ECAL crystal transparency corrections from laser monitoring analysis

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CMS Wednesday's general meeting

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On behalf of ECAL

Outline

- **ECAL Laser Monitoring system**
  - Purpose
  - Layout
- **Transparency measurement**
  - Method
  - Performances
- **First release of transparency corrections for 2010 data**
- **Improvements, second release of corrections for re-reco and validation with Z events**

Introduction

Main sources of ECAL response variations:

LY: light yield
M: APD gain

- **Scintillation process:**
  temperature dependency: $\partial(LY)/\partial T \sim -2\%/K$

- **APD gain:**
  - Temperature dependency: $1/M(\partial M/\partial T) \sim -2\%/K$
  - High voltage dependency: $1/M(\partial M/\partial V) \sim 3\%/V$

"Detector dependent" already proven to be very stable

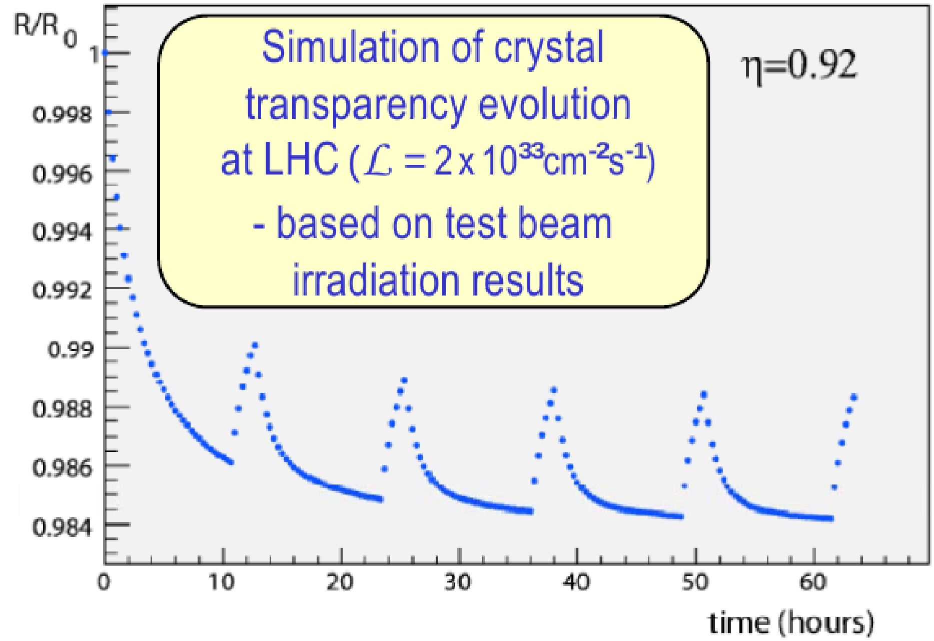
- **Crystal transparency:**
  radiation dose-rate dependency:
  from 1-2% @ $L=2.10^{33}\ cm^{-2}\ s^{-1}$ in the barrel
  to > 10% @ $L=2.10^{34}\ cm^{-2}\ s^{-1}$ at high η in the endcaps

"Detector and LHC dependent" needs to be monitored

ECAL crystal transparency needs to be monitored with a precision <0.2% to achieve the ECAL resolution of 0.5% at high energies

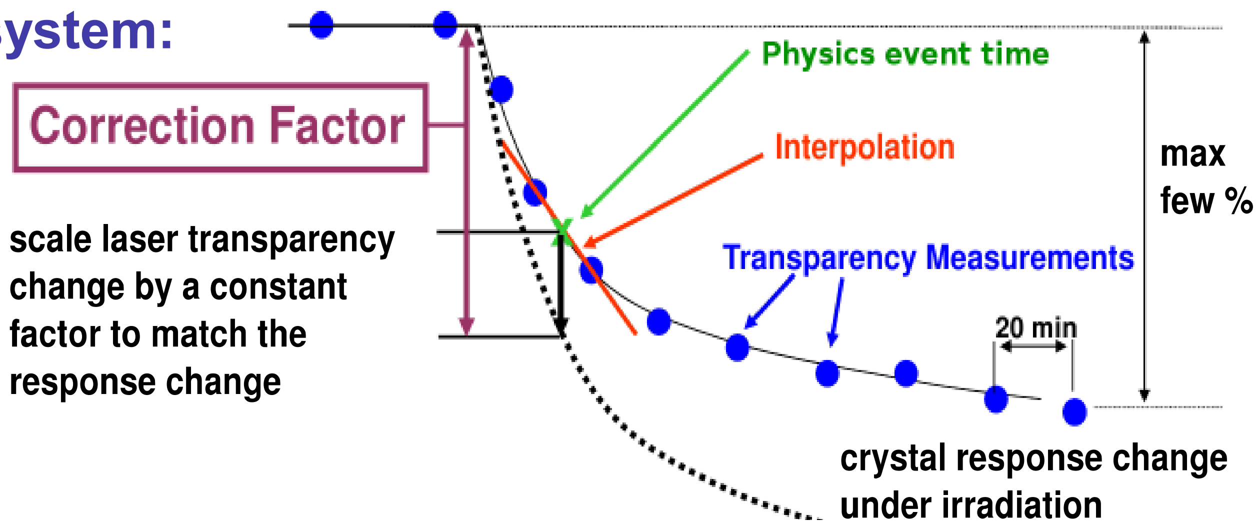
Transparency variations

- Transparency loss is due to the creation of color centers in crystals under irradiation
- Color centers absorb the transmitted light
- Rapid loss and recovery of the optical transmission under irradiation (few hours)

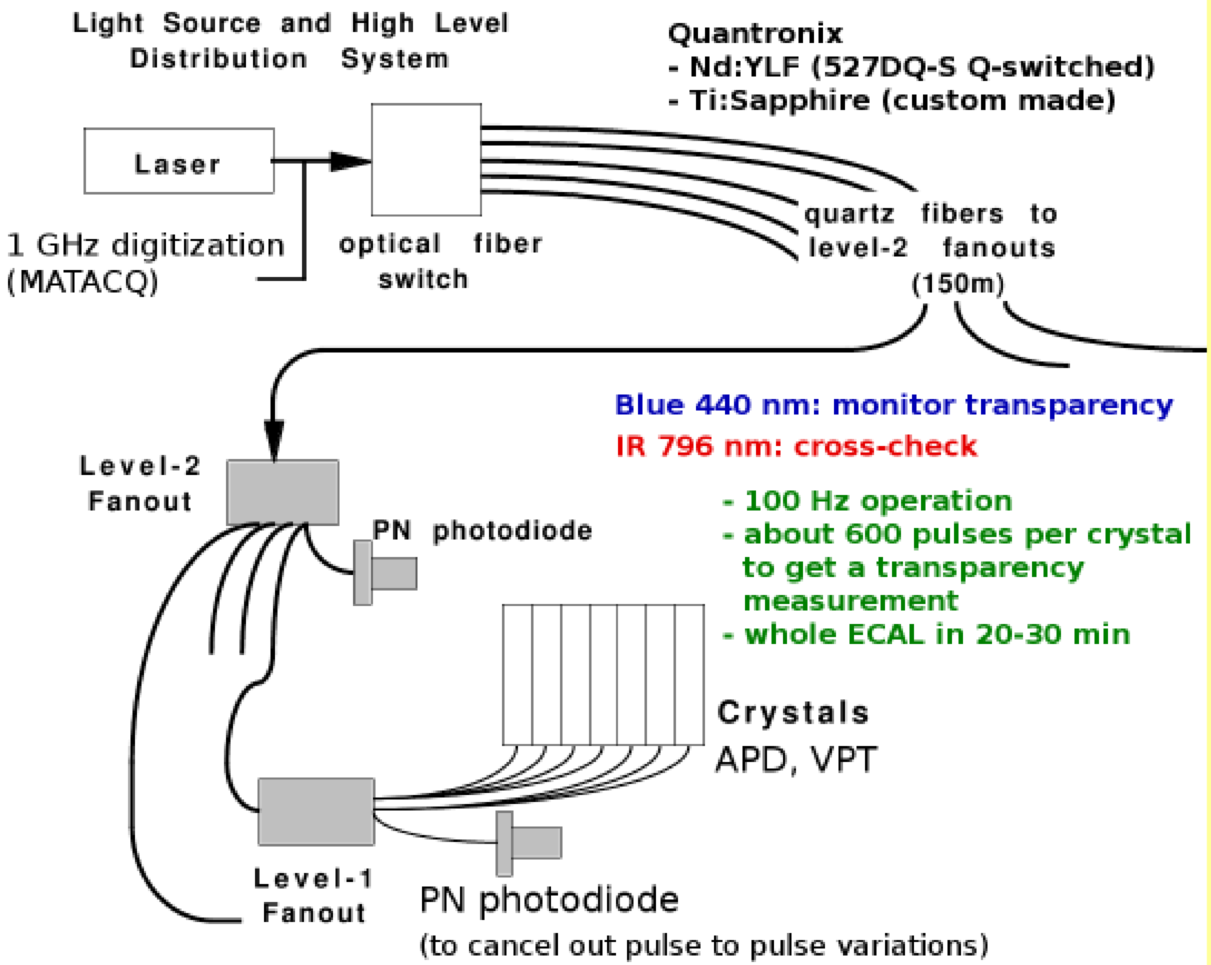


ECAL laser monitoring system:

- Measures transparency loss with a laser signal
- Energy corrections can be related to these measurements



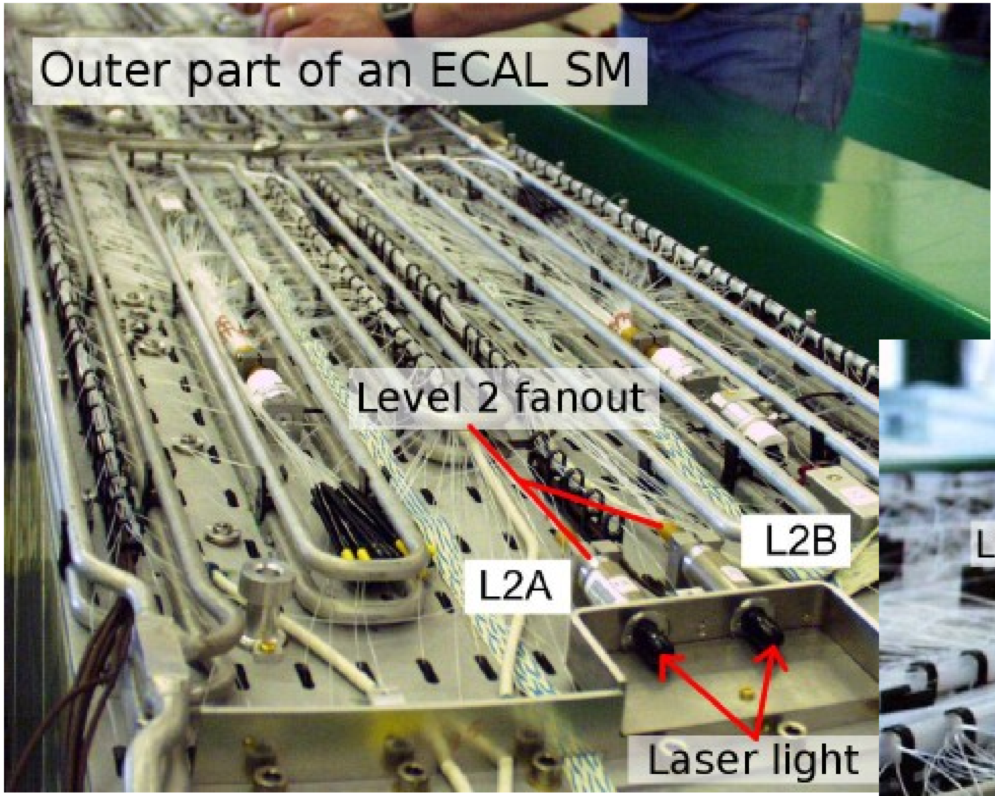
ECAL Laser Monitoring system: general layout

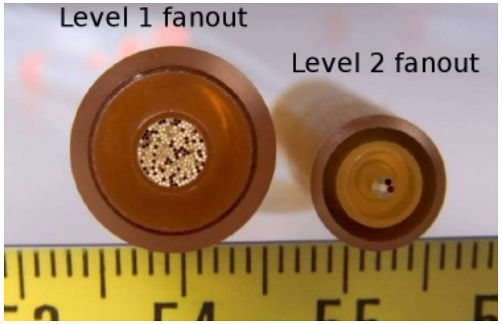


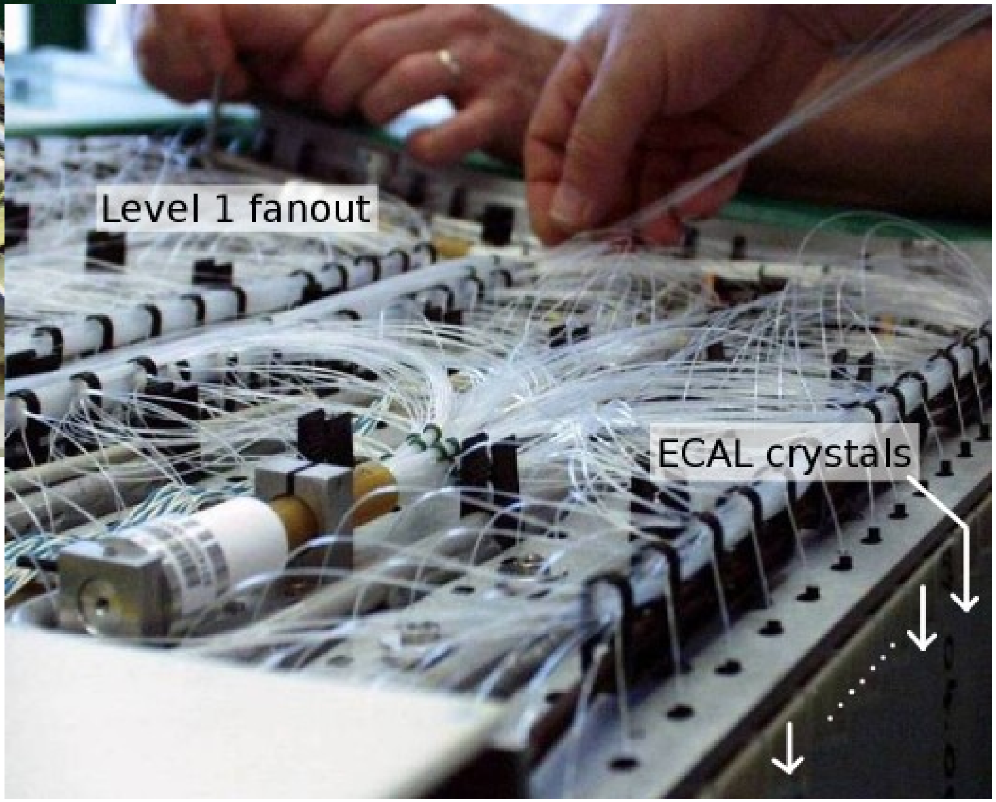
Laser features:

- Spectral contamination $<10^{-3}$
- Pulse energy: 1mJ at the source, dynamic range up to 1.3 TeV equivalent
- Pulse width: < 40 ns (fwhm) to match the ECAL readout
- Pulse jitter:
  - < 4 ns (24 hours)
  - < 2 ns (30 min)
- Pulse to pulse instability: <10%

ECAL Laser Monitoring system





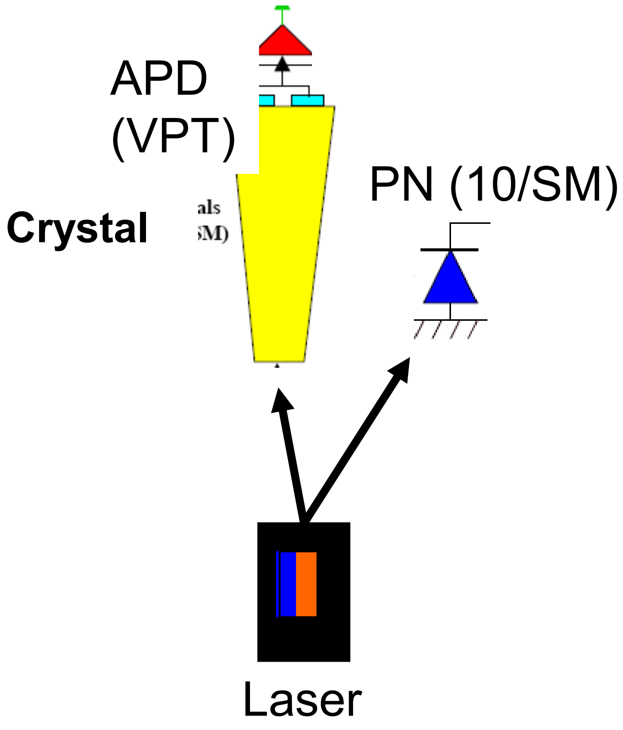


Transparency measurement

General method:

- Laser light injection in crystals: 600 events/crystal every ½ hour
- Light also injected in reference PN diodes (2 reference PN per crystal)
- ECAL response (APD amplitudes) compared with PN response evt by evt
- APD/PN amplitudes ratio averaged over 600 events:

⇒ 1 point/crystal every ½ hour used to monitor and correct ECAL response

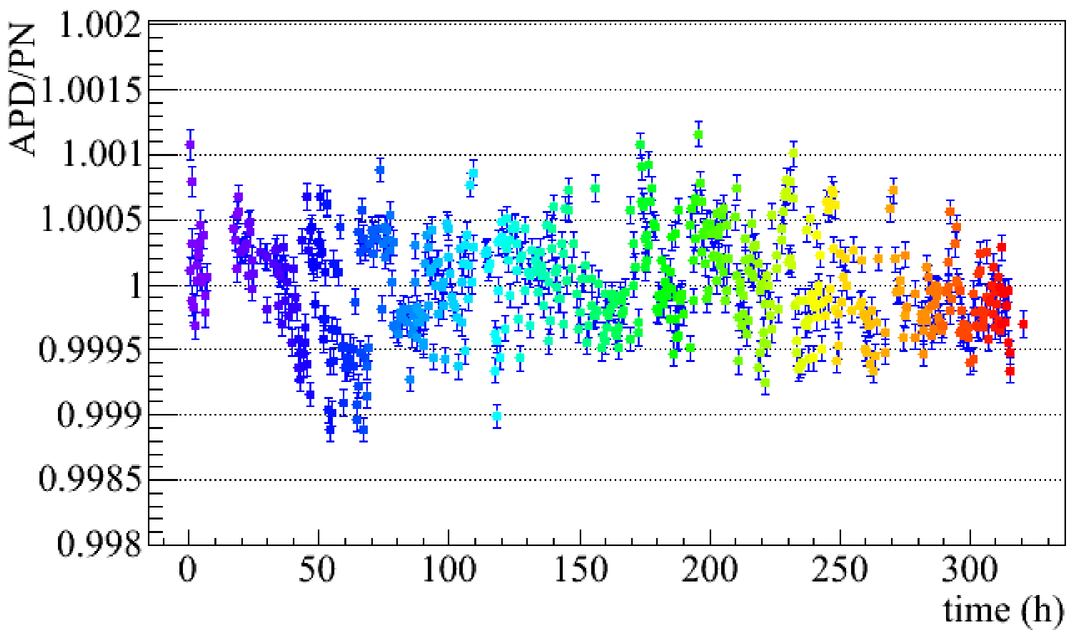


At the 0.2% level, many effects matter:

- APD (VPT) amplitudes determined by fitting samples with a convolution of the **laser pulse shape** from the 1GHz digitization and the APD (VPT) **single pulse response** (to avoid biases due to an imperfect fitting function)
- PN linearity correction is applied (for the laser signal normalization)
- Correction to account for the different shaping times of APD (VPT) and PN electronics is computed using the above convolution

Transparency measurement: performances

Transparency history for a typical channel over ~350 h at the beginning of LHC collision data taking

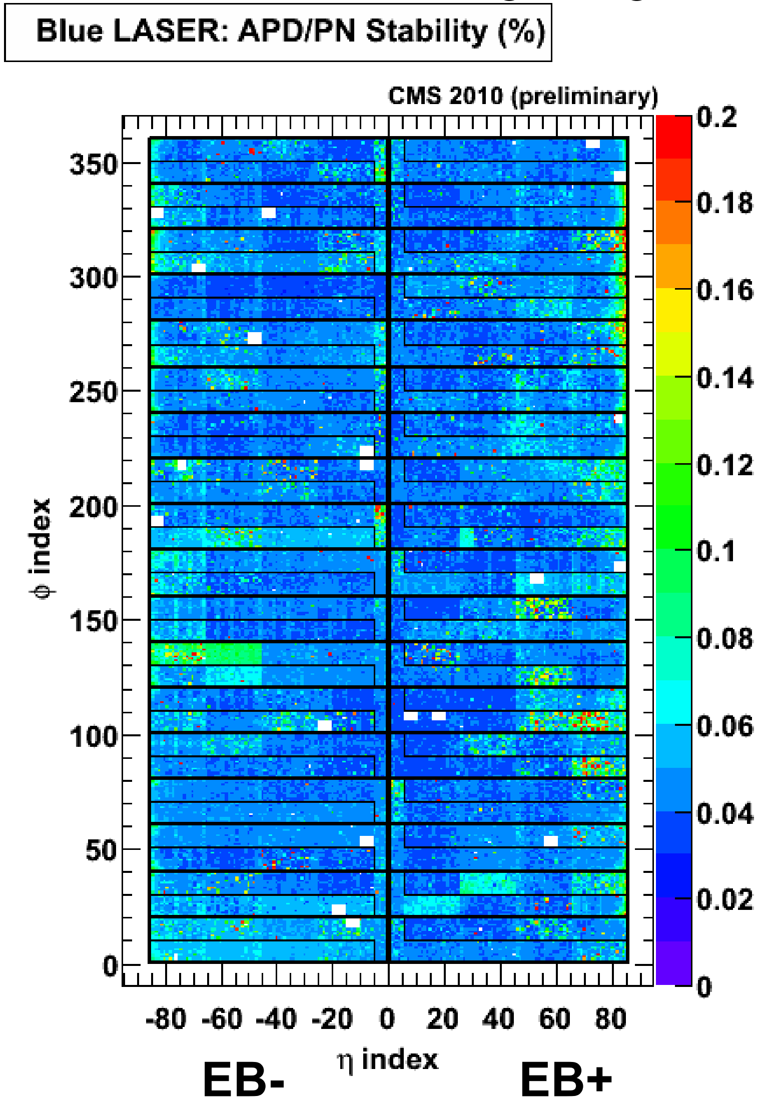


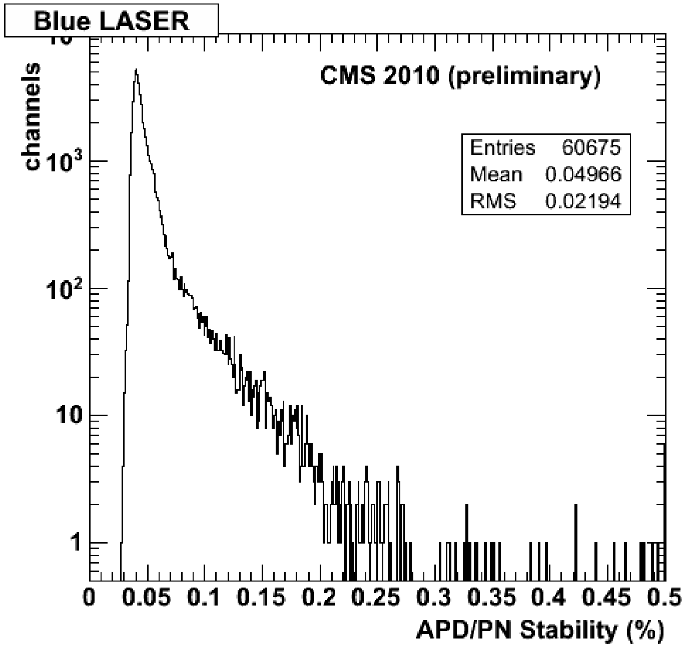
- As expected, no transparency loss at very low luminosity
- Stability defined as the relative r.m.s. of this history
- Standard loose quality cuts applied
- Very good stability (< 4.10^{-4}) well below specifications (2.10^{-3})

Stability during low luminosity data taking gives the LM system precision

Transparency measurement: performances

Stability map in the barrel for over ~ 350 h at the beginning of 2010 LHC collision data taking

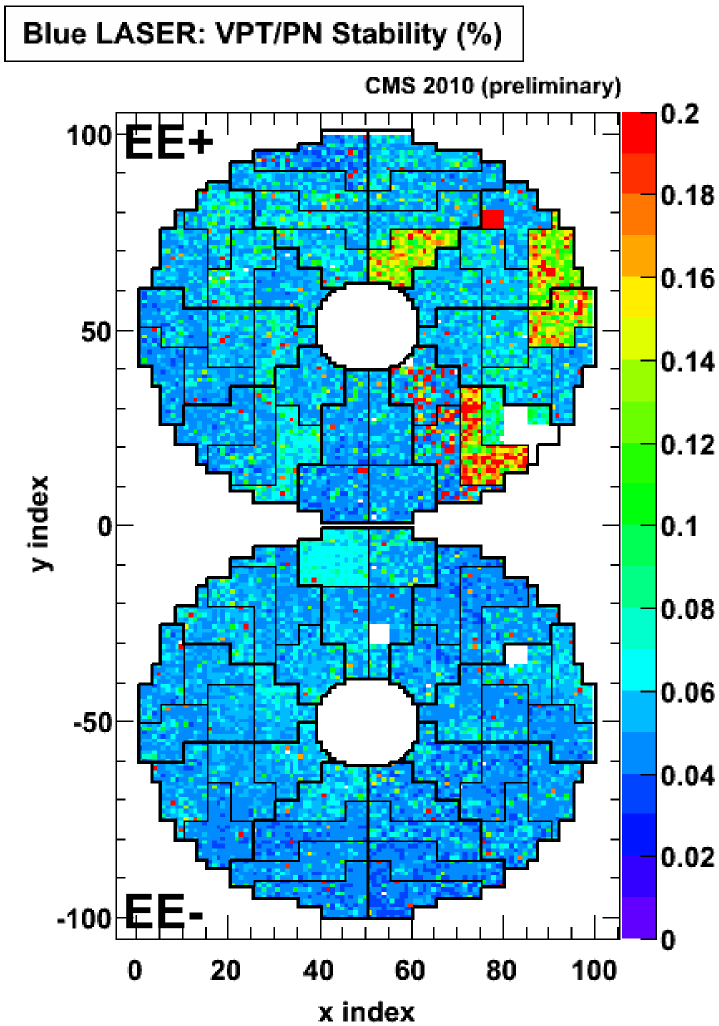


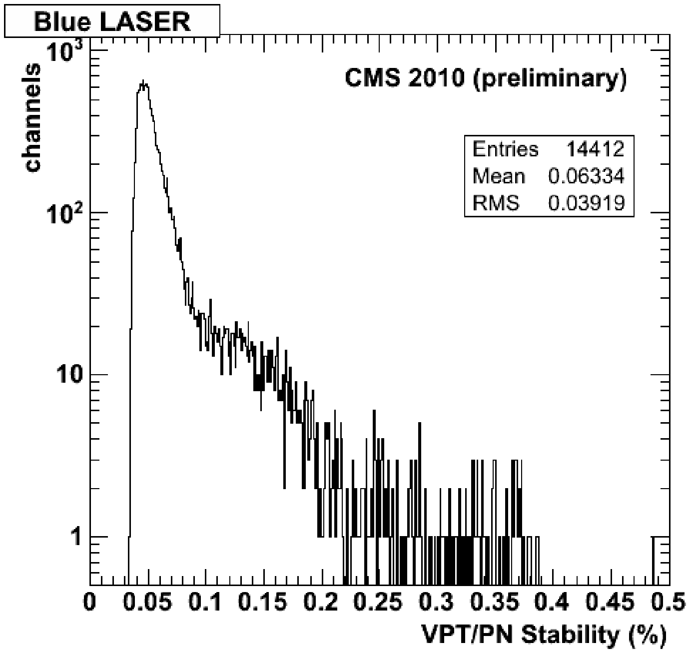


- White spots are dead readout regions
- Average stability ~ 0.05% well below 0.2%
- Excellent LM system performances

