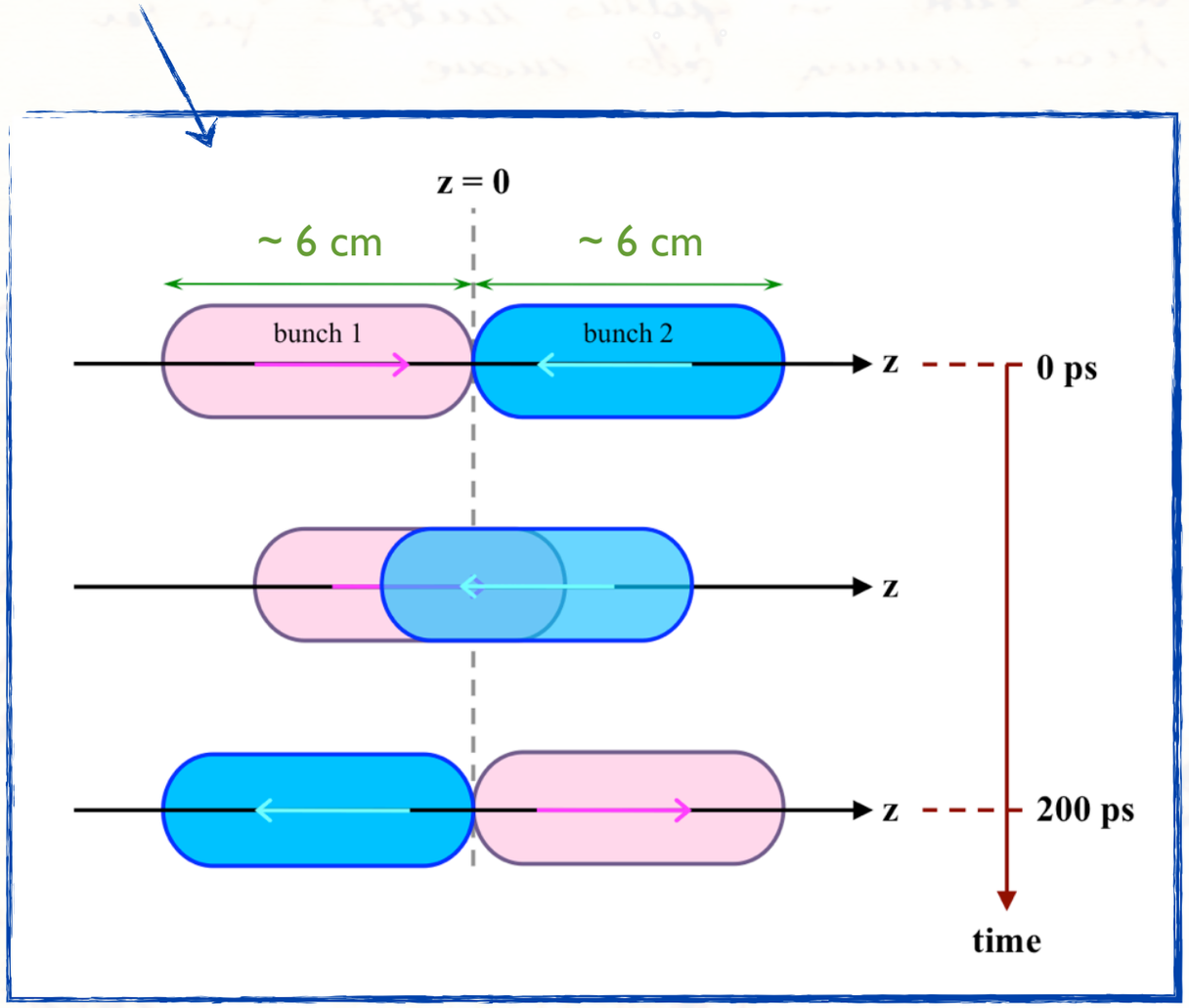


Vertex Identification

Exploit the geometrical relationship between V_z and the **Time of flight** of the photon

Measured time affected by **WHERE** and **WHEN** the collision occurs





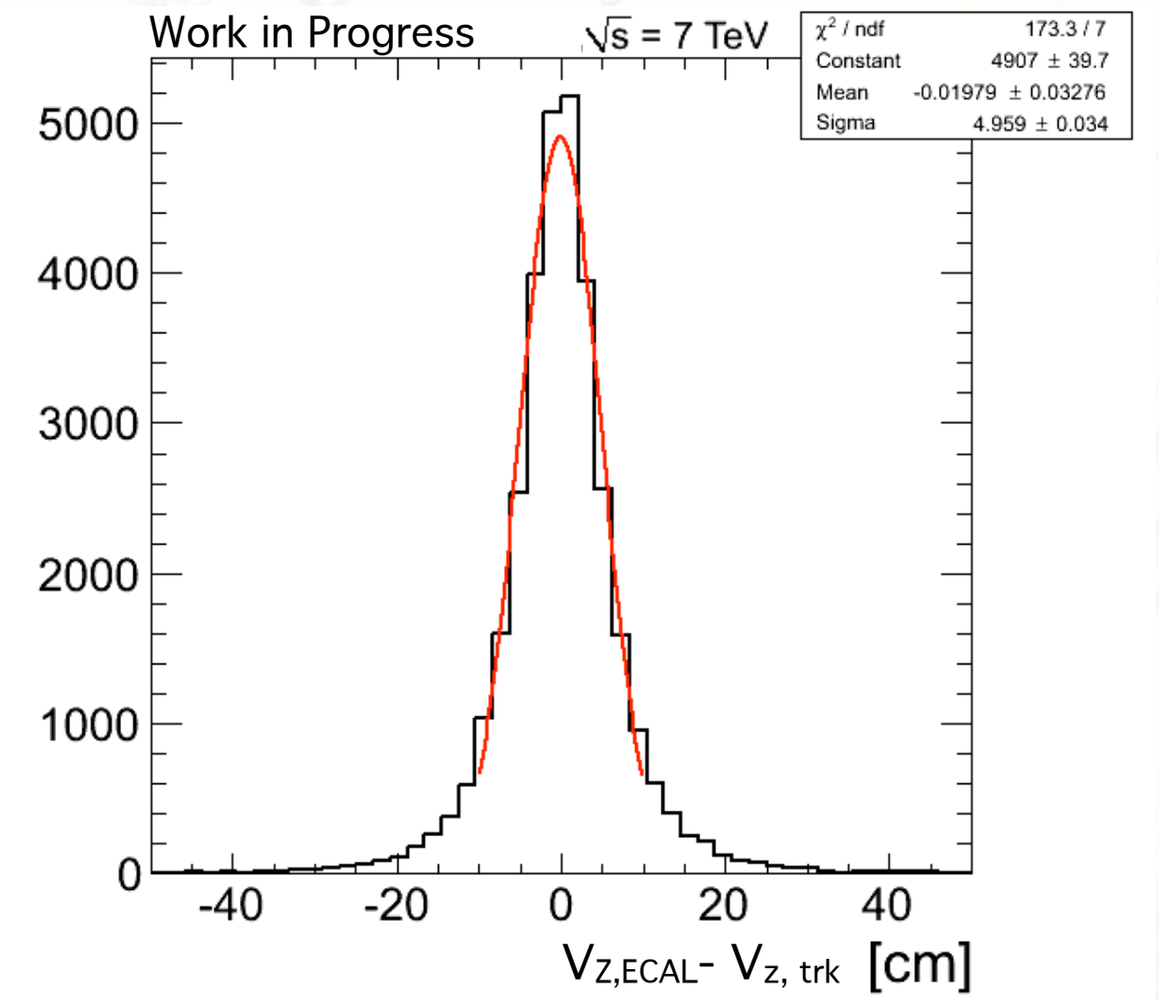
$$T_{measured} = T_{flight}(V_z) + T_{interaction}$$

V_z and $T_{interaction}$ 2 unknowns → 2 objects needed to extract Vz → **Events with two photons**

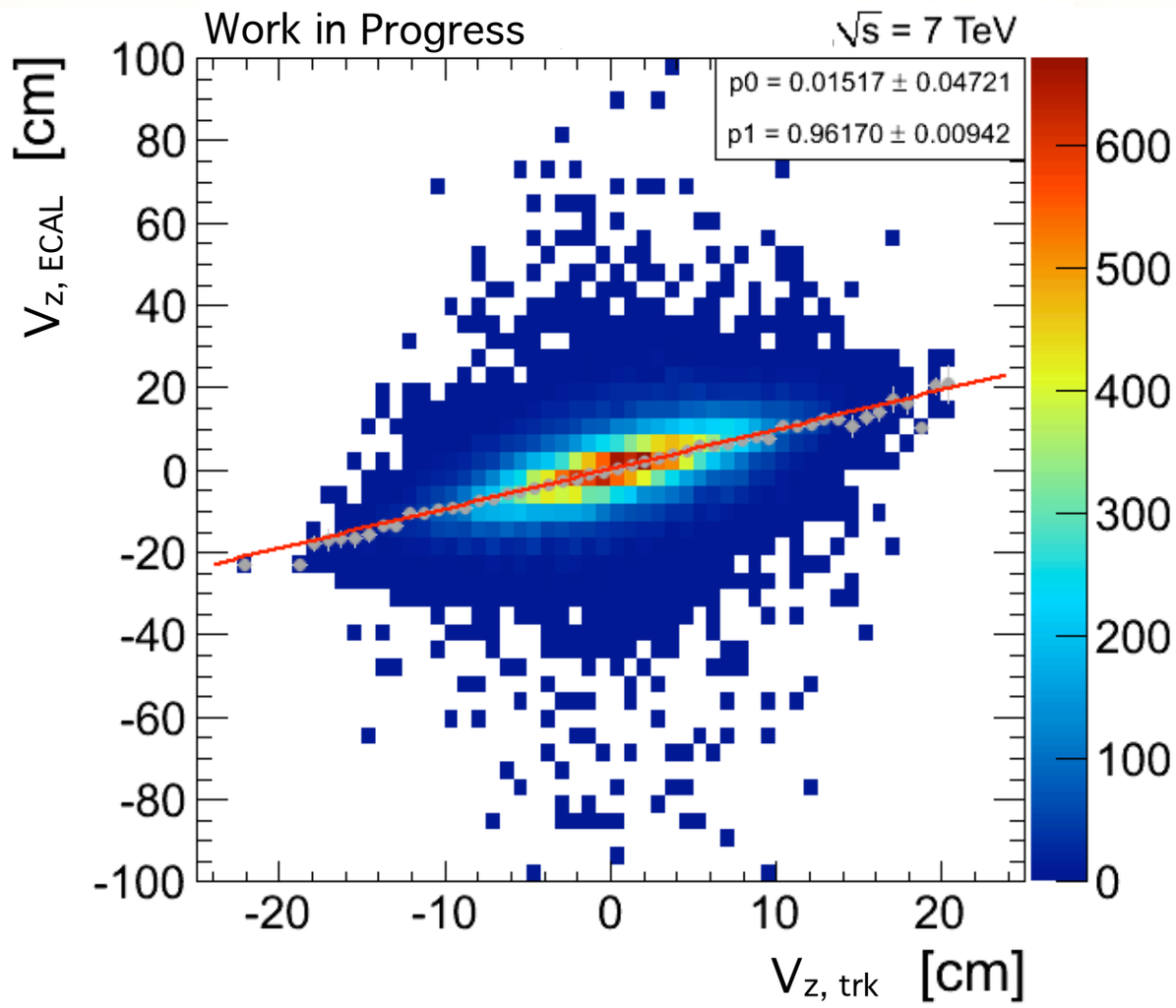
Vertex Resolution

Exploit events with High-P_T photons and Jets

Resolution of $V_{z,ECAL}$ defined assuming the position given by the tracker ($V_{z,trk}$) as true value of the interaction point