Transparency measurement: performances

Stability map in the endcaps for over ~ 350 h at the beginning of 2010 LHC collision data taking





- White spots are dead readout regions
- VPT/PN slightly less stable for the right half of EE+ because it had only one PN active (temporary electronics issues)
- Average ~ 0.06% still well below 0.2%
- Excellent LM system performances

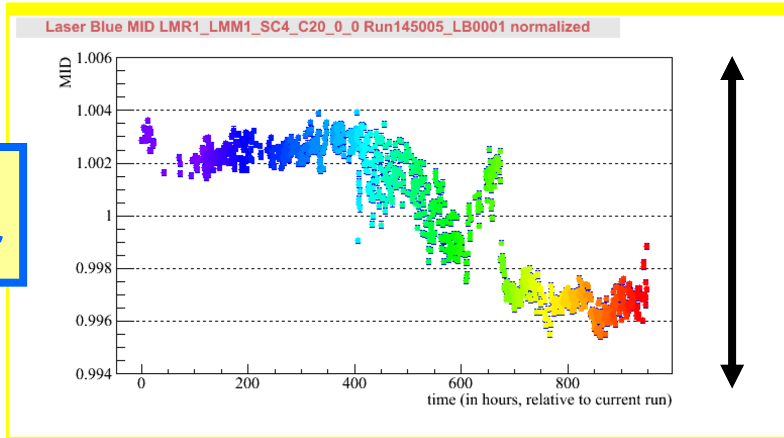
First observation of transparency loss

First observations of transparency loss occurred with increasing luminosity

- from this summer for EE
- starting around October for EB

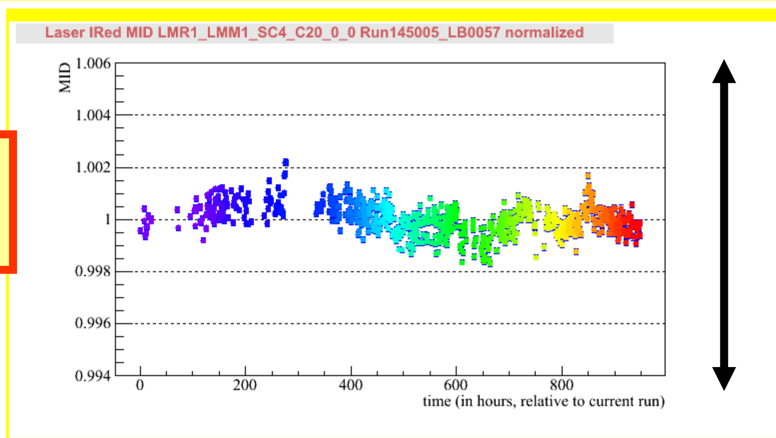
Example histories for a random channel in EB (~mid-Sept. to mid-Oct.) :

Blue Laser



same scales: 1.2%

IRed Laser

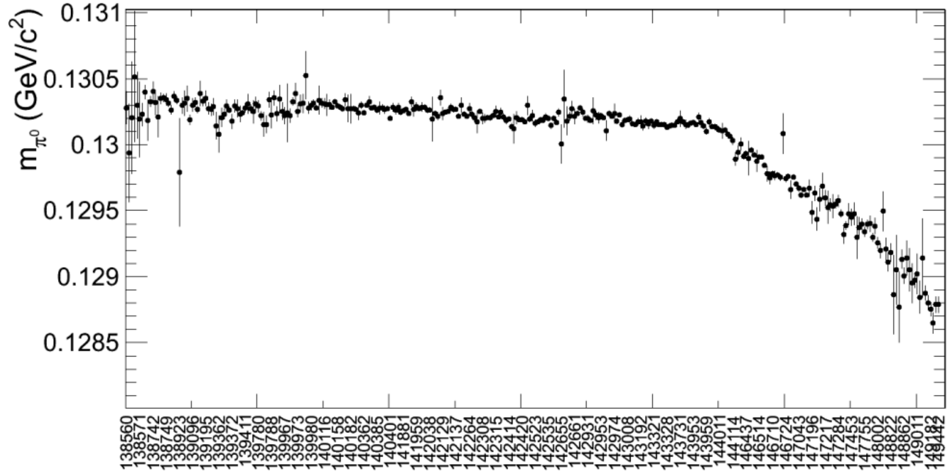


same scales: 1.2%

- Blue Laser sensitive to transparency variations whereas IRed laser is not (used as a cross-check)
- Here the loss is ~0.7%

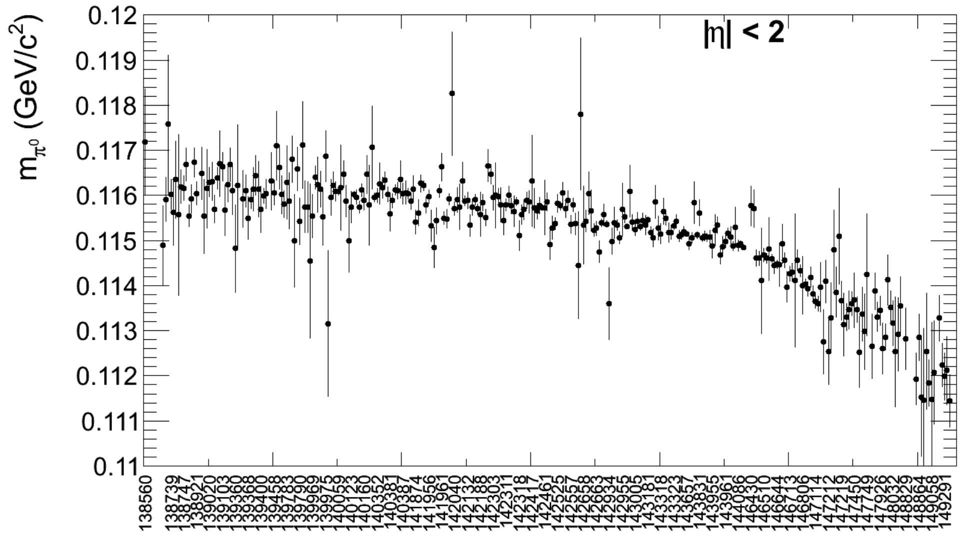
First observation of transparency loss

The effect of transparency loss can clearly be seen on data from π0 mass history



Barrel:

Mean loss at the end of pp running: **-1.3%**

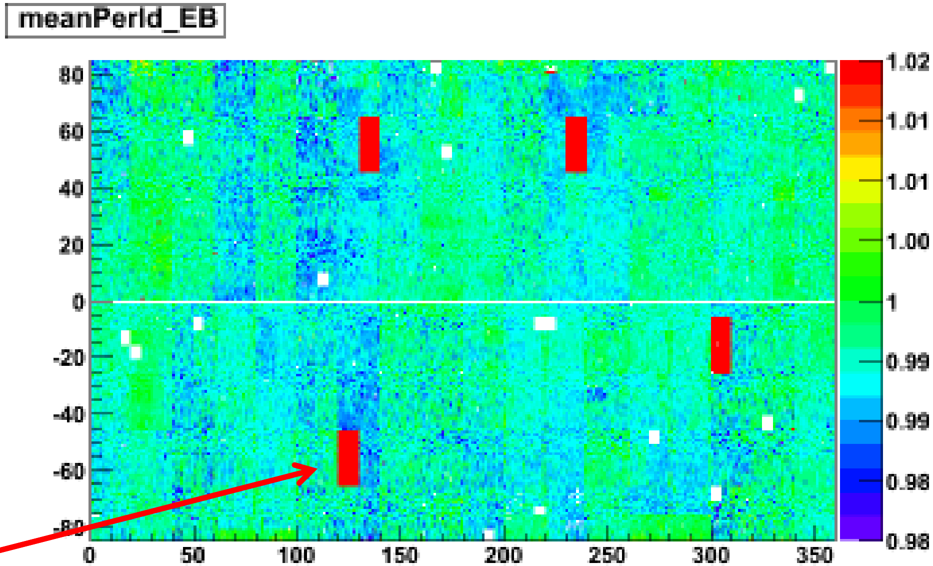


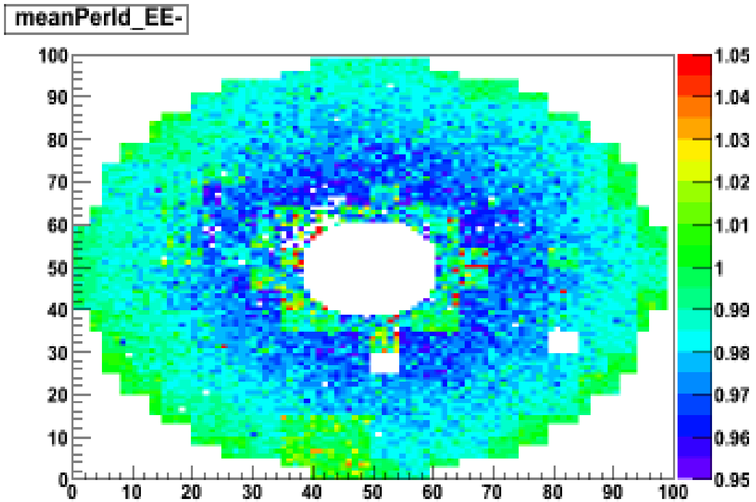
Endcap |η| < 2:

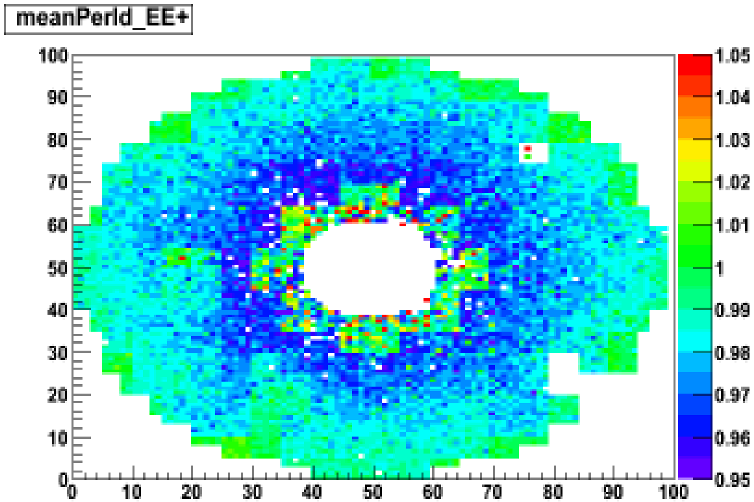
Mean loss at the end of pp running: **-3.4%**

First release of transparency corrections

- **One month of data taking:**
  - 25/09/2010 to 26/10/2010
  - Runs 146664 to 148953
  - ~ 25 pb^{-1}
- **Average laser response**
  - Outermost and innermost crystals patterns in EE: Chinese crystals (more rad-hard than Russian ones)
  - Some details were not fully understood in EB

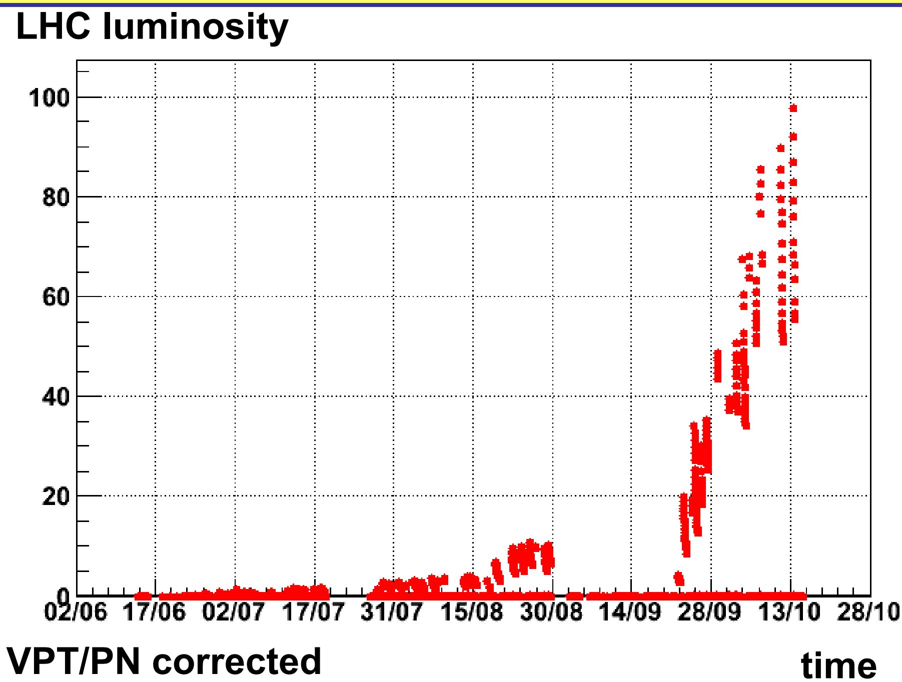


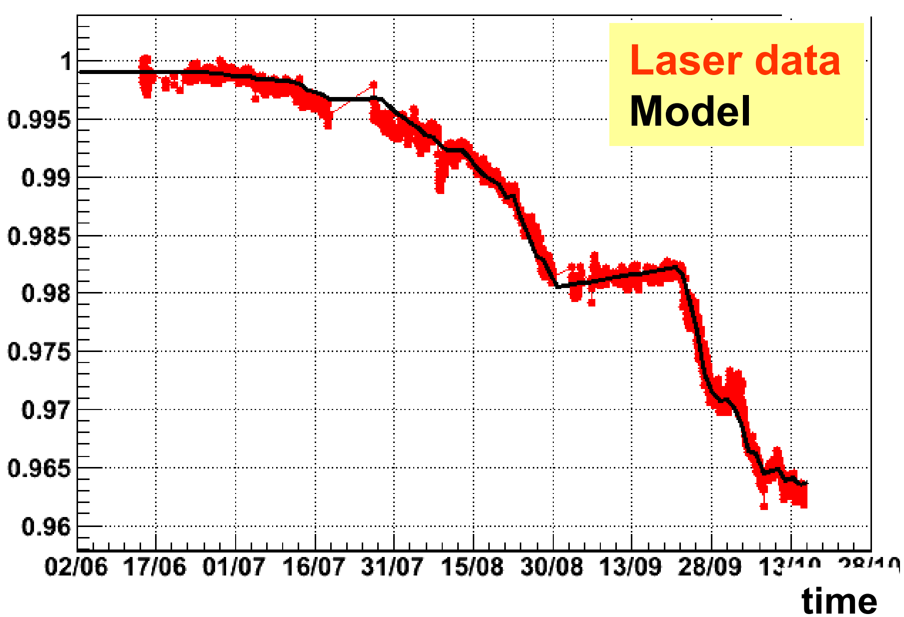




White spots are dead readout regions

Recent improvements: transparency loss model





- Dependency of transparency with luminosity (Pansart, note 1998/013):

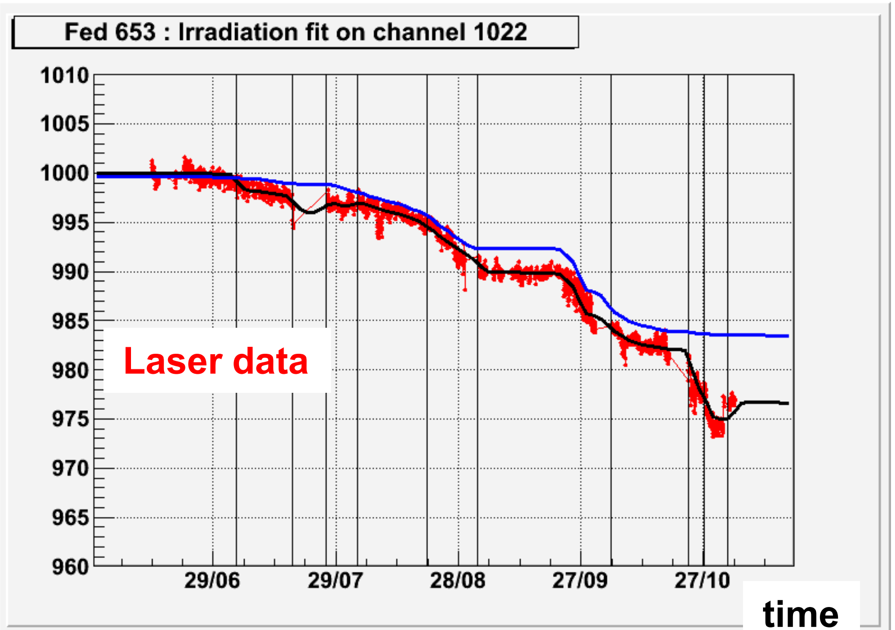
$$b(t+dt) = [\, a1 - a2\; b(t) \,]\; \mathcal{L} - a3\; b(t)$$

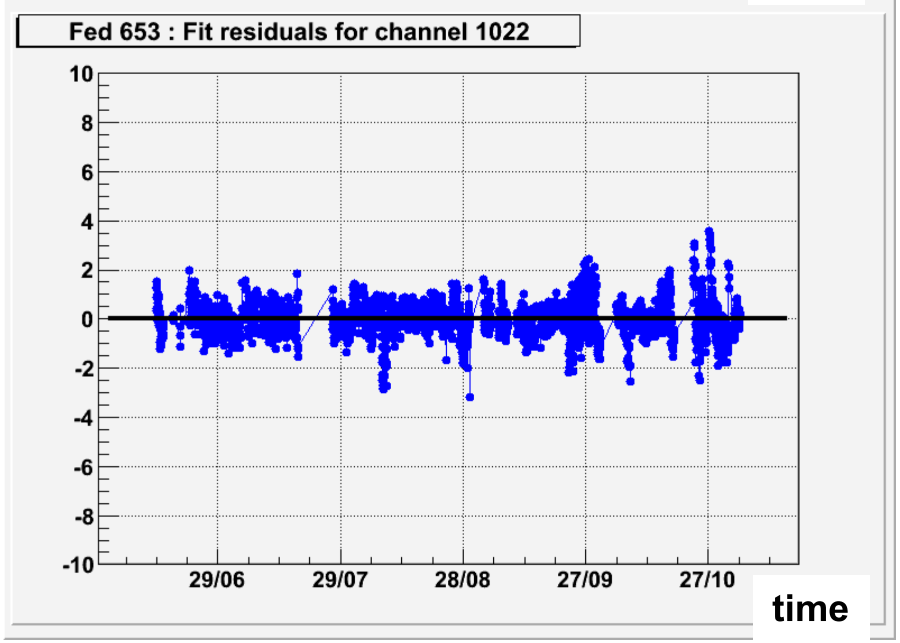
- $a1$: color centers creation rate
- $a2$: saturation term
- $a3$: recovery rate
- $\mathcal{L}$: instantaneous lumi, given by lumicalc
- $b(t)$: color centers density

Hypothesis: one type of defects, no Z dependency, transparency loss proportional to color centers density

- 3 parameters per crystal, determined for all crystals
- Can be used for missing data, interpolations and incidents

Recent improvements: transparency loss model





- At each OFF/ON cycle on HV, LV or B field, unexpected discontinuities in APD/PN histories have been noticed
- This adds to the fit one normalization parameter for each ON/OFF cycle

- In this plot:
  - **Vertical lines** are ON/OFF cycles
  - **Black curve** is the result of the fit
  - **Blue curve** is the irradiation effect without discontinuities

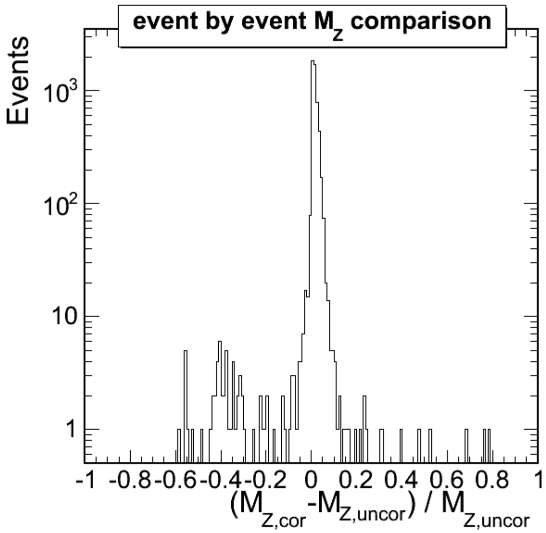
These discontinuities are due to the LM system itself and have to be removed from corrections.

This transparency model has been integrated to the second release of the corrections

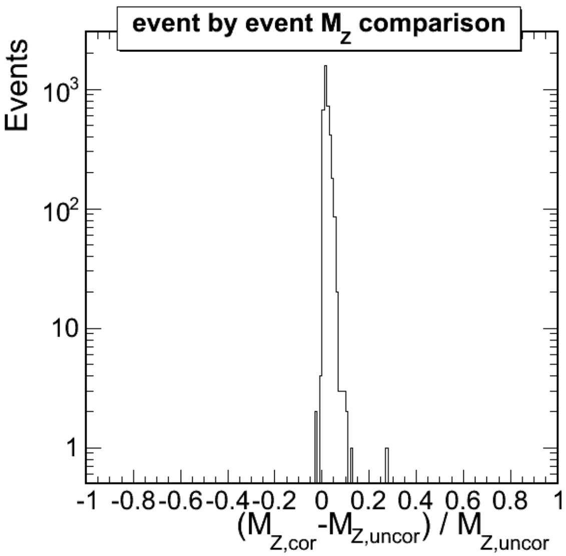
Second release of transparency corrections

- The laser transparency corrections for the whole period have been produced
  - with basic quality checks (very few problematic channels)
  - transparency model has been integrated to smooth the data, remove outliers, and protect from observed step variations
- These correction coefficients will be used for re-reco

1st release



2nd release



Outliers seen in 1st release were removed in the 2nd one

Transparency corrections validation on Z →ee events

Data

- Runs used: 146644 to 148953
- Electron selection:
    - 2e with $p_T > 20$ GeV
    - EB fiducial volume $|\eta| < 1.47$
    - EE fiducial volume $1.56 < |\eta| < 2.5$
    - VBTF isolation @ working point 95%
    - VBTF identification @ working point 95%

Data/MC comparisons for:

- Z peak from a reference period without irradiation effects (7 pb^{-1})
- Z peak from the latest period with irradiation effects (25 pb^{-1})
- Look at macro-regions of ECAL

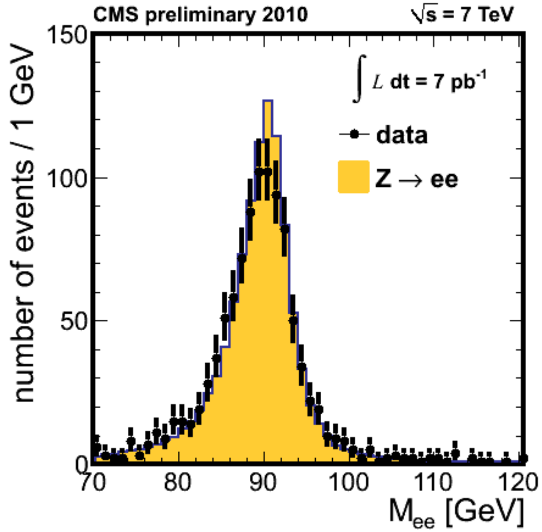
Transparency corrections validation on Z → ee events

Comparisons for all ECAL:

First period:

•7 pb^{-1}
•no transparency loss

“reference period”



Conclusions:

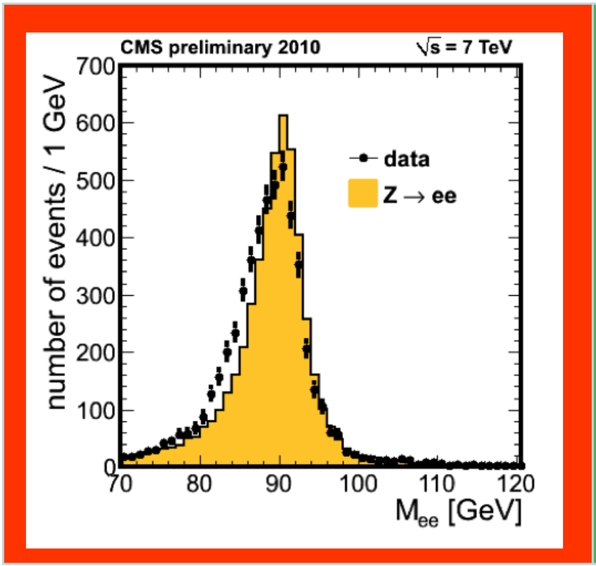
- Laser corrections allow to recover events in the left tail
- Resolution improved

Second period:
1st corrections release

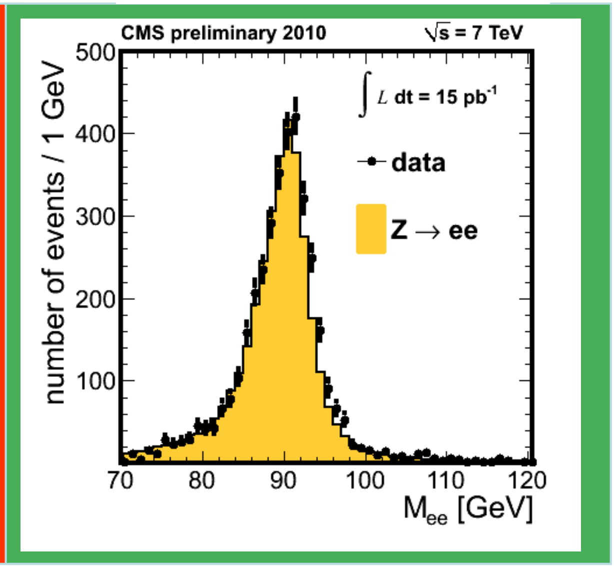
•25 pb^{-1}
•transparency loss

“validation period”