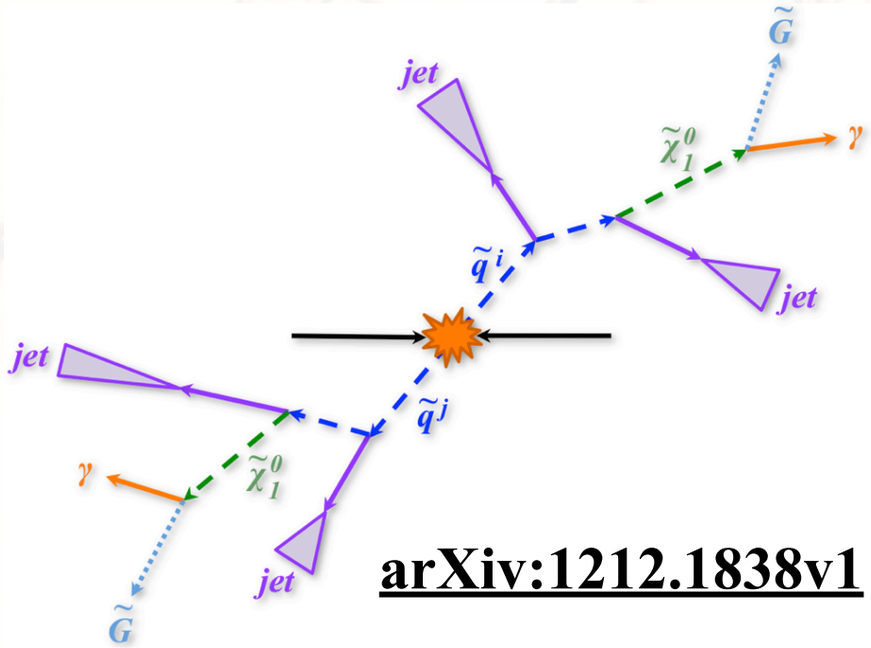
σ_{MC}~ 5 cm



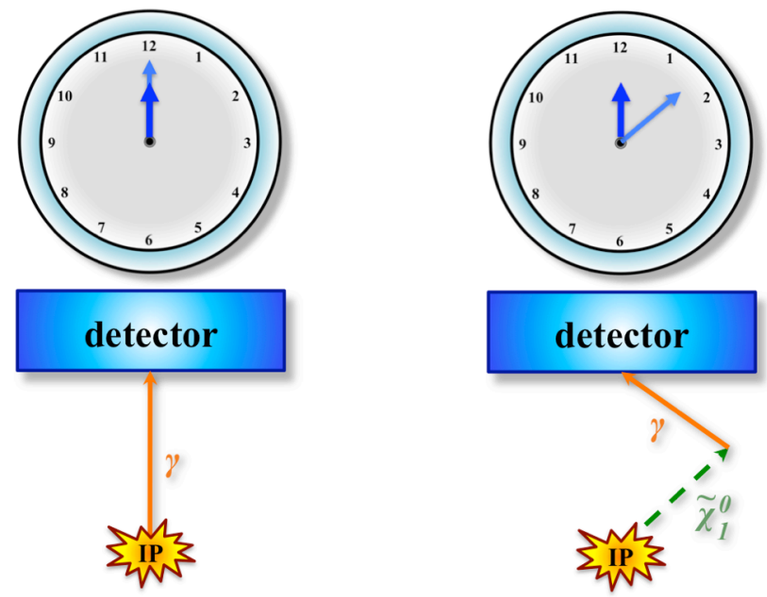
Linearity 1:1 between $V_{z,ECAL}$ and $V_{z,trk}$

$V_{z,ECAL}$ resolution currently limited by time resolution and crystals intercalibration

First search using ECAL Time

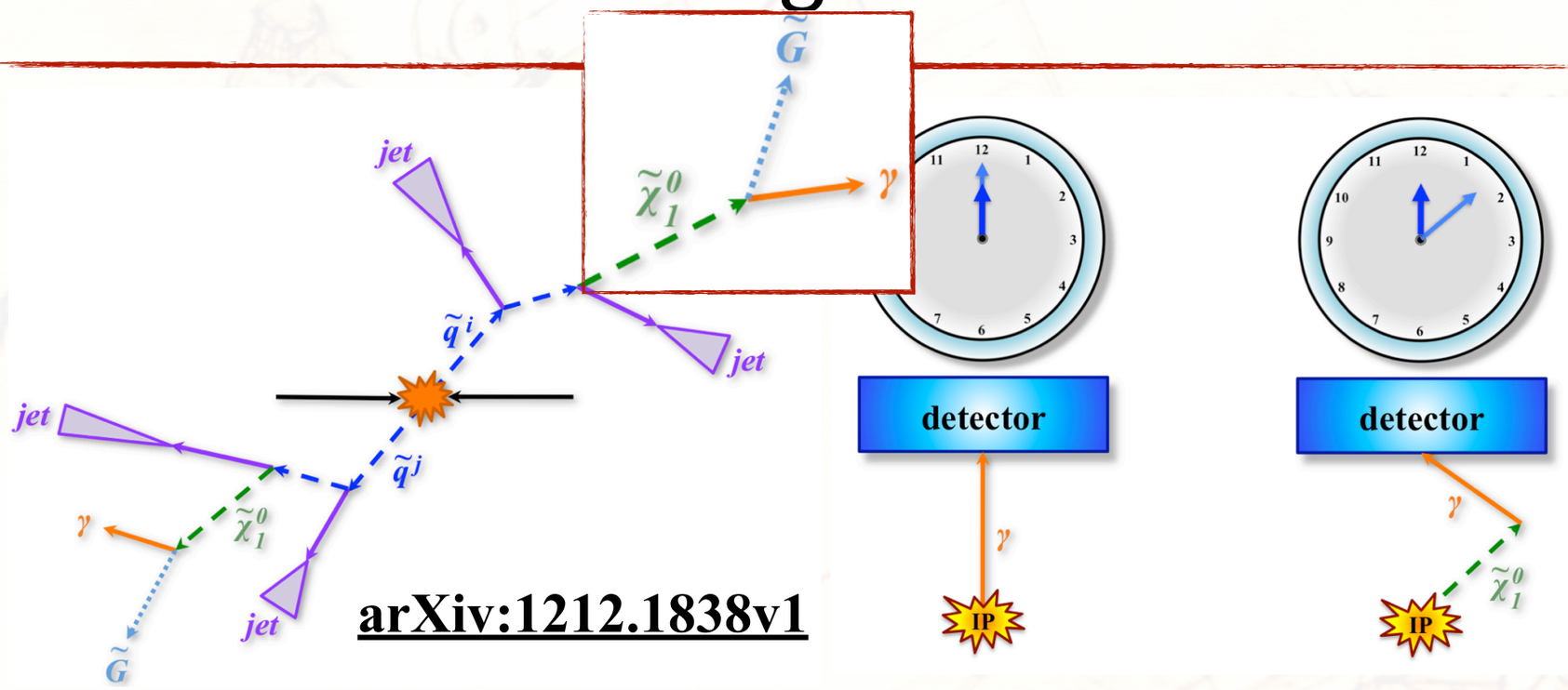


arXiv:1212.1838v1

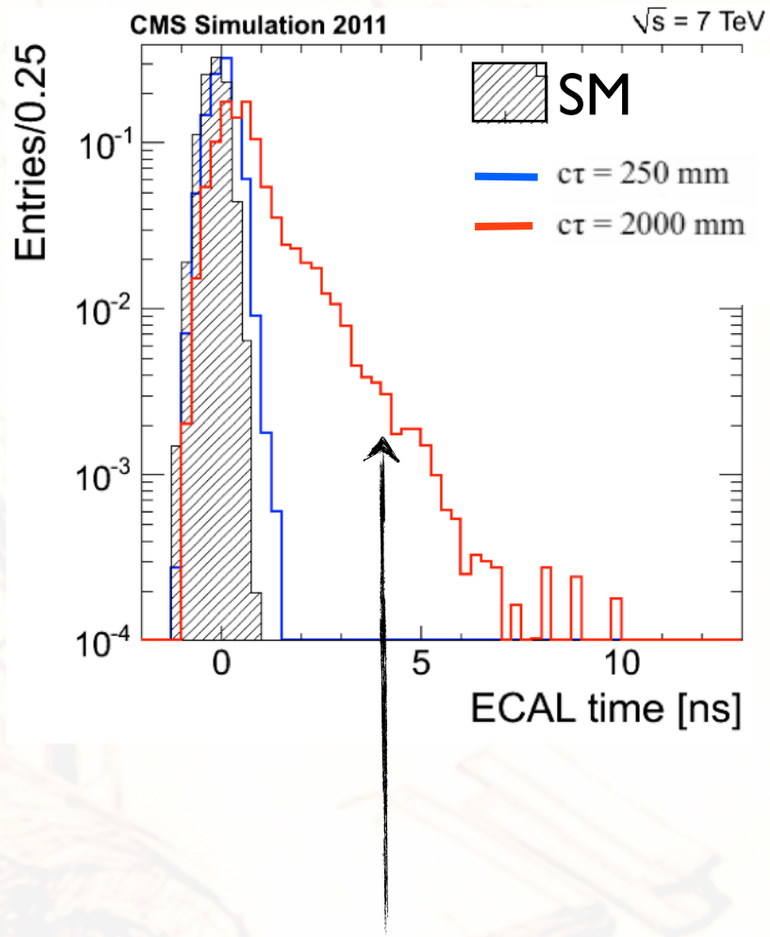


Search for **long-lived particles** within the **GMSB** model

First search using ECAL Time



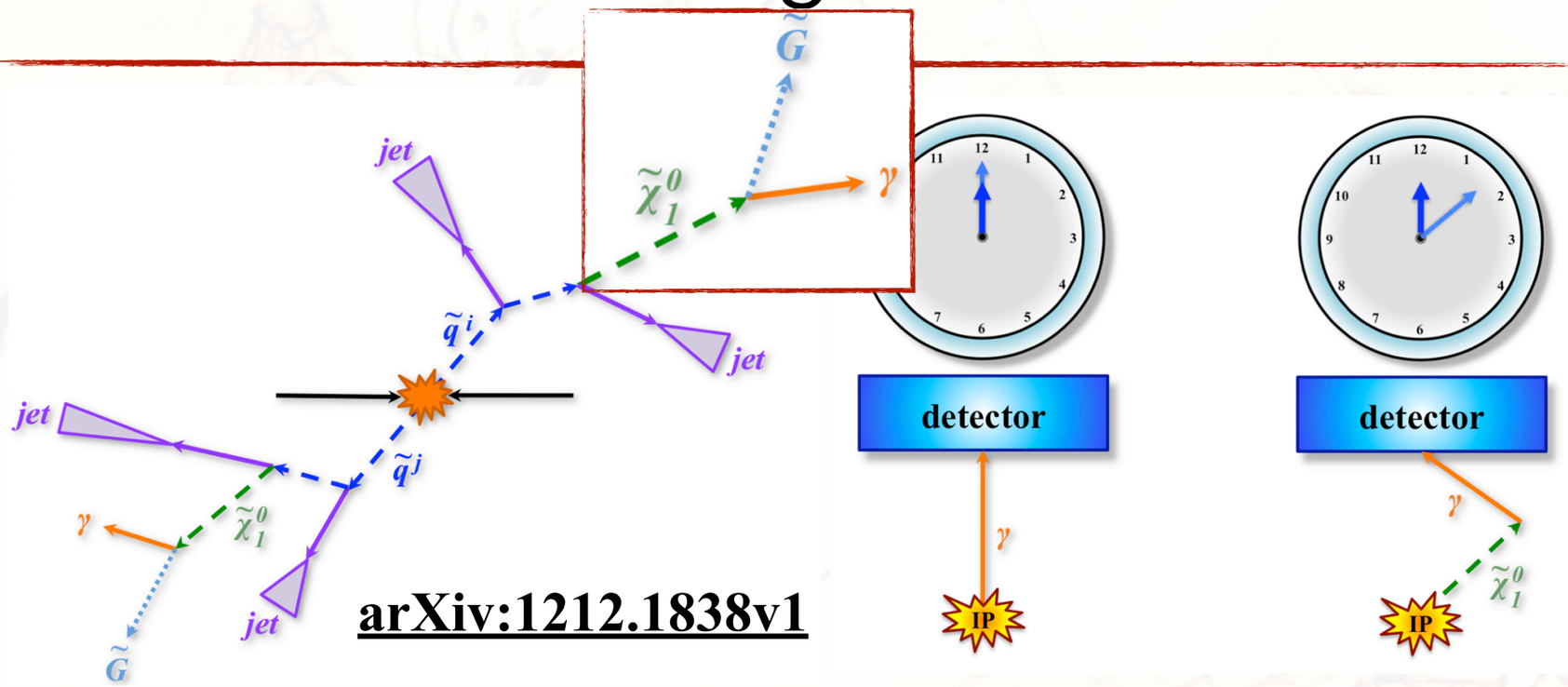
arXiv:1212.1838v1



Search for **long-lived particles** within the **GMSB** model

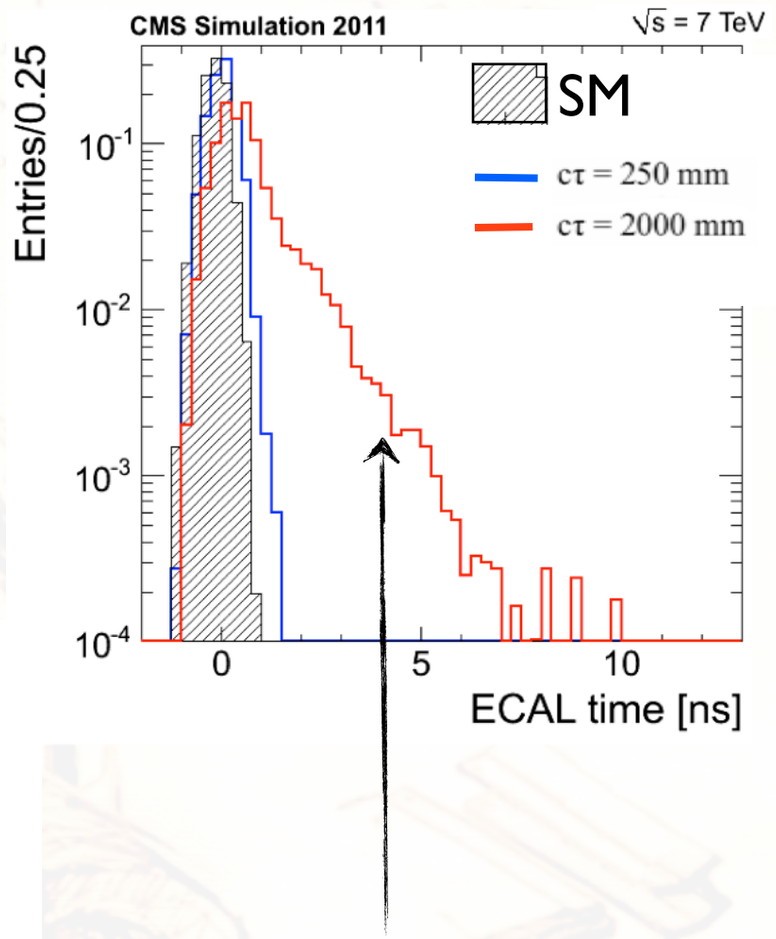
Signal expected in **high time region**

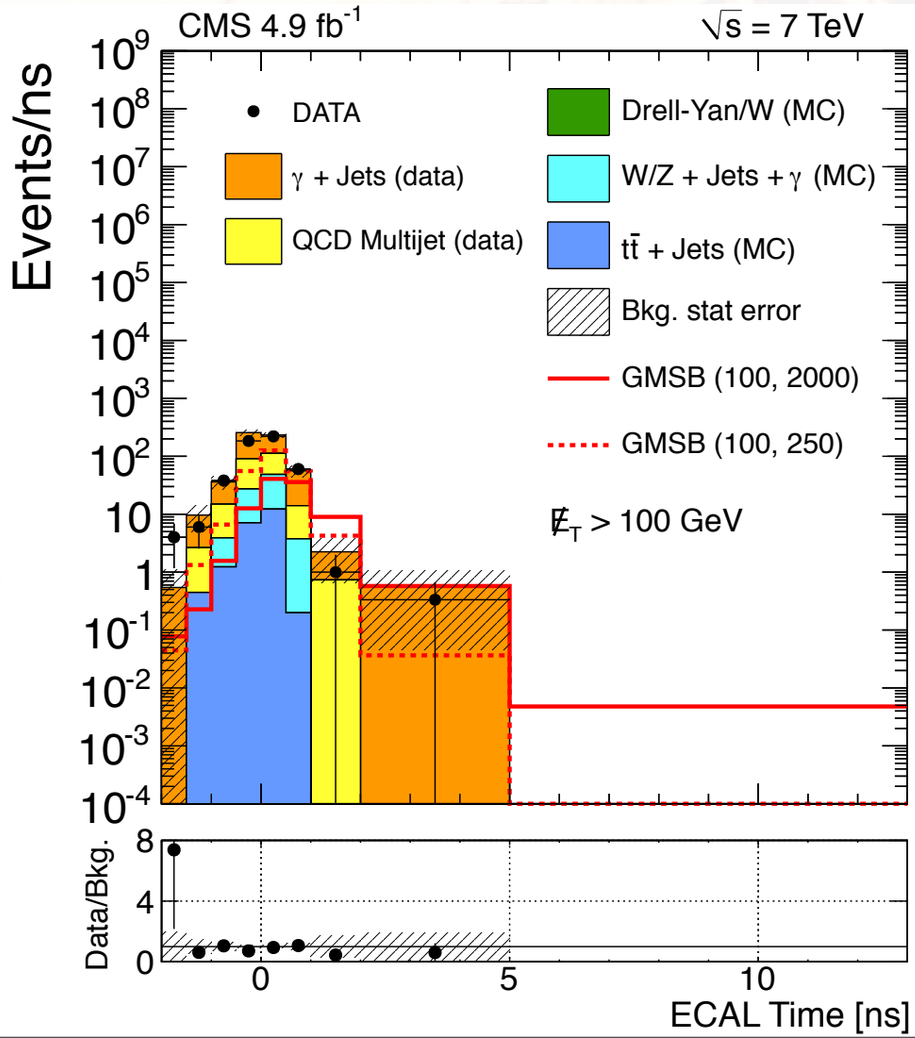
First search using ECAL Time



arXiv:1212.1838v1

Search for **long-lived particles** within the **GMSB** model





No excess observed
Best existing limit on long-lived neutralino

Signal Expected in **high time region**

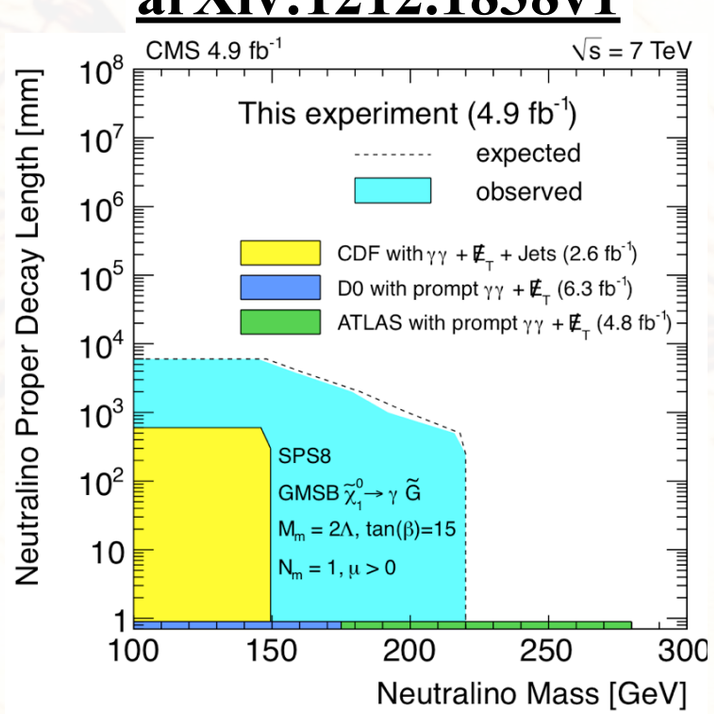
Conclusion

- Fast scintillation timescale of PBWO4 allows precise time measurement with CMS ECAL.

- Time of flight and time development of electromagnetic showers can be exploited in physics analysis.

- First CMS publication that exploits time from the ECAL set the best existing limit on long lived neutralinos in the SUSY model.

arXiv:1212.1838v1



Backup

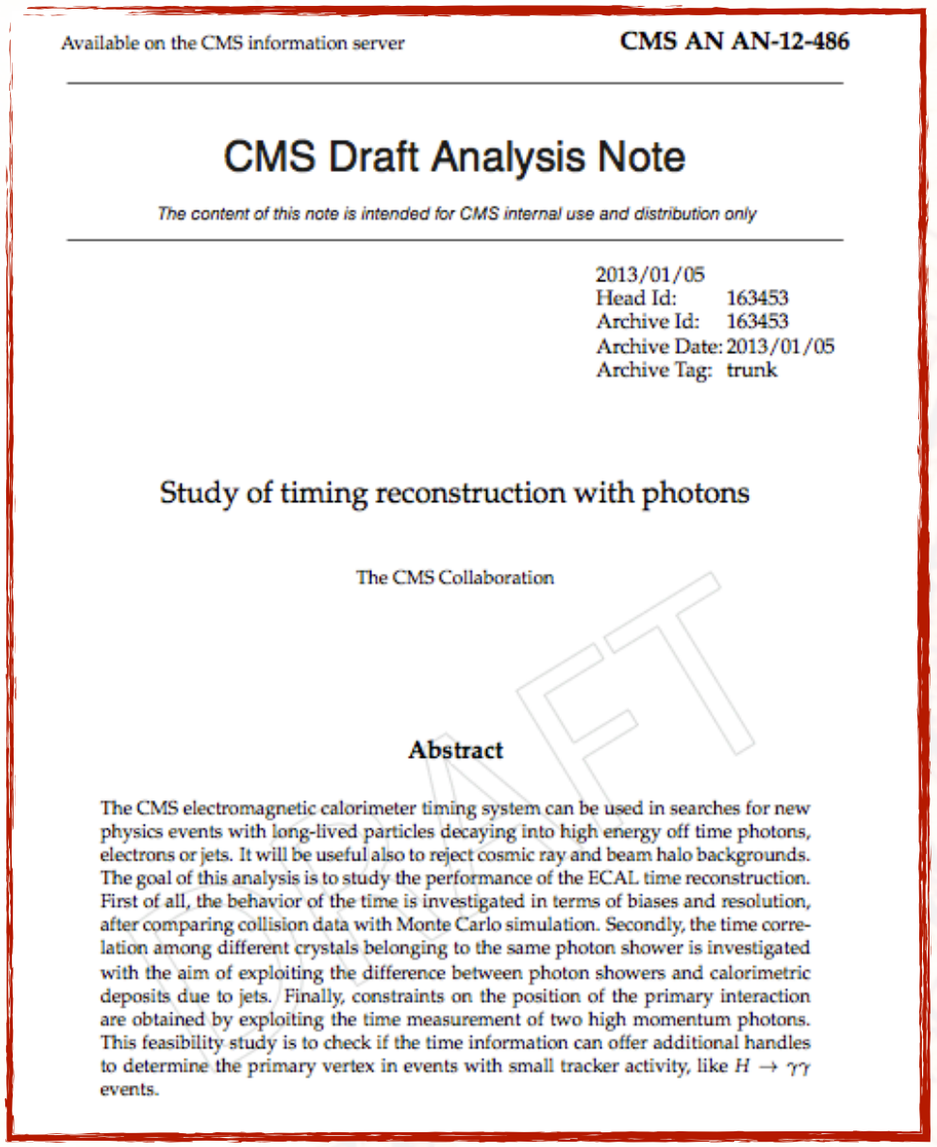
Outline

Data Sample:

492.6 pb−1: /Photon/Run2011A PromptReco-v4/AOD
182.5 pb−1: /Photon/Run2011A 05Aug2011-v1/AOD
354.7 pb−1: /Photon/Run2011A PromptReco-v6/AOD
1382.7 pb−1: /Photon/Run201 PromptReco-v1/AOD

MC Sample:

GMSB Lambda-100 CTau-1 7TeV pythia6 cff/Summer11*
GMSB Lambda-120 CTau-1 7TeV pythia6 cff/Summer11*
GMSB Lambda-140 CTau-1 7TeV pythia6 cff/Summer11*
GMSB Lambda-160 CTau-1 7TeV pythia6 cff/Summer11*
GMSB Lambda-180 CTau-1 7TeV pythia6 cff/Summer11*



Available on the CMS information server CMS AN AN-12-486

CMS Draft Analysis Note

The content of this note is intended for CMS internal use and distribution only

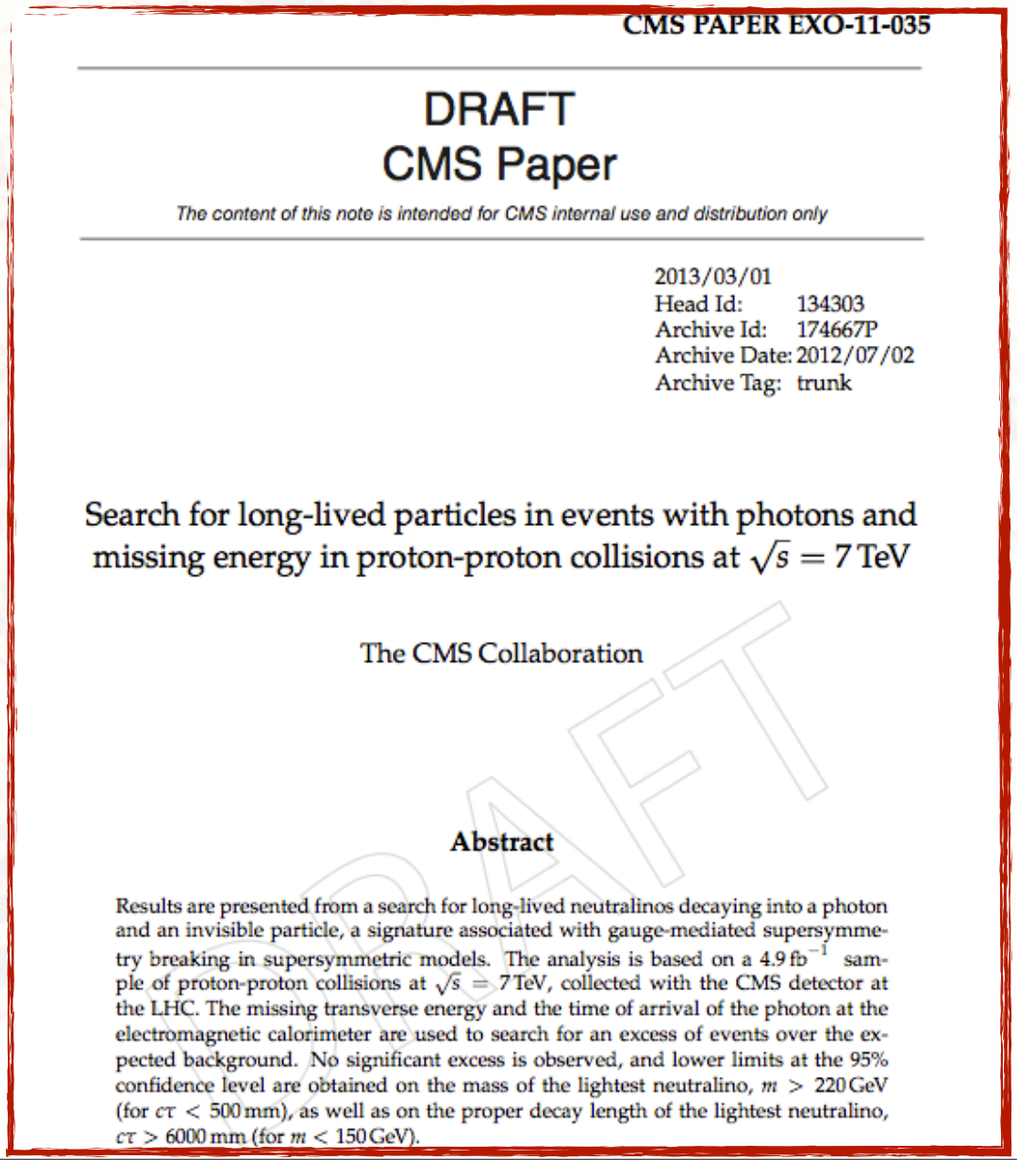
2013/01/05
Head Id: 163453
Archive Id: 163453
Archive Date: 2013/01/05
Archive Tag: trunk

Study of timing reconstruction with photons

The CMS Collaboration

Abstract

The CMS electromagnetic calorimeter timing system can be used in searches for new physics events with long-lived particles decaying into high energy off time photons, electrons or jets. It will be useful also to reject cosmic ray and beam halo backgrounds. The goal of this analysis is to study the performance of the ECAL time reconstruction. First of all, the behavior of the time is investigated in terms of biases and resolution, after comparing collision data with Monte Carlo simulation. Secondly, the time correlation among different crystals belonging to the same photon shower is investigated with the aim of exploiting the difference between photon showers and calorimetric deposits due to jets. Finally, constraints on the position of the primary interaction are obtained by exploiting the time measurement of two high momentum photons. This feasibility study is to check if the time information can offer additional handles to determine the primary vertex in events with small tracker activity, like $H \to \gamma\gamma$ events.



CMS PAPER EXO-11-035

DRAFT
CMS Paper

The content of this note is intended for CMS internal use and distribution only

2013/03/01
Head Id: 134303
Archive Id: 174667P
Archive Date: 2012/07/02
Archive Tag: trunk

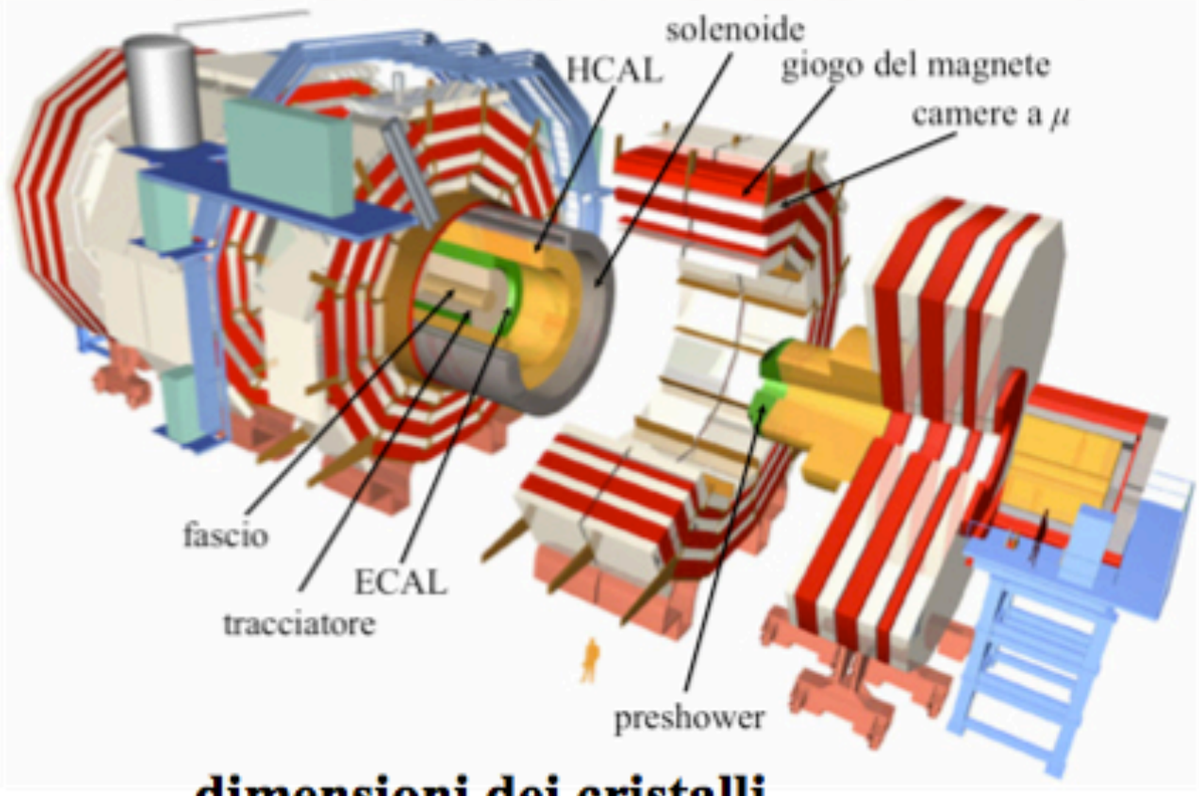
Search for long-lived particles in events with photons and missing energy in proton-proton collisions at $\sqrt{s} = 7\,\text{TeV}$

The CMS Collaboration

Abstract

Results are presented from a search for long-lived neutralinos decaying into a photon and an invisible particle, a signature associated with gauge-mediated supersymmetry breaking in supersymmetric models. The analysis is based on a $4.9\,\text{fb}^{-1}$ sample of proton-proton collisions at $\sqrt{s} = 7\,\text{TeV}$, collected with the CMS detector at the LHC. The missing transverse energy and the time of arrival of the photon at the electromagnetic calorimeter are used to search for an excess of events over the expected background. No significant excess is observed, and lower limits at the 95% confidence level are obtained on the mass of the lightest neutralino, $m > 220\,\text{GeV}$ (for $c\tau < 500\,\text{mm}$), as well as on the proper decay length of the lightest neutralino, $c\tau > 6000\,\text{mm}$ (for $m < 150\,\text{GeV}$).