No Correction



Laser Corrected 2nd release



Transparency corrections validation on Z →ee events

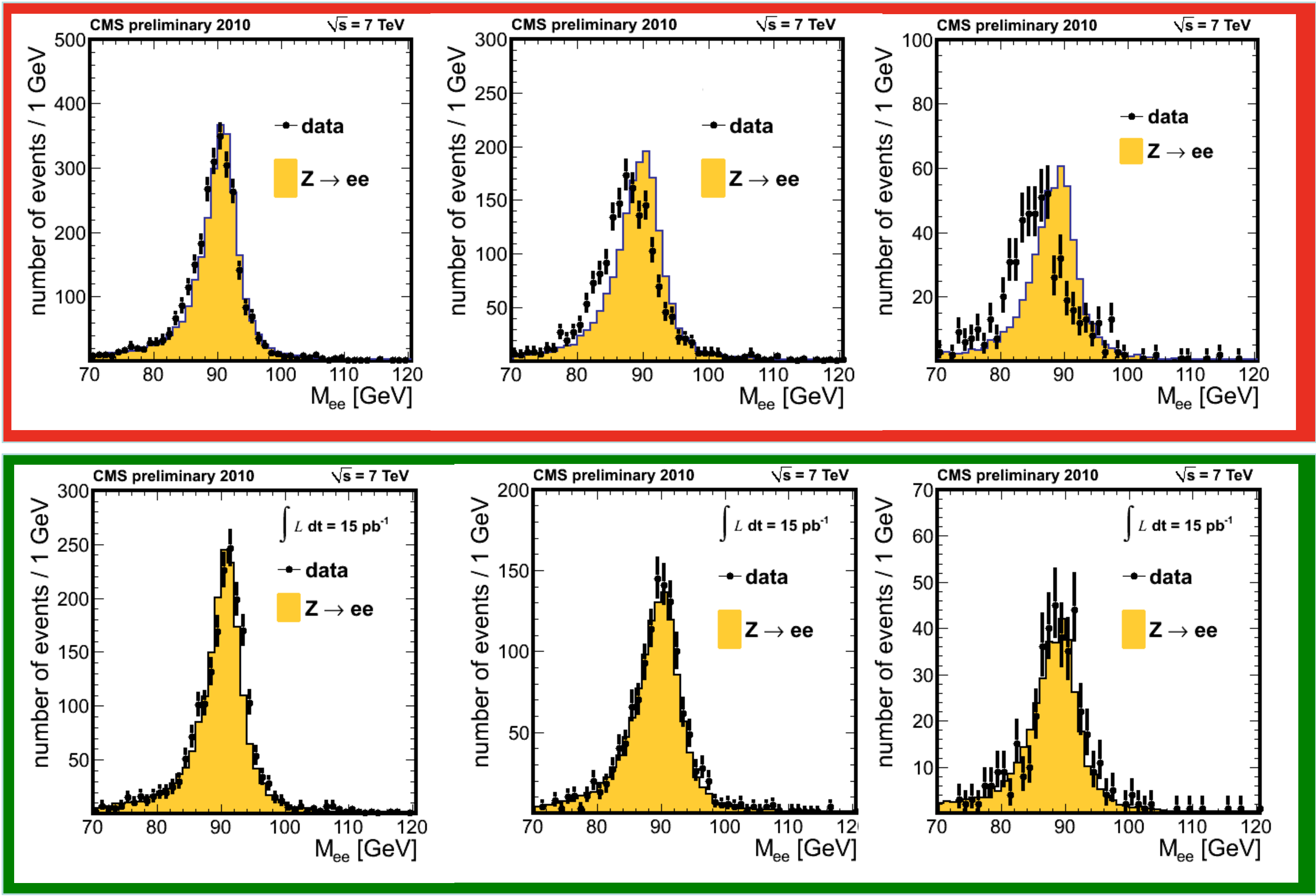
Same comparisons for ECAL macro regions:

EB-EB | **EB-EE** | **EE-EE**

Not Corrected 25pb-1

Laser corrected

2nd release



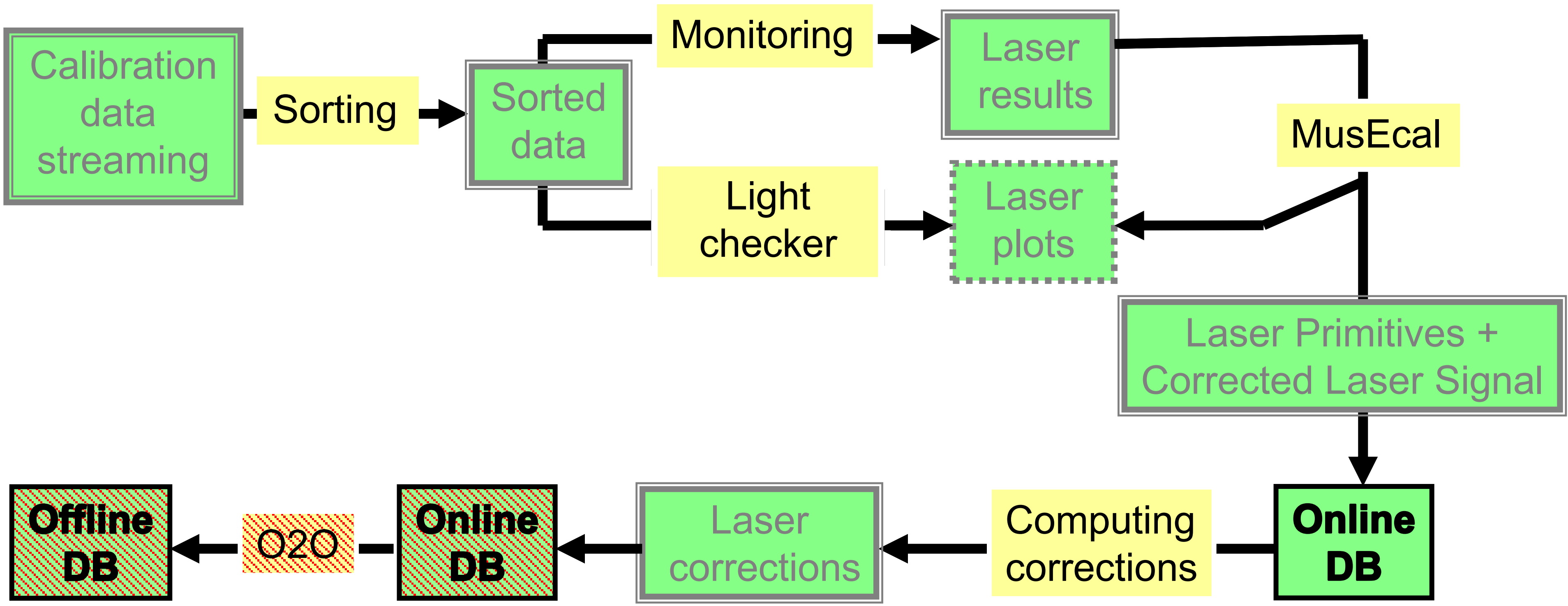
Conclusions

These results rest on the effort of many people of ECAL contributing to ECAL hardware and software development and operation

- After these many years of efforts, the laser monitoring system is now showing its full potential
- During low-irradiation periods, it has proven to be very stable, well below design specifications
- Provided corrections have proven to be very effective
- The precise quantification of the effects of laser corrections on Z peak, electrons from W and Z (E/p), and π0 is on-going already: stay tuned!

Backup slides

ECAL Laser Monitoring system: workflow



- Laser data analysis achieved quasi-online on the LM farm at P5 from acquisition to online database writing (in the test database for 2010)
- The last part of the chain (O2O, writing in real DB) will be automatic for 2011 data taking once 2010 data will be fully understood
- Corrections were computed and written to offline directly from results without reading back online and using O2O

APD (VPT) amplitude calculation: convolution method

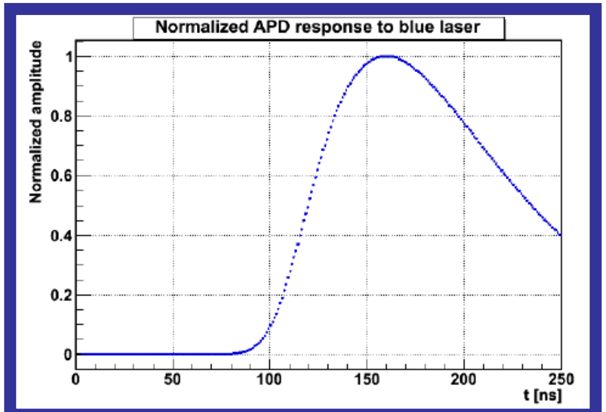
"shape" method: Marc Déjardin

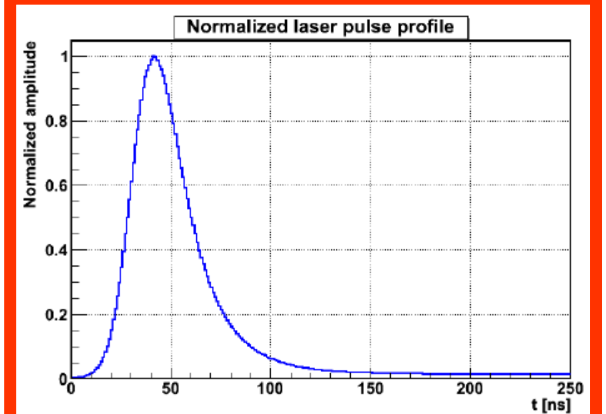
Detector Note-2008/001 (draft)

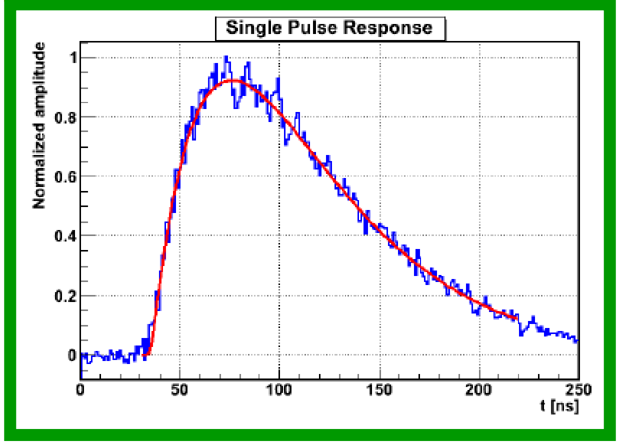
- **Idea:** instead of an analytic function, use the real signal shape by convoluting APD (VPT) SPR with the laser pulse shape from MATACQ

- **Method to get SPR:**
  - Get the APD(VPT) response with a fine sampling on dedicated data exploring the full range of phase within the LHC clock (data taken by adding delays in the laser trigger line)
  - Get the LASER pulse shape from MATACQ on the same data
  - Deconvolute the APD (VPT) SPR using Fourier Transforms

- **In the LM processing:** convolute this stable APD SPR with the laser shapes from MATACQ sequence by sequence to get the APD (VPT) amplitude fitting function







APD (VPT) amplitude calculation: convolution method

Detector Note-2008/001 (draft)

- EE and EB electronics do not have the same responses, thus their SPR have been parameterized by two different functions:

EB APD

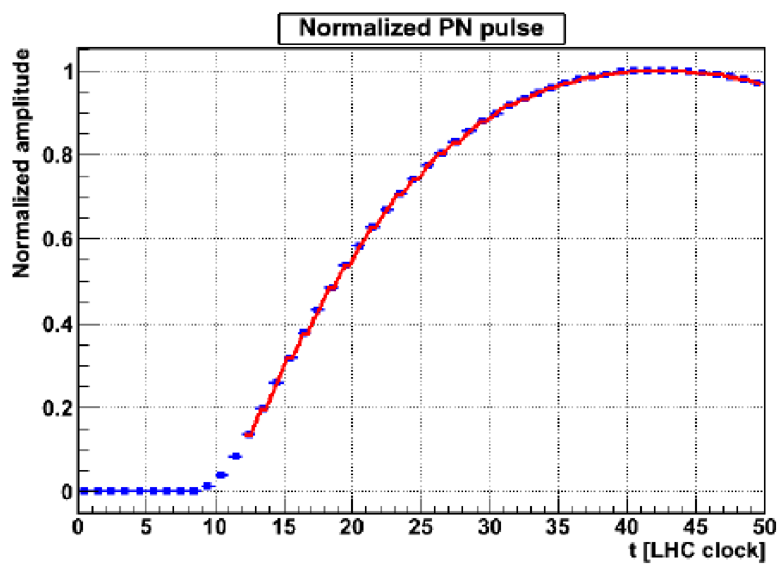
$$h(t) = \frac{t}{\tau} e^{-\frac{t}{\tau}}$$

EE VPT

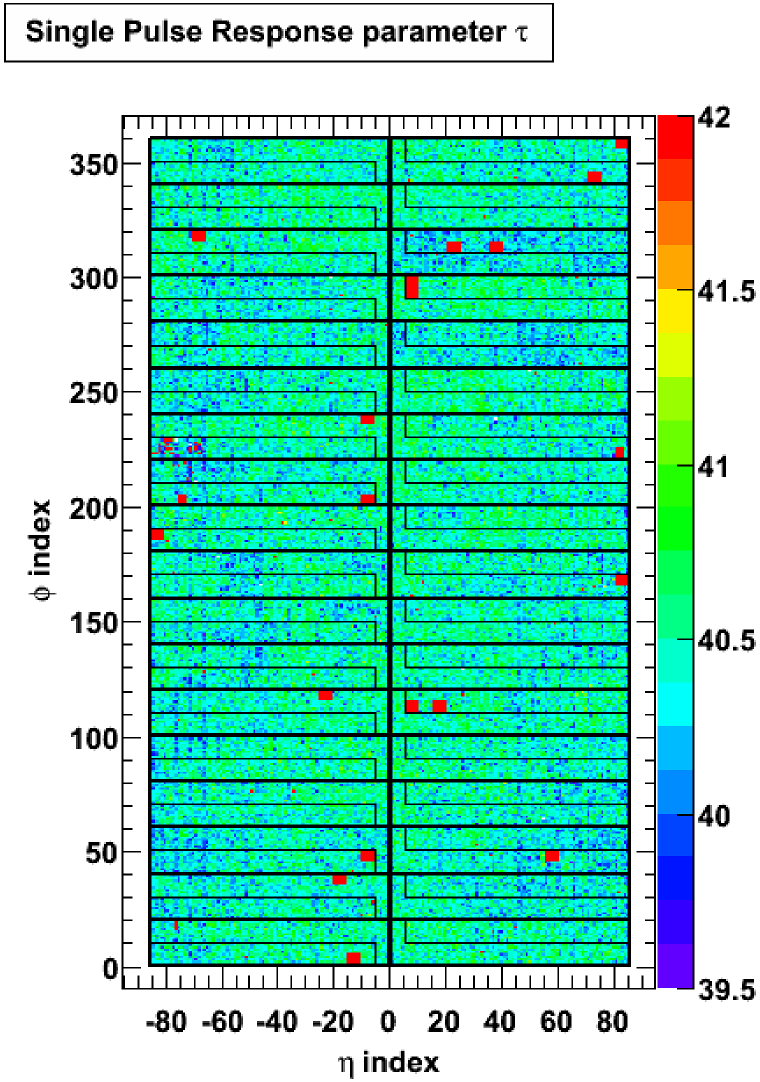
$$h(t) = \frac{t}{\tau_1} e^{-\frac{t}{\tau_1}} * e^{-\frac{t}{\tau_2}}$$