CMS



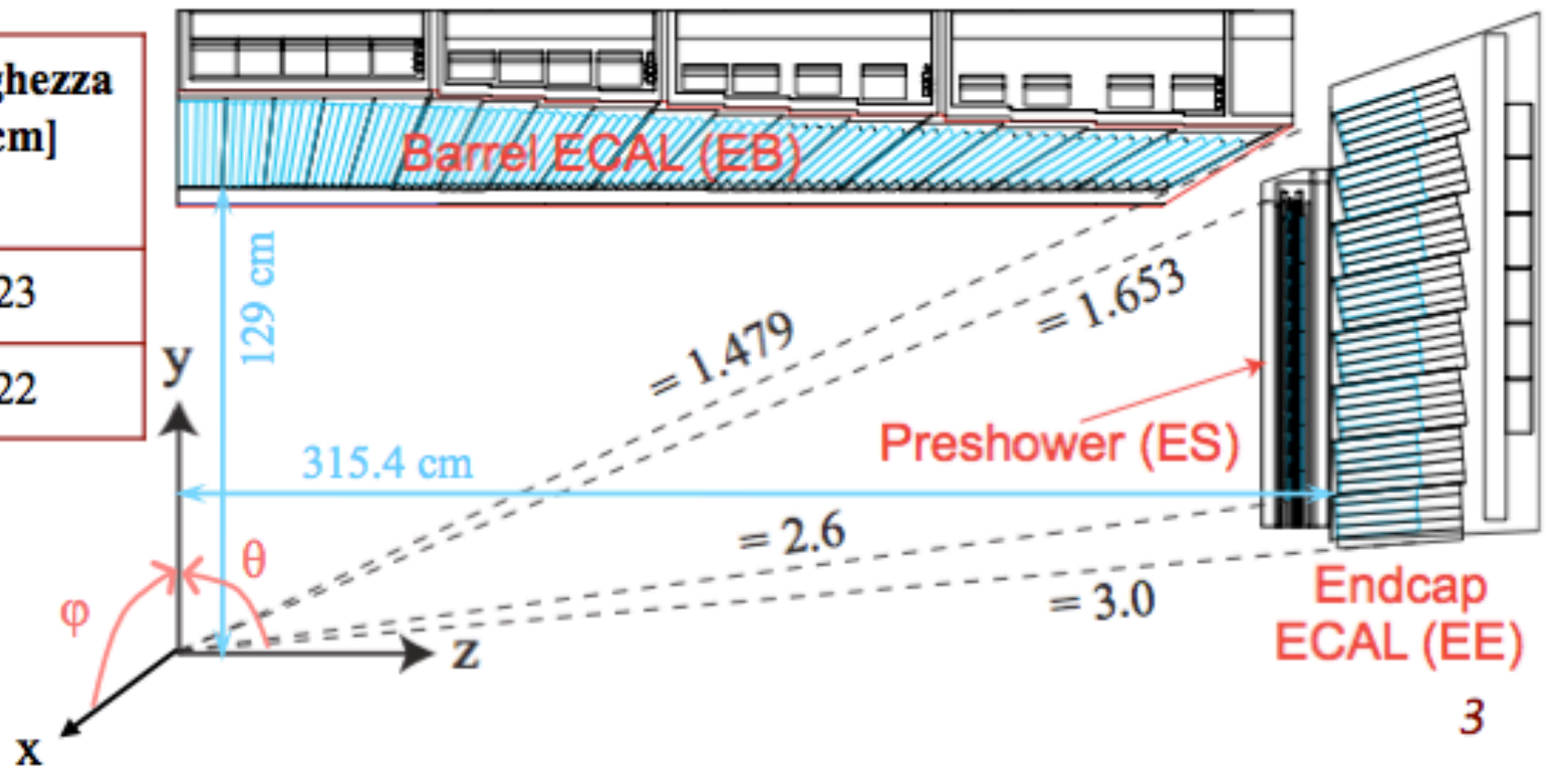
calorimetro elettromagnetico

- cristalli di $PbWO_4$
  - 61200 nel barrel
  - 7324 in ogni endcap
- tempo di scintillazione di $PbWO_4$
  - 80% della luce emessa in 25 ns

dimensioni dei cristalli

	faccia frontale [cm²]	faccia posteriore [cm²]	lunghezza [cm]
barrel	2.2 x 2.2	2.6 x 2.6	23
endcap	2.86 x 2.86	3 x 3	22

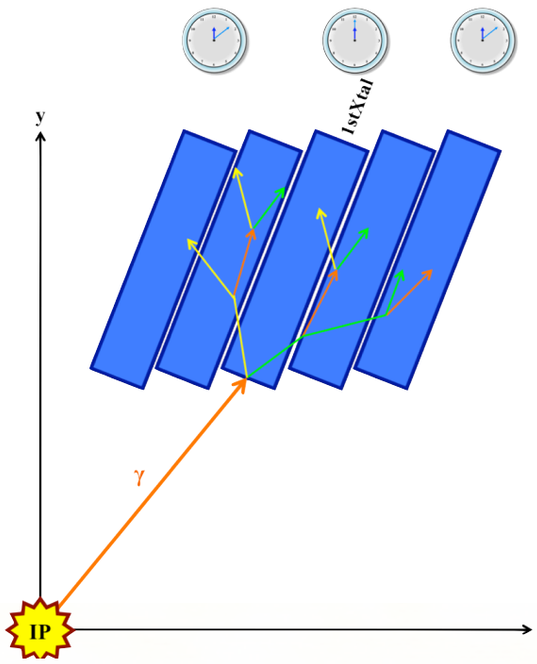
$$\eta = -\ln \tan\left(\frac{\theta}{2}\right)$$



3

Electromagnetic Shower

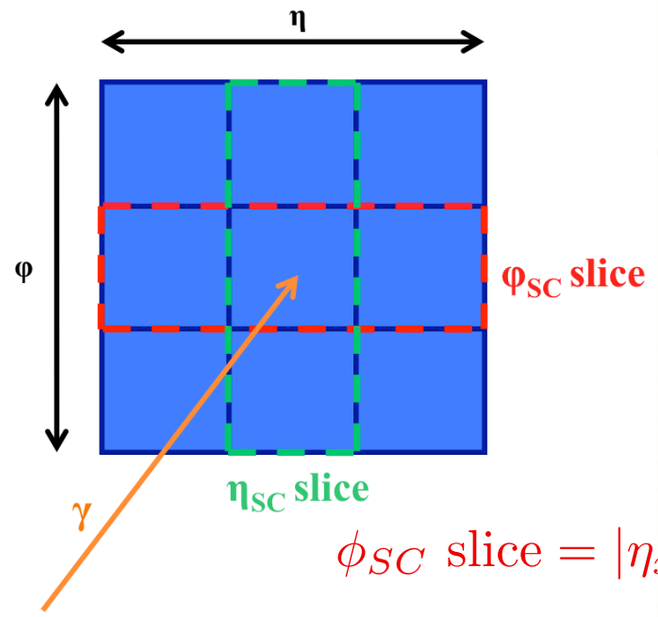
- Matched Photons $\Delta R(\gamma_{reco},\gamma_{gen})<0.1$ with pT > 30 GeV/c and |η| < 1.4



$$\Delta T_i = T_{xtal,i} - T_{seed}$$

$$\Delta\eta_i = \frac{\eta_{xtal,i} - \eta_{SC}}{0.0174}$$

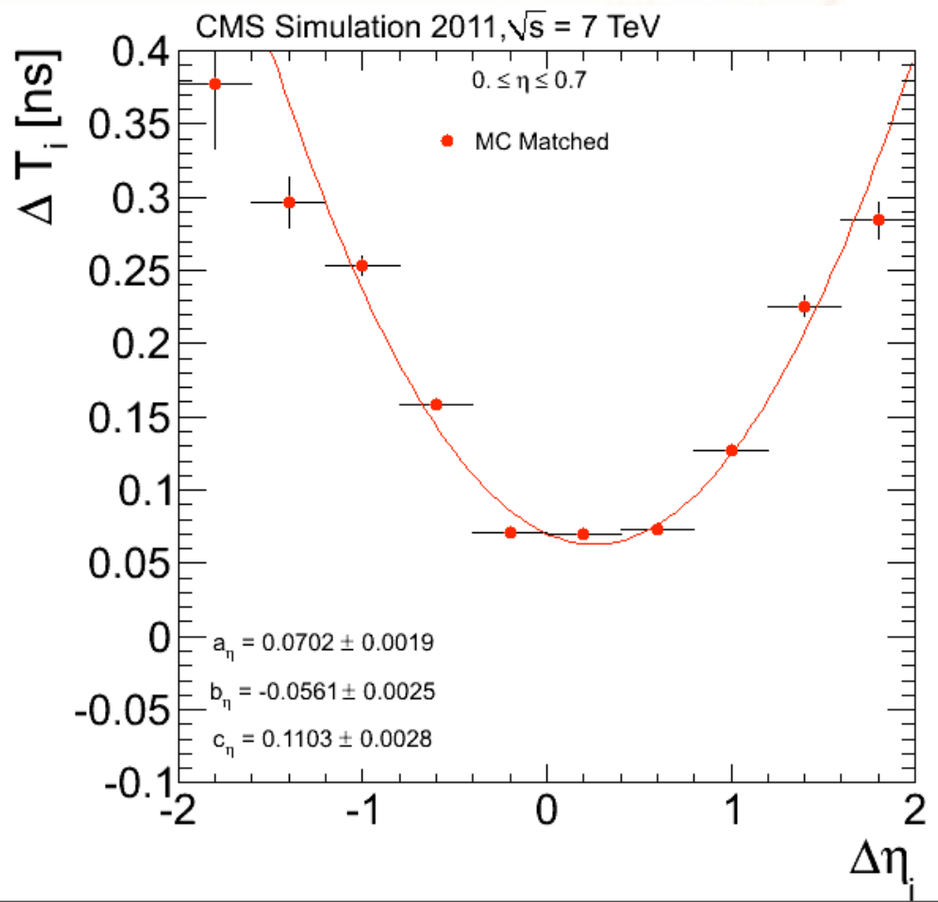
$$\Delta\varphi_i = \frac{\varphi_{xtal,i} - \varphi_{SC}}{0.0174}$$

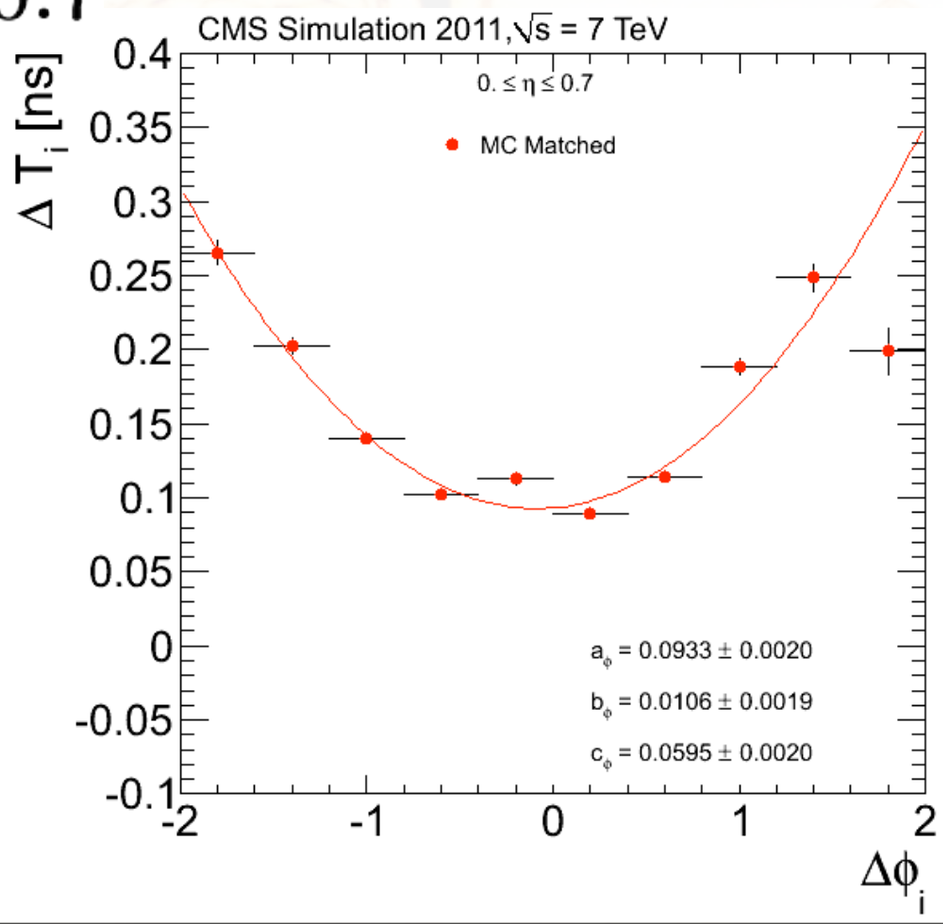


$$\phi_{SC} \text{ slice} = |\eta_{xtal,i} - \eta_{sc}| < 0.0174$$

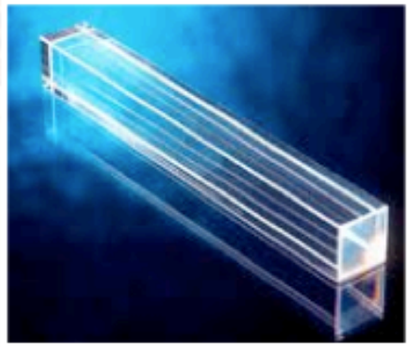
$$\eta_{SC} \text{ slice} = |\phi_{xtal,i} - \phi_{sc}| < 0.0174$$

$$0. \leq \eta \leq 0.7$$

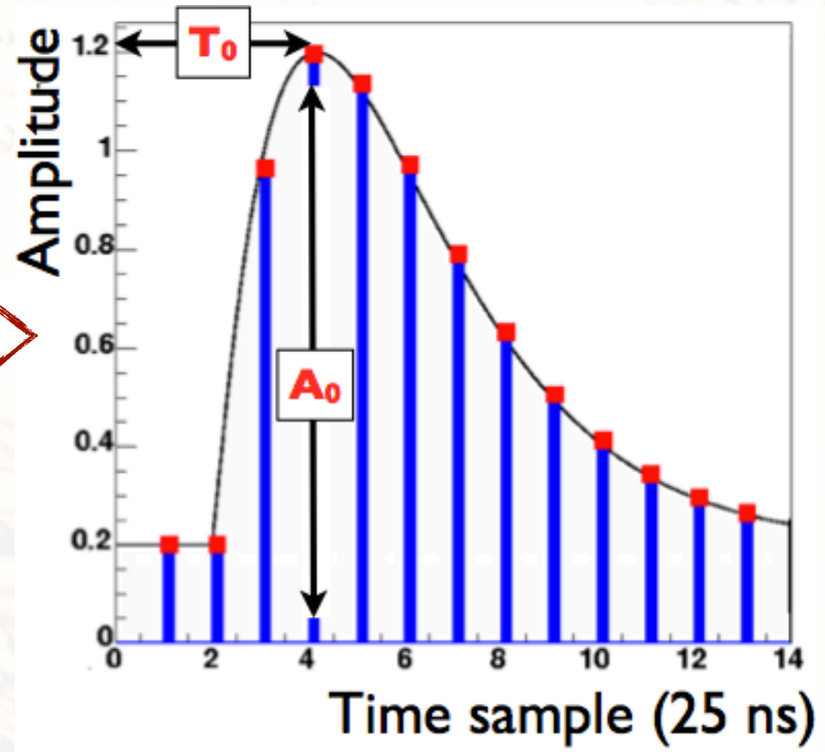




ECAL Time Measurement



Photodectors
FE electronics

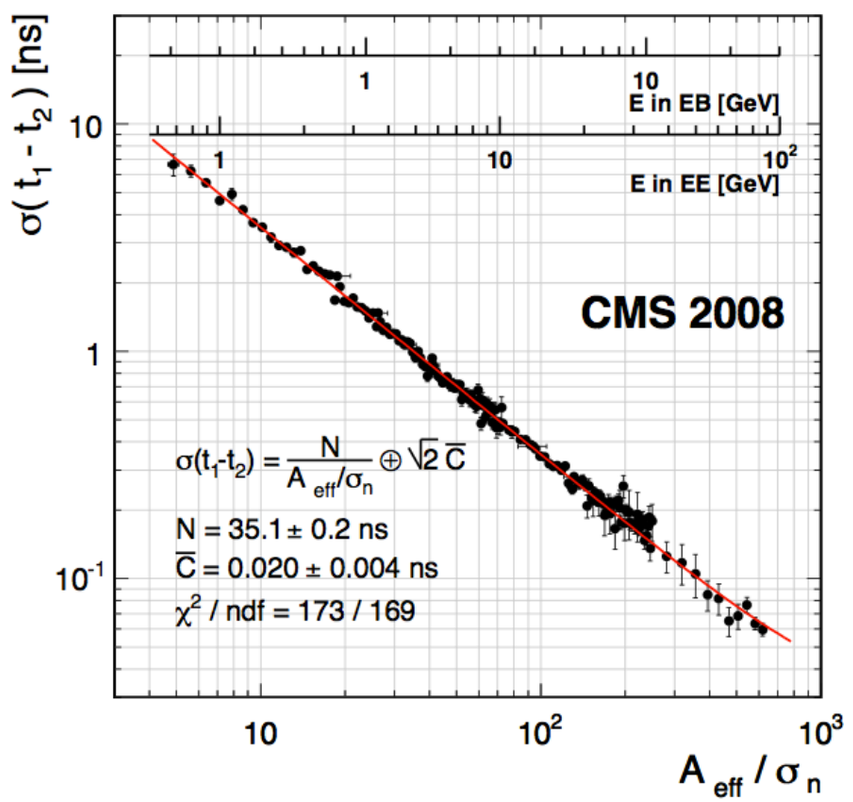


$$E_{xtal} \propto A_0$$
$$T_{xtal} \propto T_0$$

Time resolution @TestBeam

$$\sigma(t_1 - t_2) = \frac{N}{A_{eff}/\sigma_n} \oplus \sqrt{2}\bar{C}$$

$$A_{eff} = A_1 A_2 / \sqrt{A_1^2 + A_2^2}$$



E_{xtal} > 3 GeV (barrel)

E_{xtal} >10 GeV (endcap)

→ $\sigma_{xtal,i}$<1 ns

cristalli di $PbWO_4$

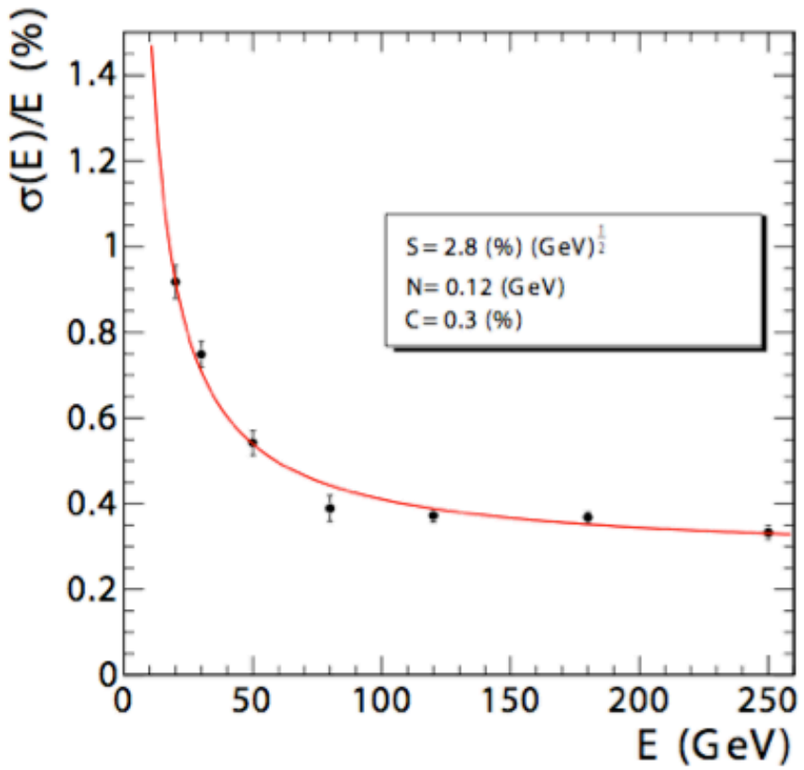
- 61200 nel barrel
- 7324 in ogni endcap

parameter	value
density	8.28 g/cm^3
X_0	0.89 cm
R_M	2.2 cm

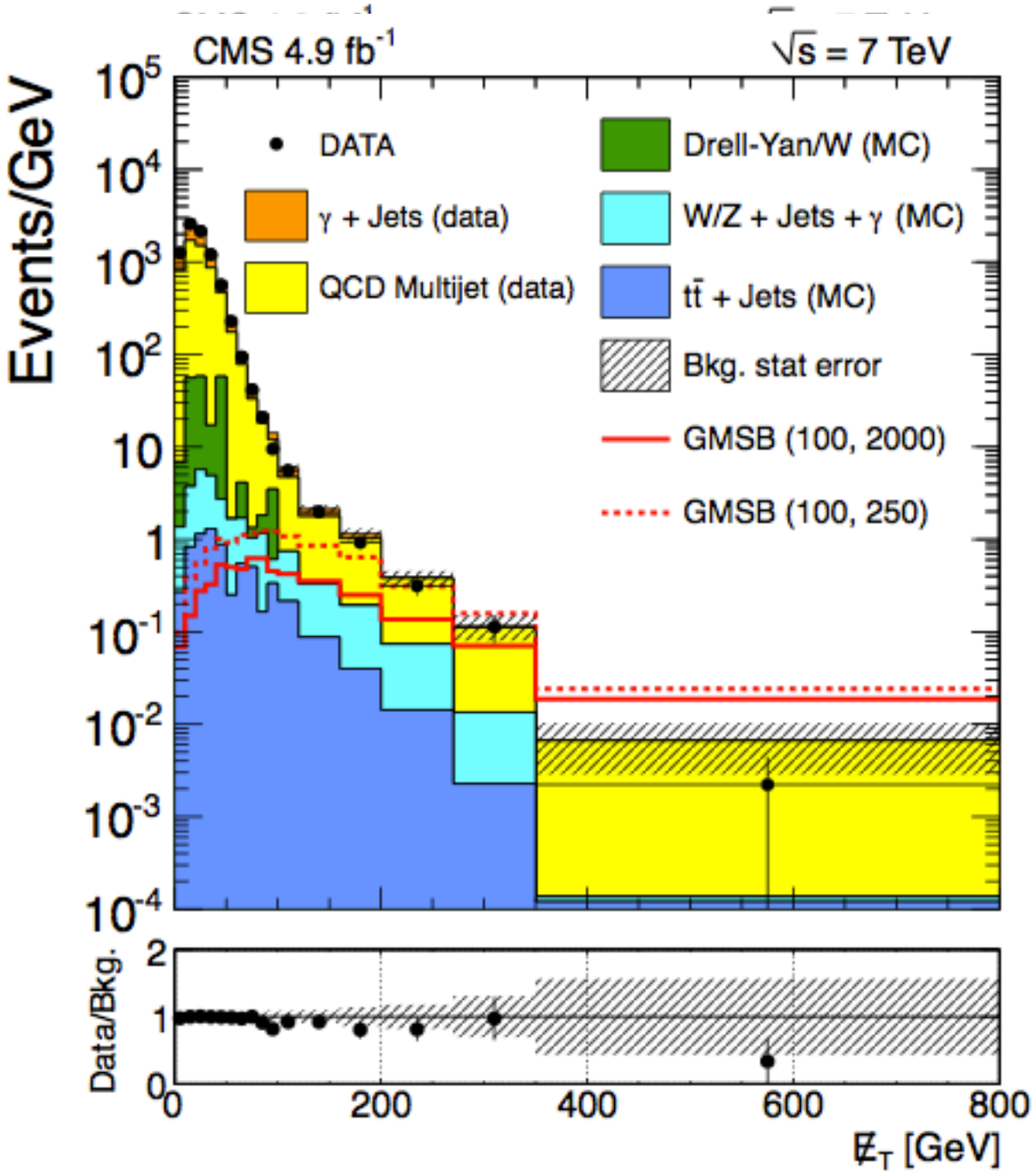
	faccia frontale [cm^2]	faccia posteriore [cm^2]	lunghezza [cm]
barrel	2.2 x 2.2	2.6 x 2.6	23 (25.8 X_0)
endcap	2.86 x 2.86	3 x 3	22 (24.7 X_0)