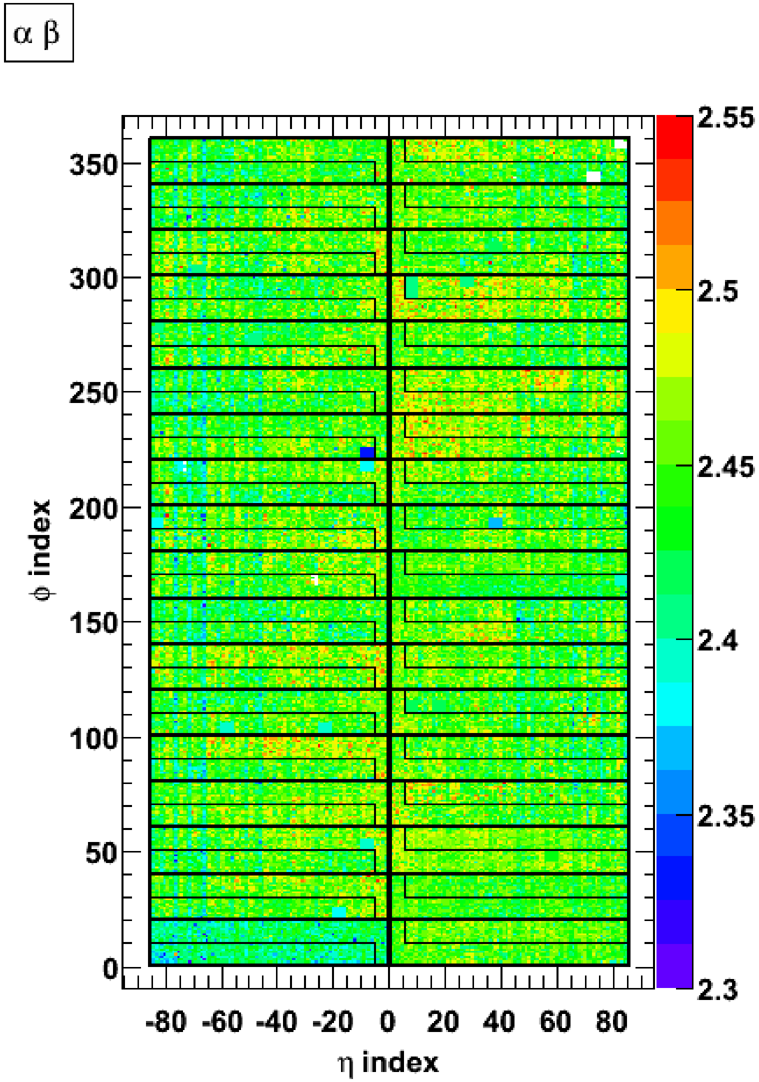
- SPR determination and parameterization has also been done for PN signals:

Example of PN signal and superimposed SPR response convoluted with LASER pulse from the MATACQ



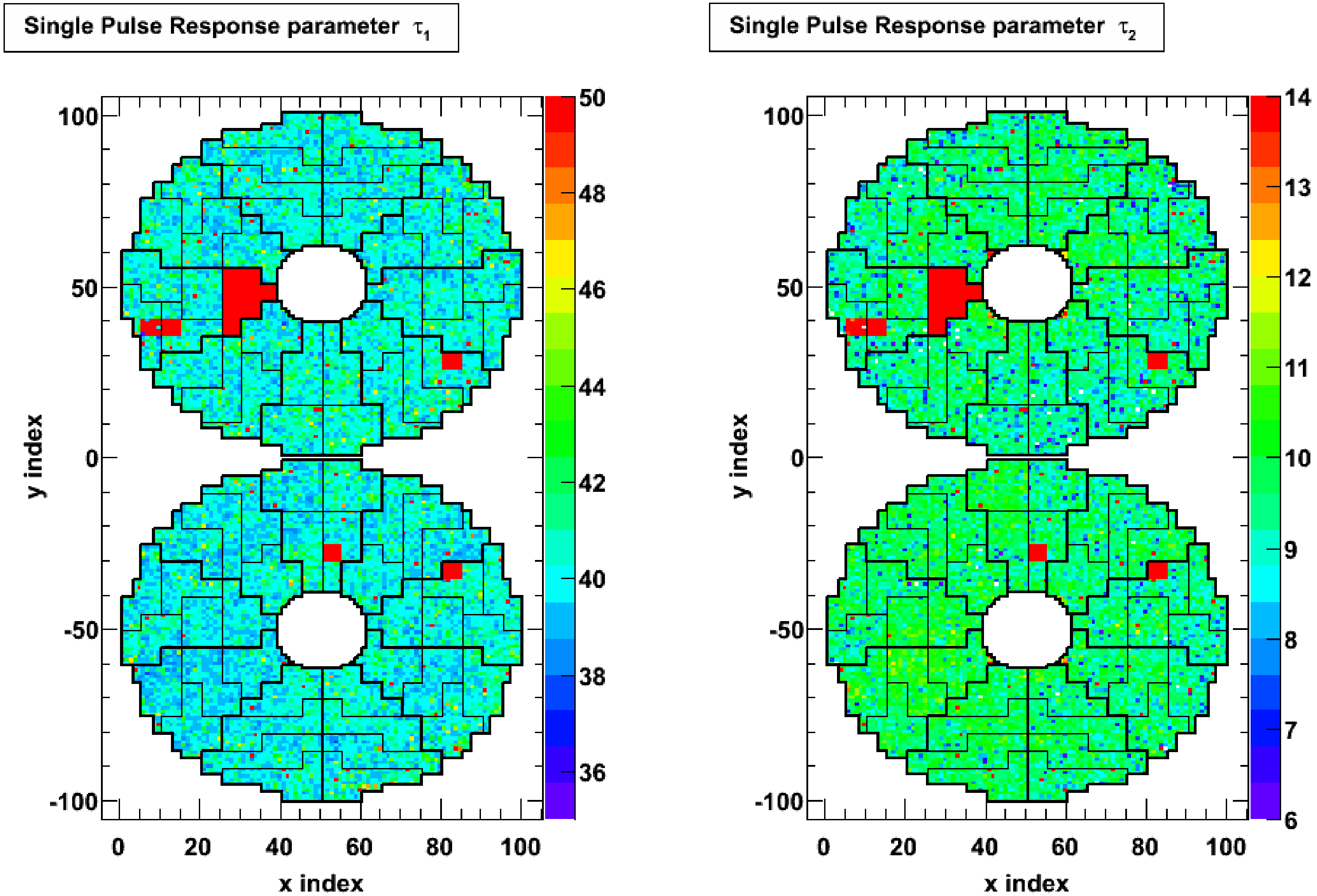
EB: SPR parameter τ and $\alpha\beta$ parameters





EB has a uniform response

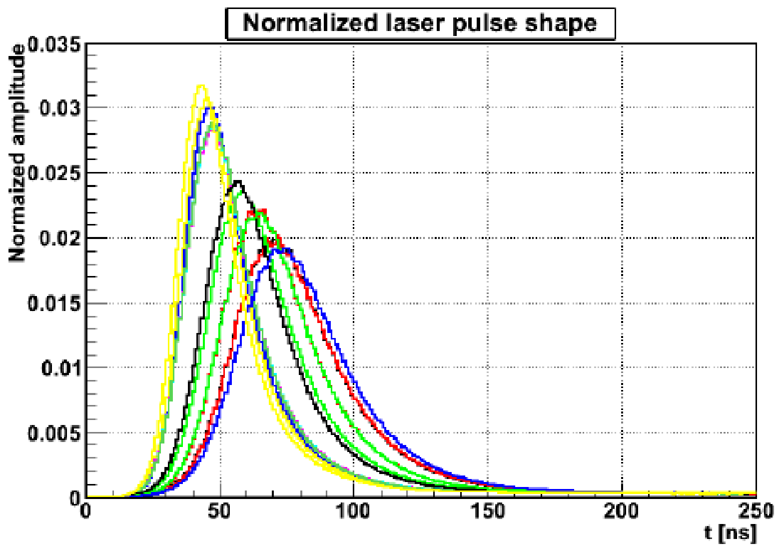
EE: SPR parameters τ_1, τ_2



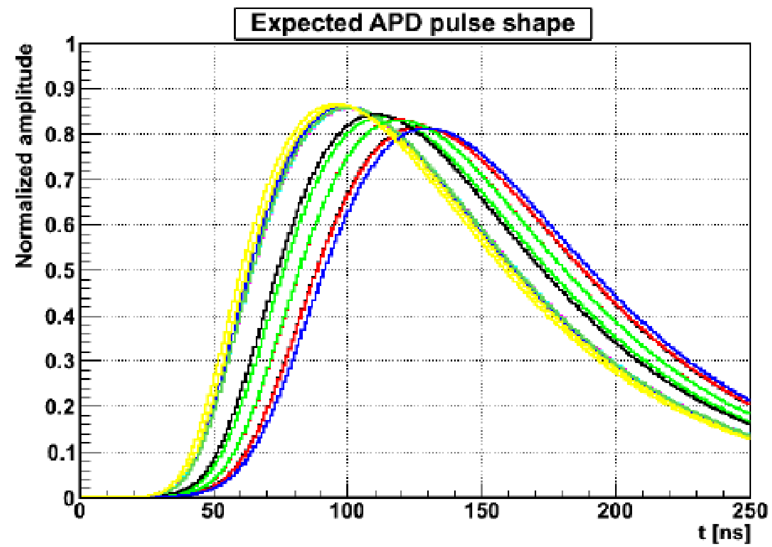
- EE and EB have different electronic responses
- Electronic response more uniform in EB than in EE (not problematic as long as we know the SPR)

APD amplitude calculation: “convolution method”

Knowing SPR allows to know the APD response for a given laser pulse shape:



Laser signals (constant energy)



Corresponding APD shapes

Two effects have to be considered:

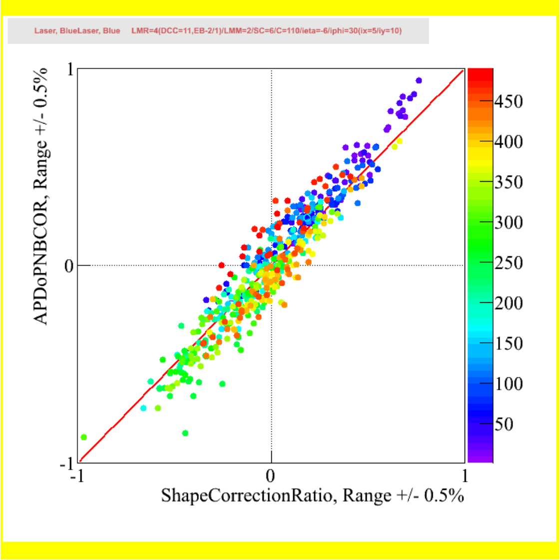
1. APD (VPT) pulse amplitude reconstruction has to take into account those variations to avoid fitting bias with varying laser pulses ⇒ done by the “convolution method”
2. The measured amplitude, even unbiased, is not directly related to the laser energy and depends also on the laser pulse shape

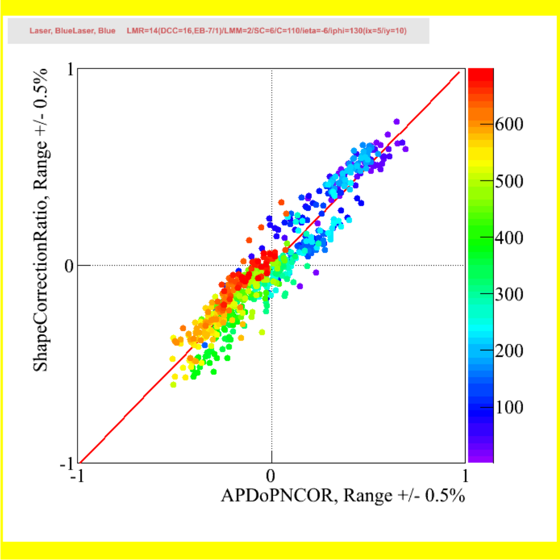
Laser variation correction within convolution method

- LASER width correction formerly computed by removing the correlation between APD/PN and the measured LASER FWHM
- Knowing SPRs and the LASER pulse shape for each sequence allows to compute what would be the ratio APD(VPT)/PN and to correct directly with it:

$$\boxed{corr = \frac{max(SPR(APD,VPT) * laser)}{max(SPR(PN) * laser)}}$$

- known universal correlation
- correct for all LASER variations (width, tails)





- **example channels in 2 different SM**
- **color is the sequence number (time)**

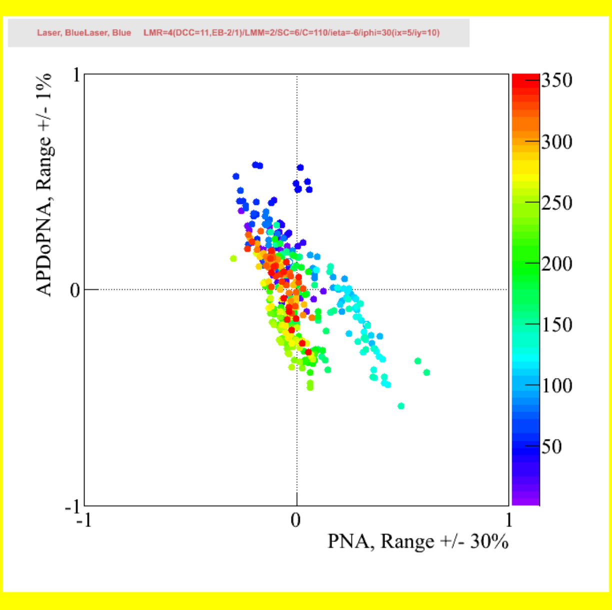
corr Vs APD/PN for 2 periods of 2010 data taking: correlation is 1