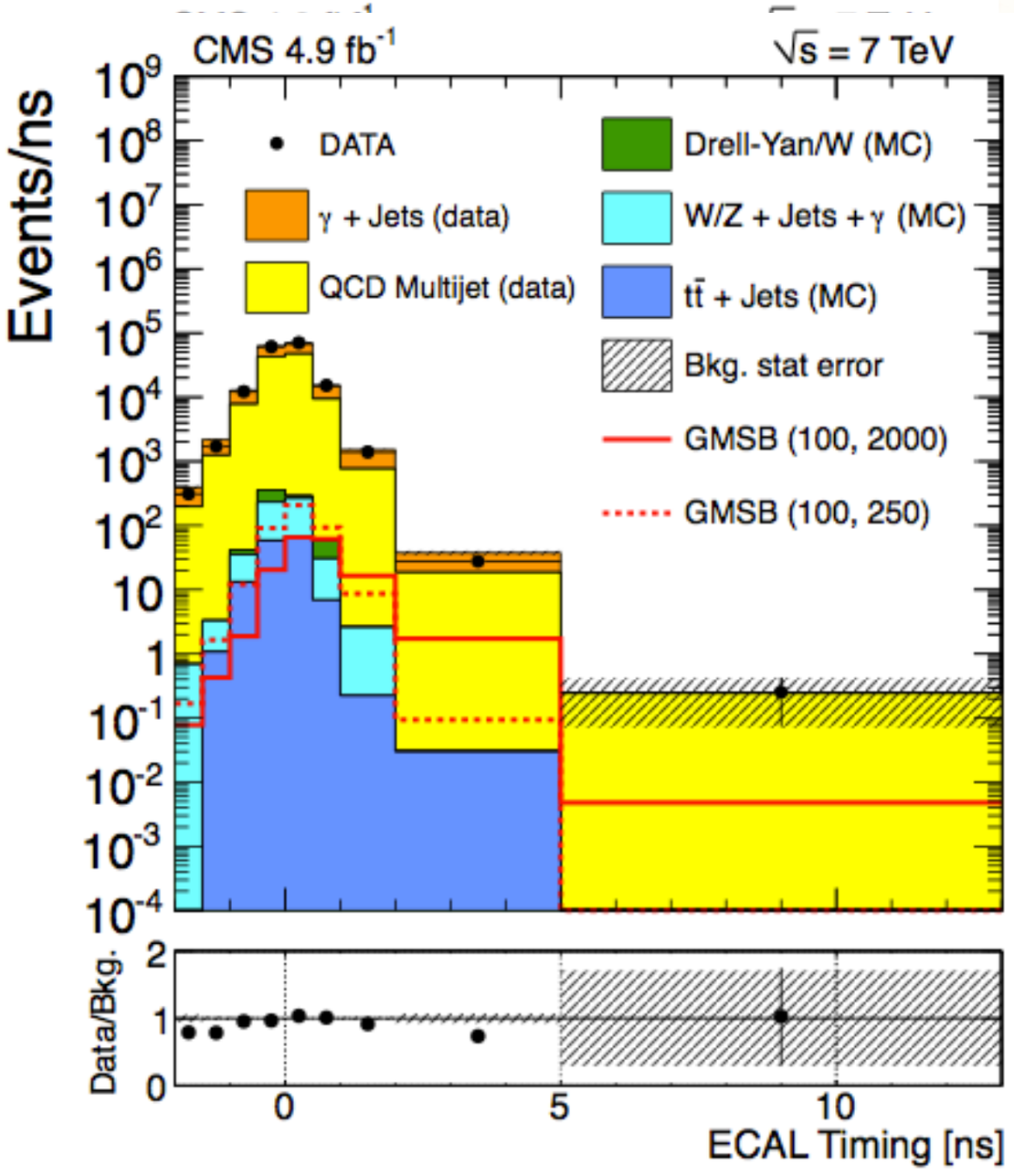
$$\frac{\sigma(E)}{E} = \frac{S}{\sqrt{E}} \oplus \frac{N}{E} \oplus C$$

- S: termine stocastico
- N: termine di noise
- C: costante



GMSB ANALYSIS

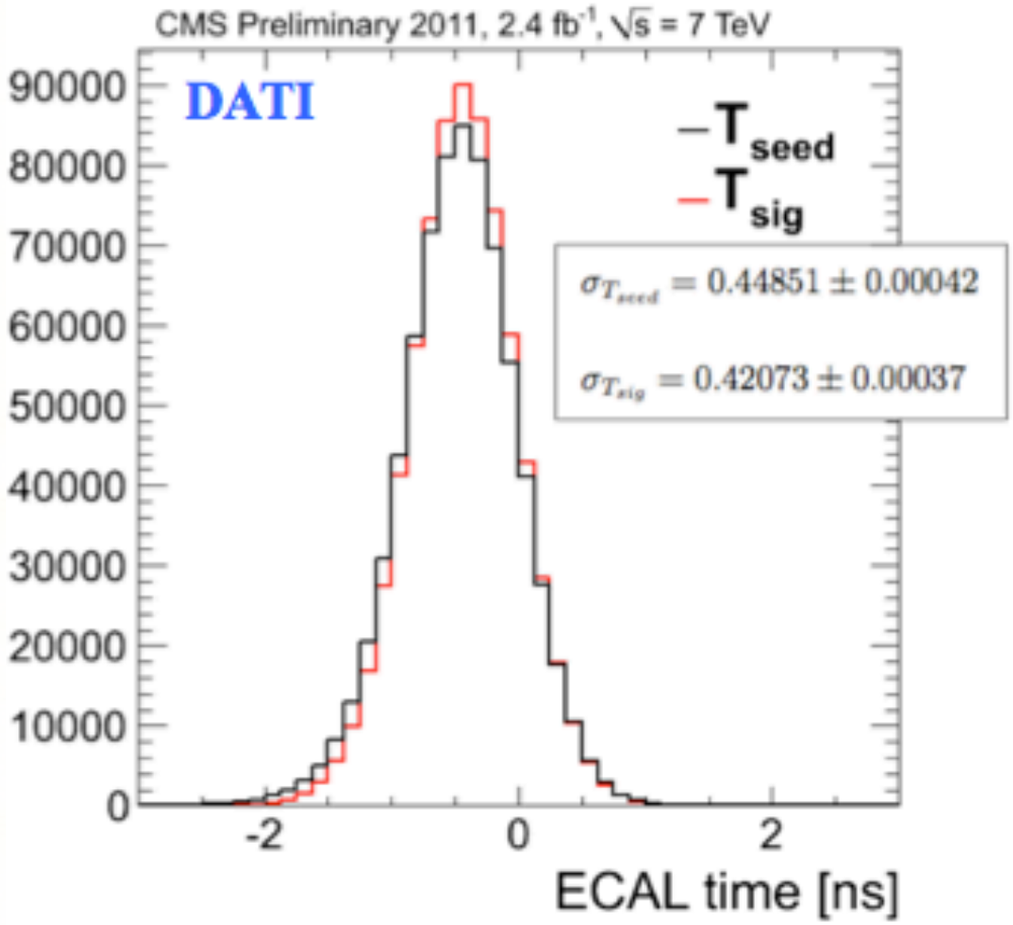


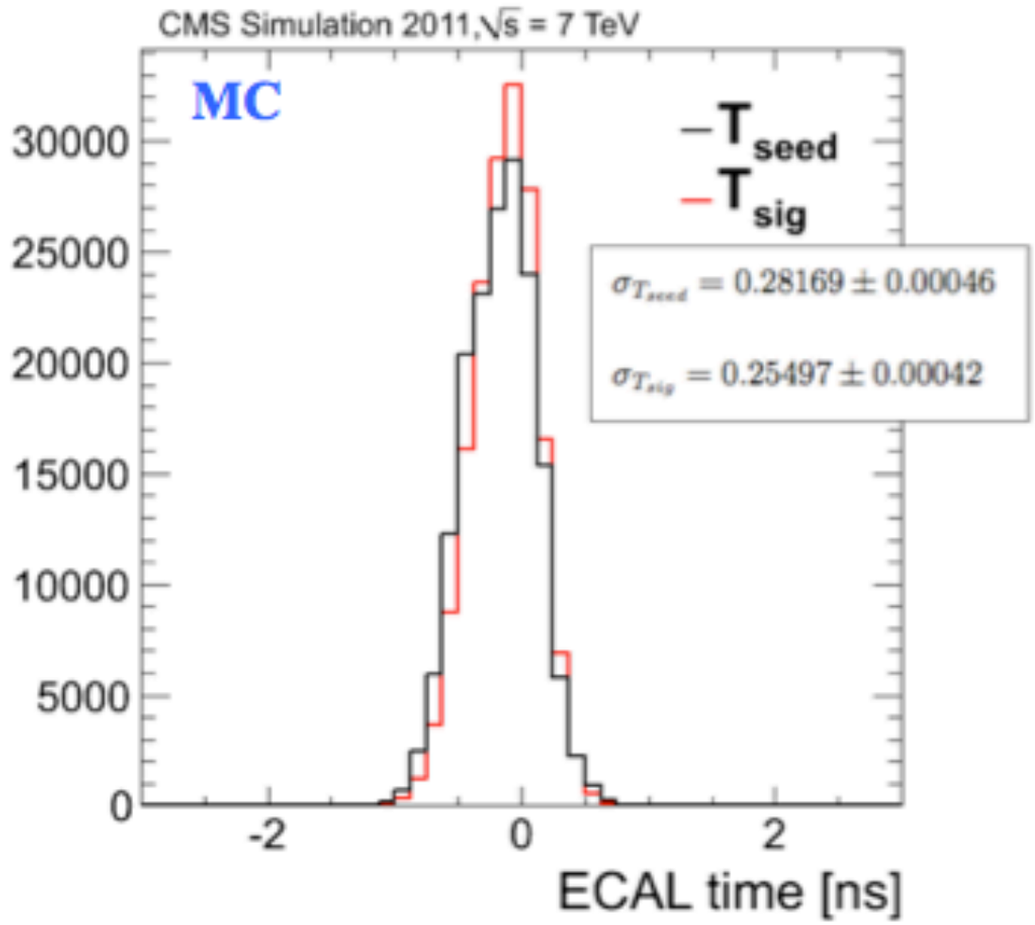


TSIG In DATA and MC

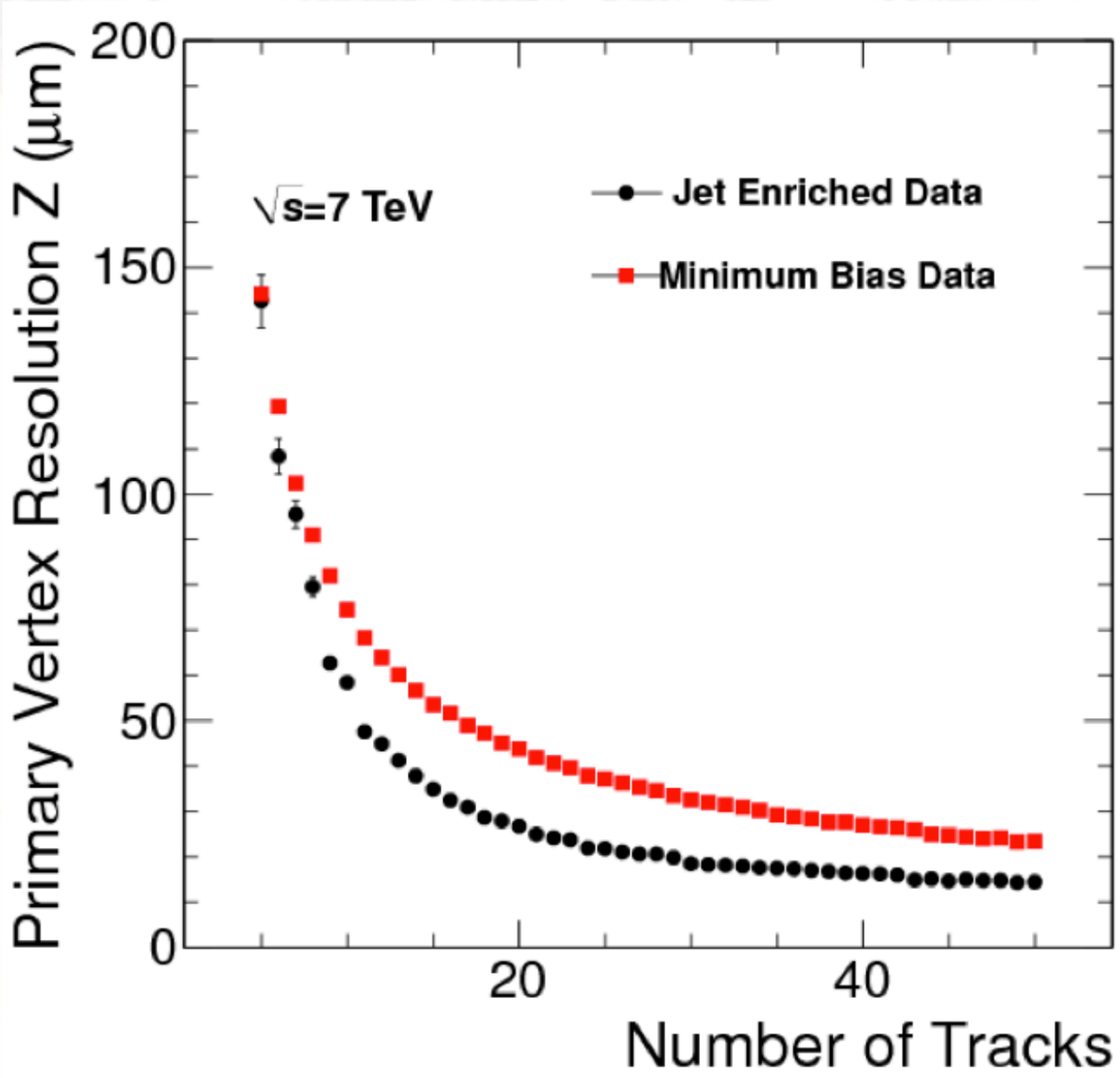
$$T_{sig} = \frac{\sum_i \frac{T_{xtal,i}}{\sigma^2_{xtal,i}}}{\sum_i \frac{1}{\sigma^2_{xtal,i}}}$$

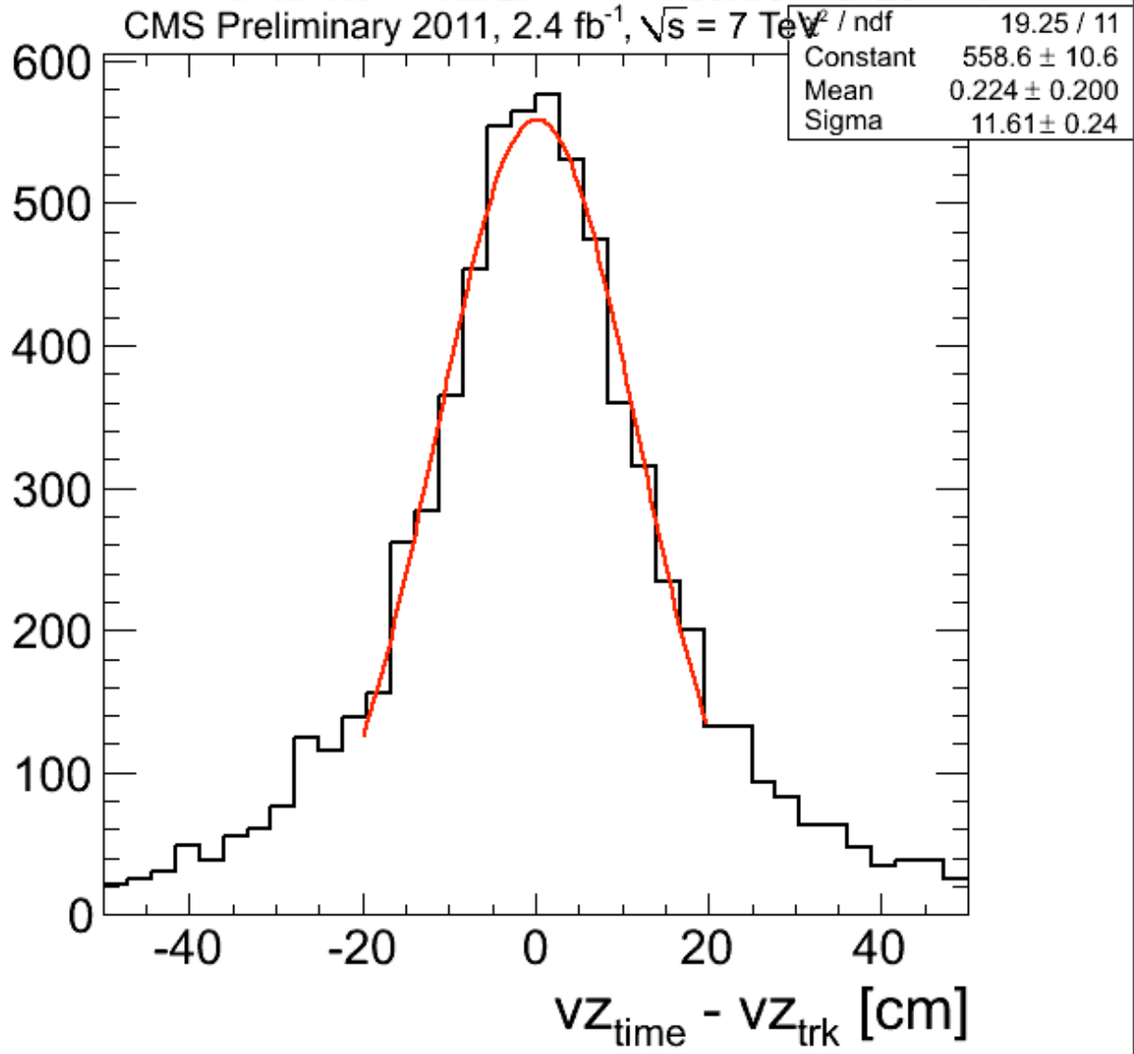
- $E_{xtal,i} > 1\ \text{GeV}$
- $-2\ \text{ns} < T_{xtal,i} < 2\ \text{ns}$
-
- $\sigma^2_{xtal,i} = \left(N \frac{\sigma_n}{E_{xtal,i}}\right)^2 + \sigma^2_{intercalib}$





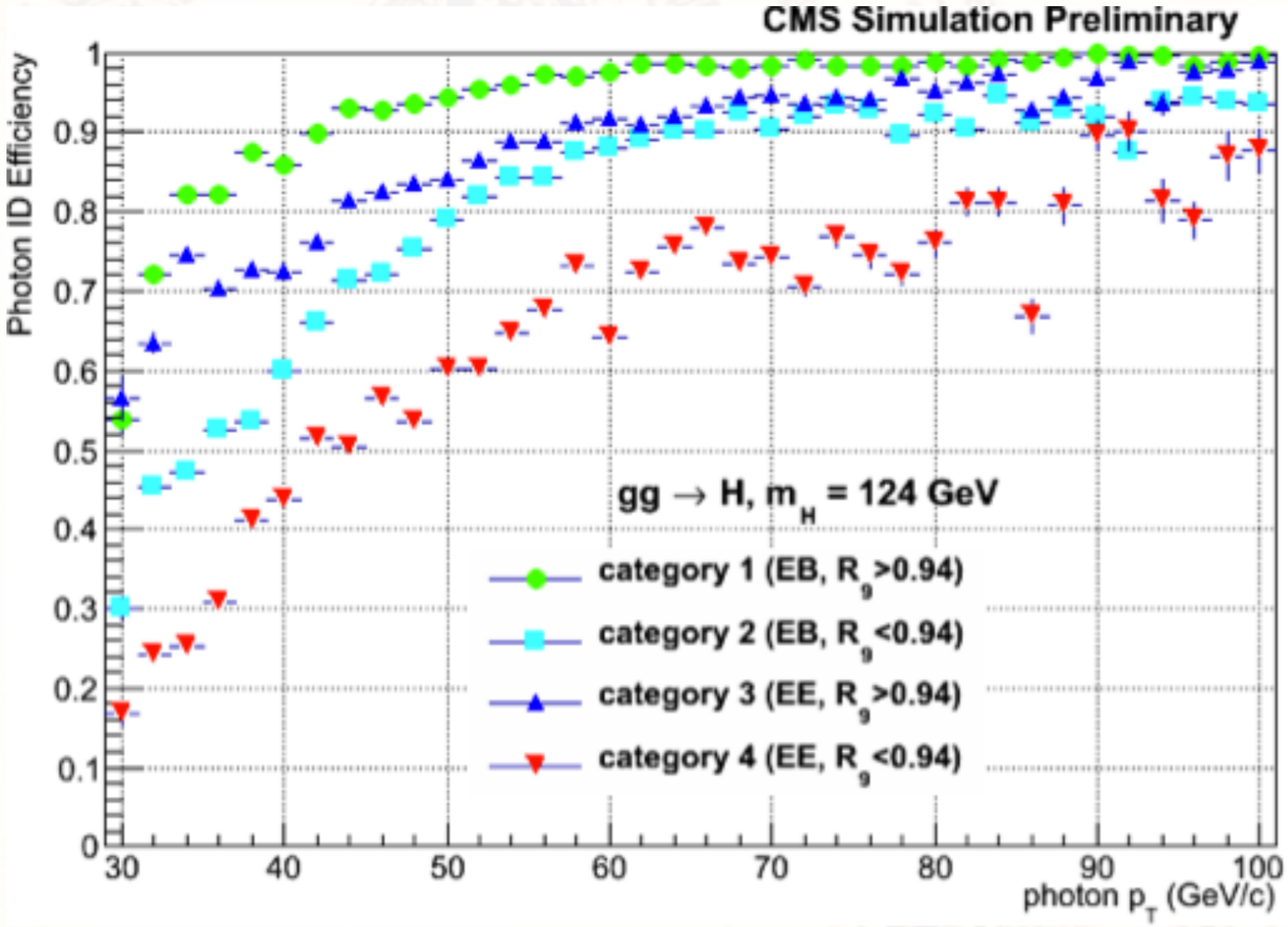
VZ In DATA


√s=7 TeV
Jet Enriched Data
Minimum Bias Data
Primary Vertex Resolution Z (μm)
Number of Tracks
200
150
100
50
0
20
40


CMS Preliminary 2011, 2.4 fb-1, √s = 7 TeV
χ² / ndf 19.25 / 11
Constant 558.6 ± 10.6
Mean 0.224 ± 0.200
Sigma 11.61± 0.24
vztime - vztrk [cm]
600
500
400
300
200
100
0
-40
-20
0
20
40

Identification performance

Photon ID



Vertex ID