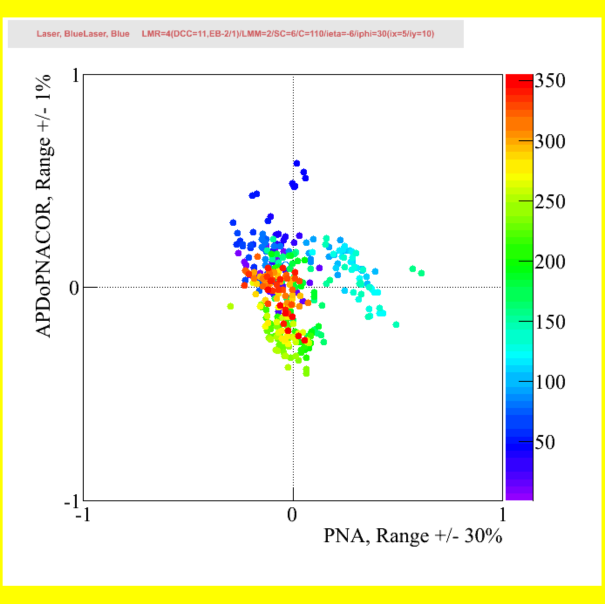
PN linearity corrections

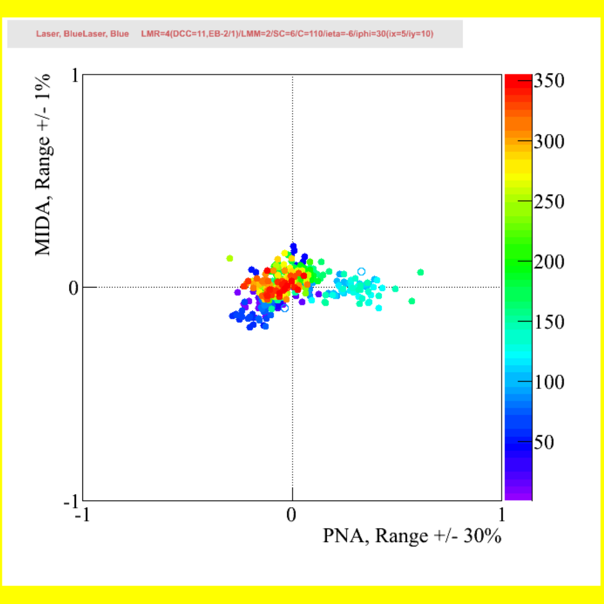
- Formerly, the same PN linearity corrections were applied to all PNs
- They have been refined for each PN
- The processing now includes these new corrections

APD/PN Versus PN

- example channel
- color is the sequence number





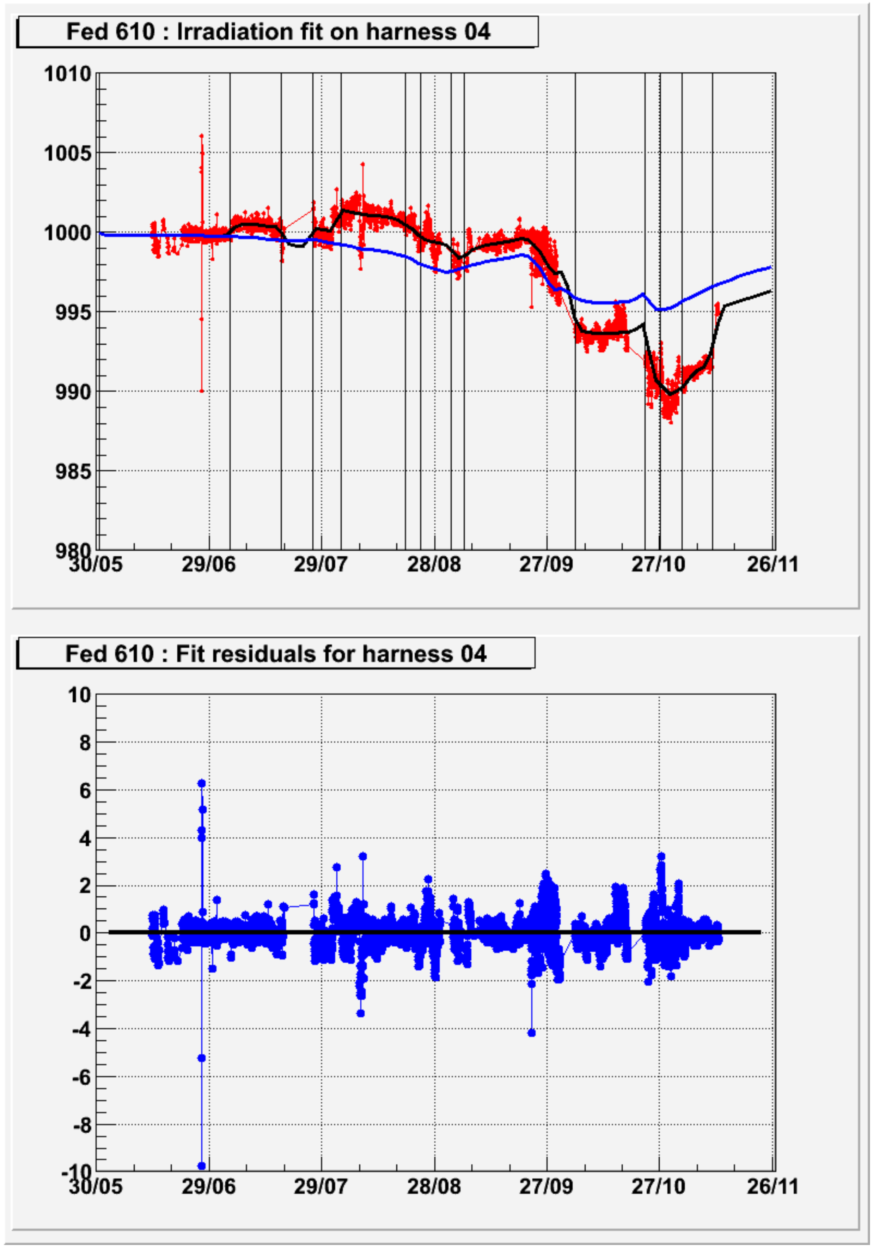


- NO PN linearity correction
- NO LASER width correction

- PN linearity correction
- NO LASER width correction

- PN linearity correction
- LASER width correction

Recent improvements: transparency loss model



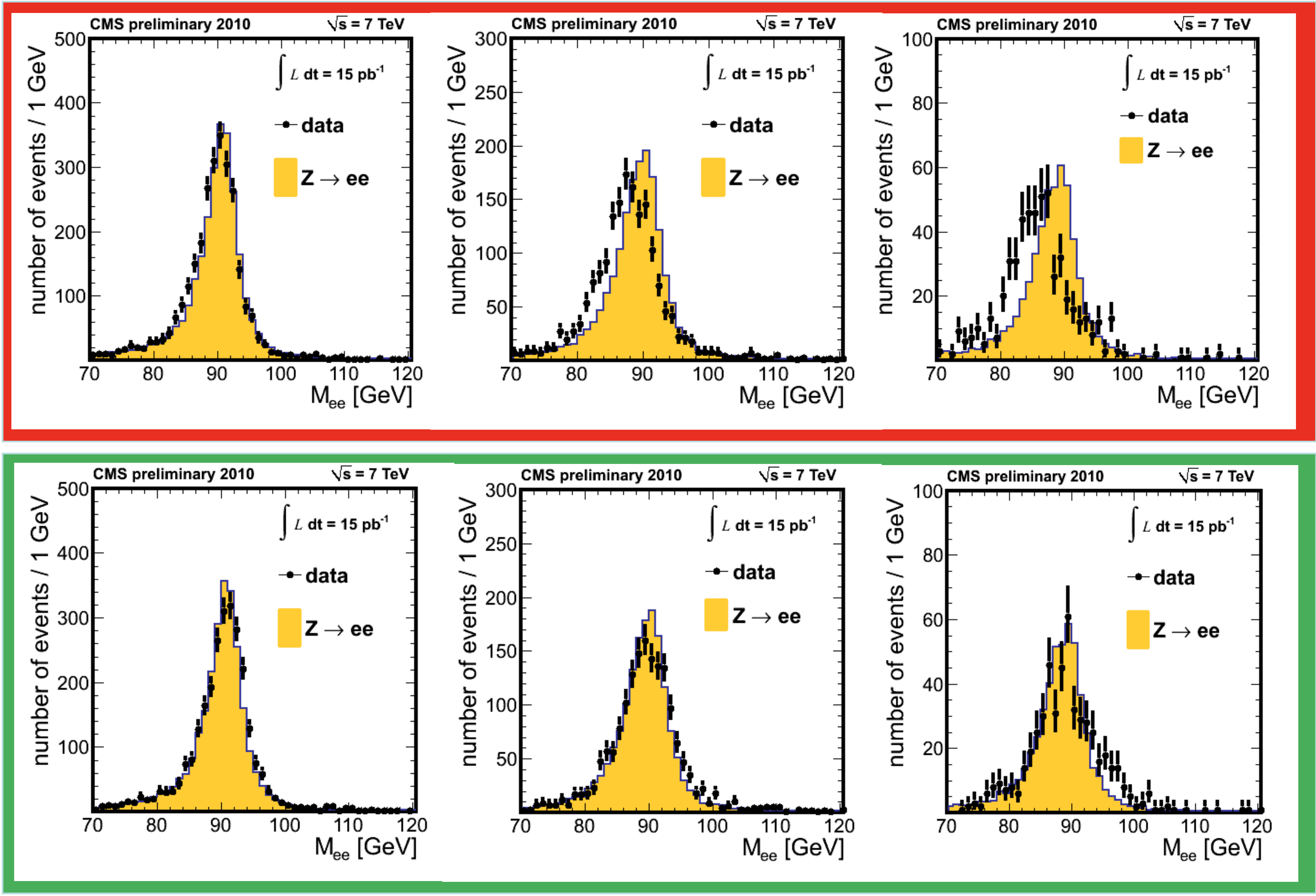
Transparency corrections validation on Z →ee events

Same comparisons for ECAL macro regions:

EB-EB | **EB-EE** | **EE-EE**

Not corrected

Laser corrected

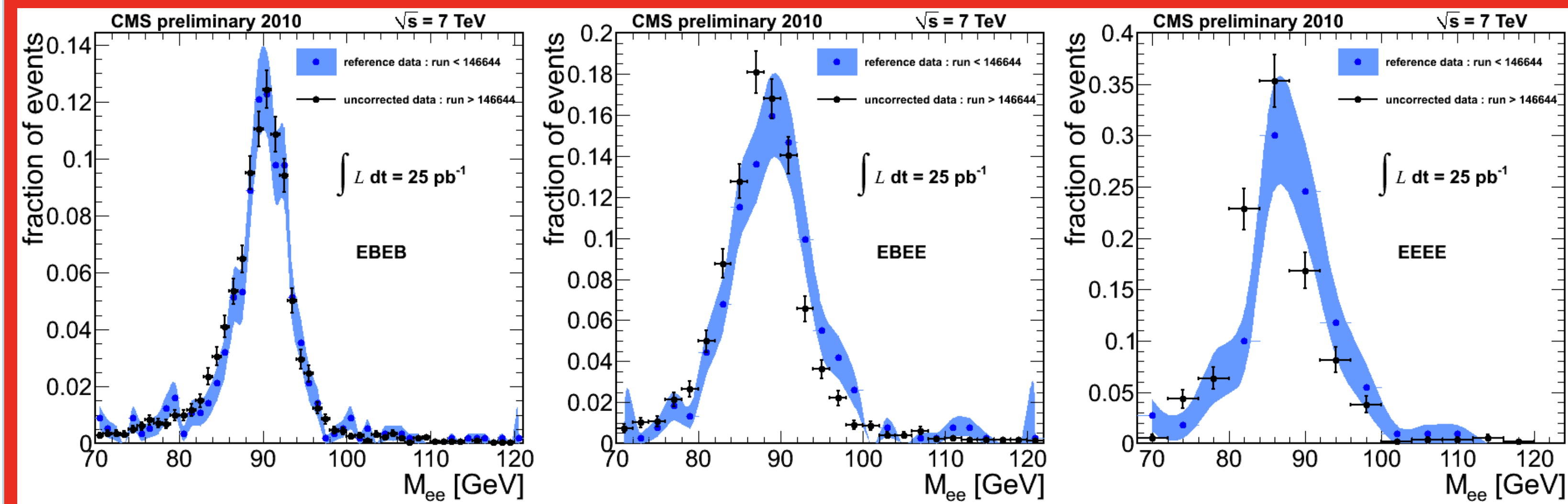


Transparency corrections validation on Z →ee events

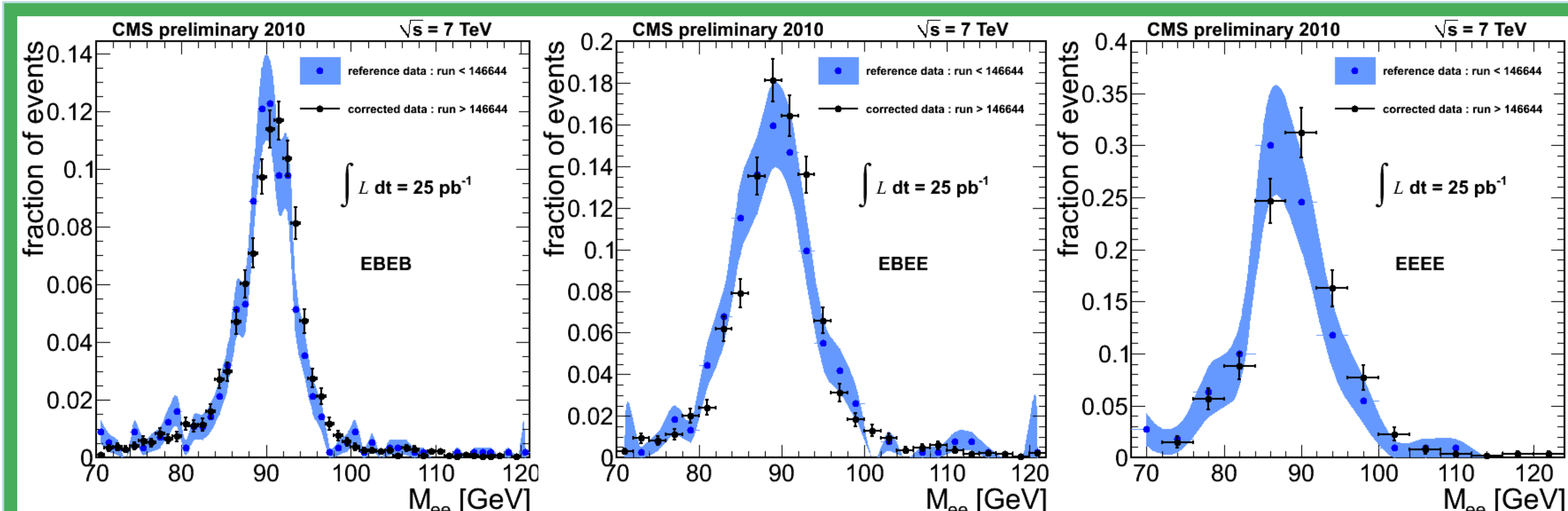
Comparisons with reference data for ECAL macro regions:

EB-EB **EB-EE** **EE-EE**

Not corrected



Laser corrected



New transparency corrections validation on Z → ee events

Comparison of 1st and 2nd correction releases for ECAL macro regions:

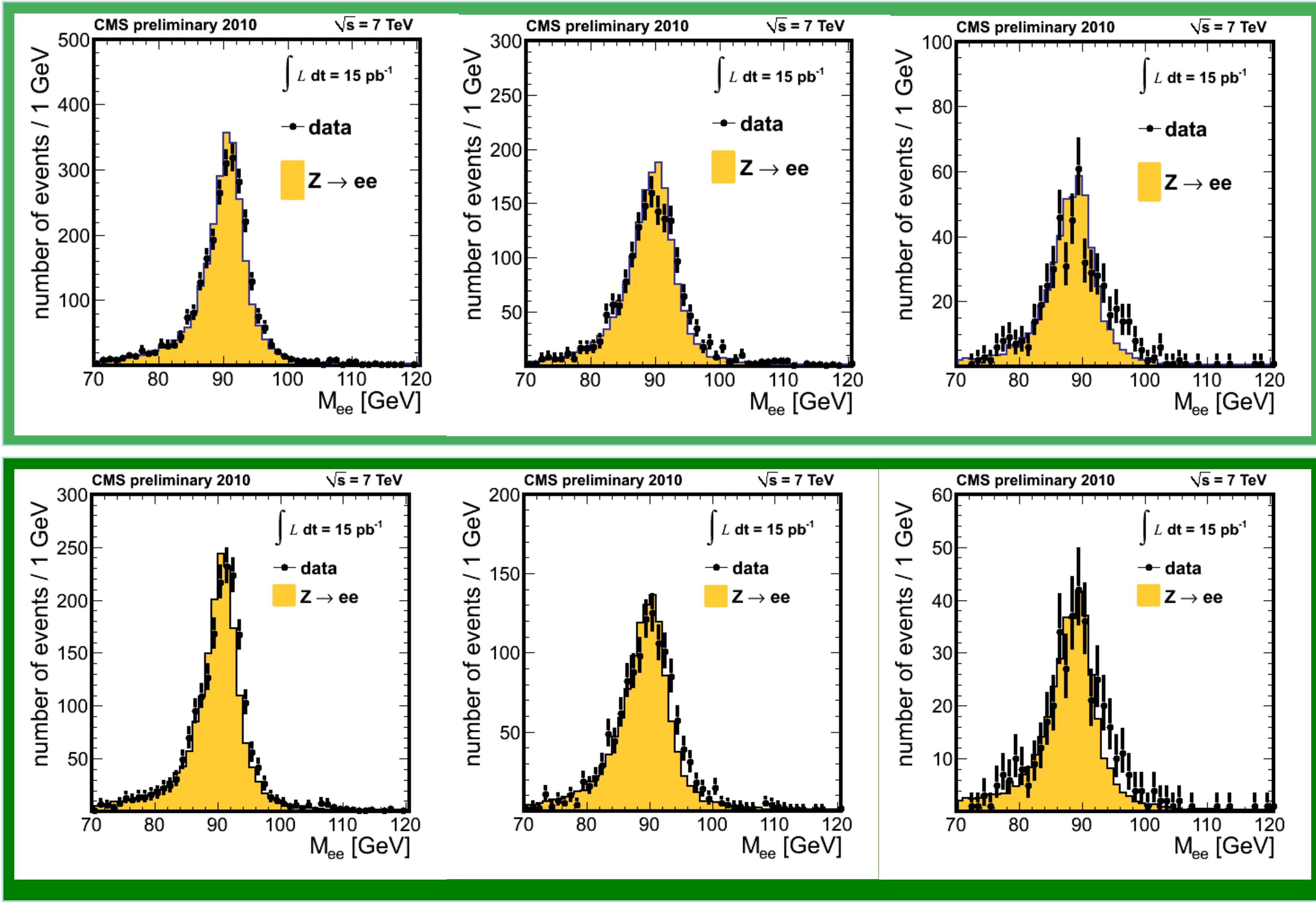
EB-EB **EB-EE** **EE-EE**

Laser Corrected

1st release

Laser corrected

2nd release

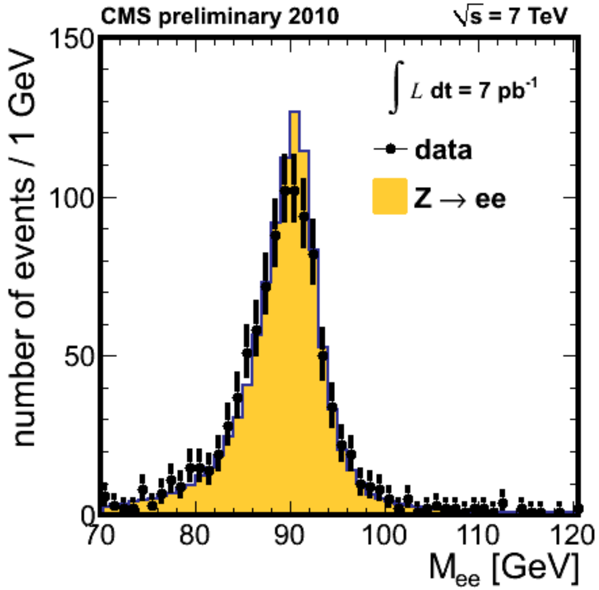


Transparency corrections validation on Z →ee events

First period:

•3 pb^{-1}
•no transparency loss

“reference period”



Conclusions:

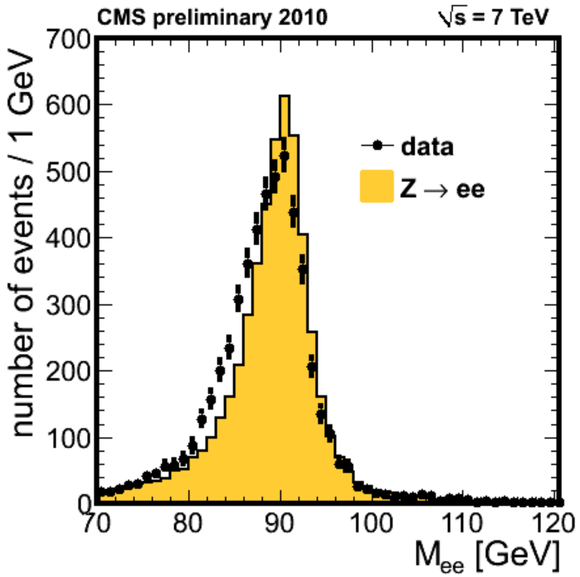
- Laser corrections allow to recover events in the left tail
- Hint for a small over correction

Second period: 1st corrections release

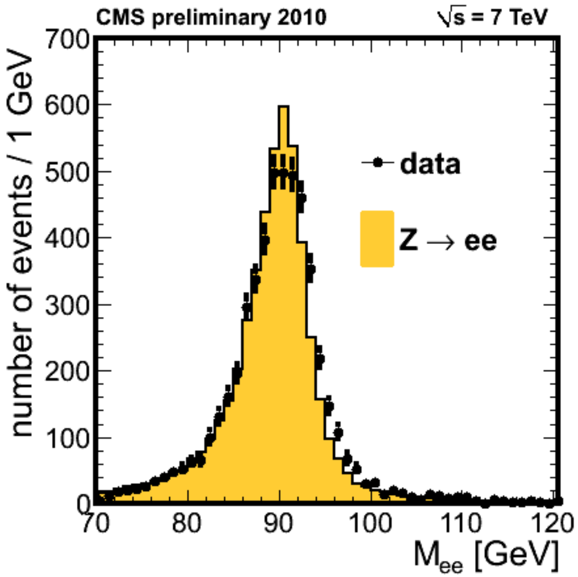
•25 pb^{-1}
•transparency loss

“validation period”

uncorrected, all ECAL



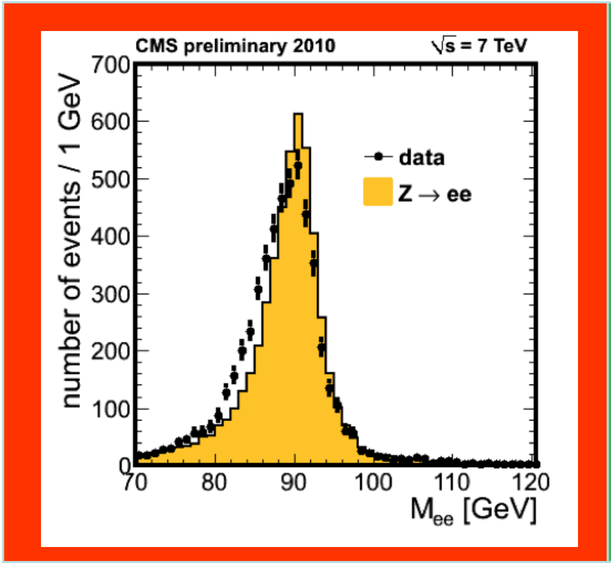
laser corrected, all ECAL

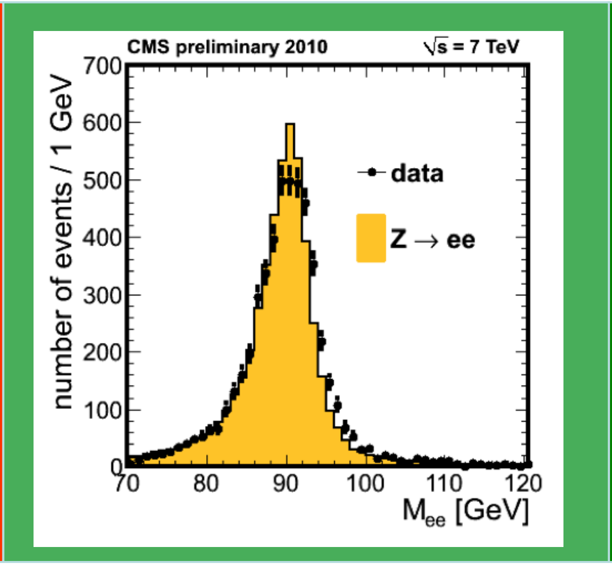


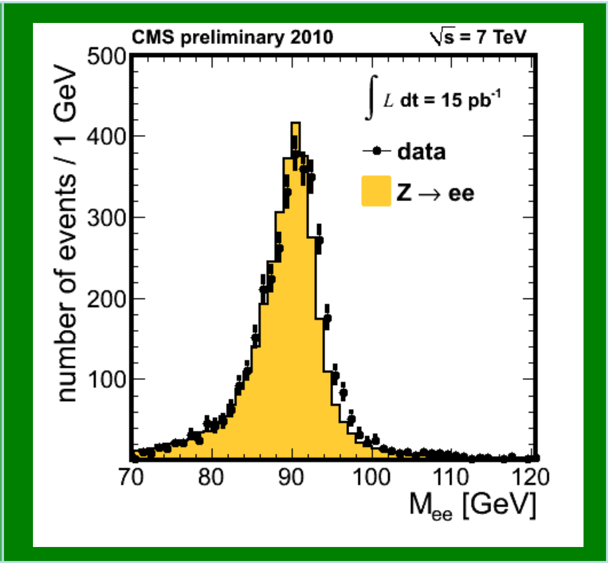
New transparency corrections validation on Z → ee events

Comparisons for all ECAL:

No Correction	Laser Corrected 1st release	Laser Corrected 2nd release







The second release of the corrections allows to:

- recover problematic channels
- get rid of steps due to ON/OFF transitions

Resolution is slightly improved, the peak being more populated

Second release of transparency corrections

- The laser transparency corrections for the whole period have been produced
    - with basic quality checks (very few problematic channels)
    - transparency model has been integrated to smooth the data and protect from observed step variations
- They were written in the "prep" DB (test DB) on Tuesday, the 16th
- A tag was also provided on Tuesday to be used for the RelVal production, including a reprocessing of the WZ skim
- A validation with physics was launched as soon as the "prep" account was fully populated: reconstruction of the Z peak within few hours from the DB population
- These correction coefficients will be used for re-reco