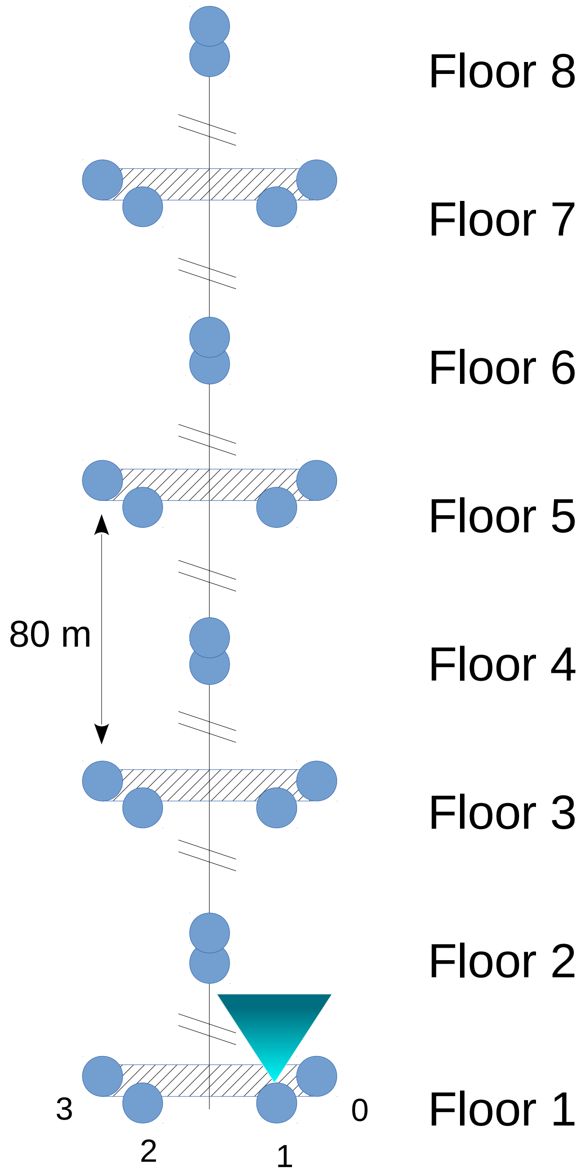
Time Calibration with nanobeacons in KM3Net Italia

Christophe Hugon
INFN Genova

Overview and objectives

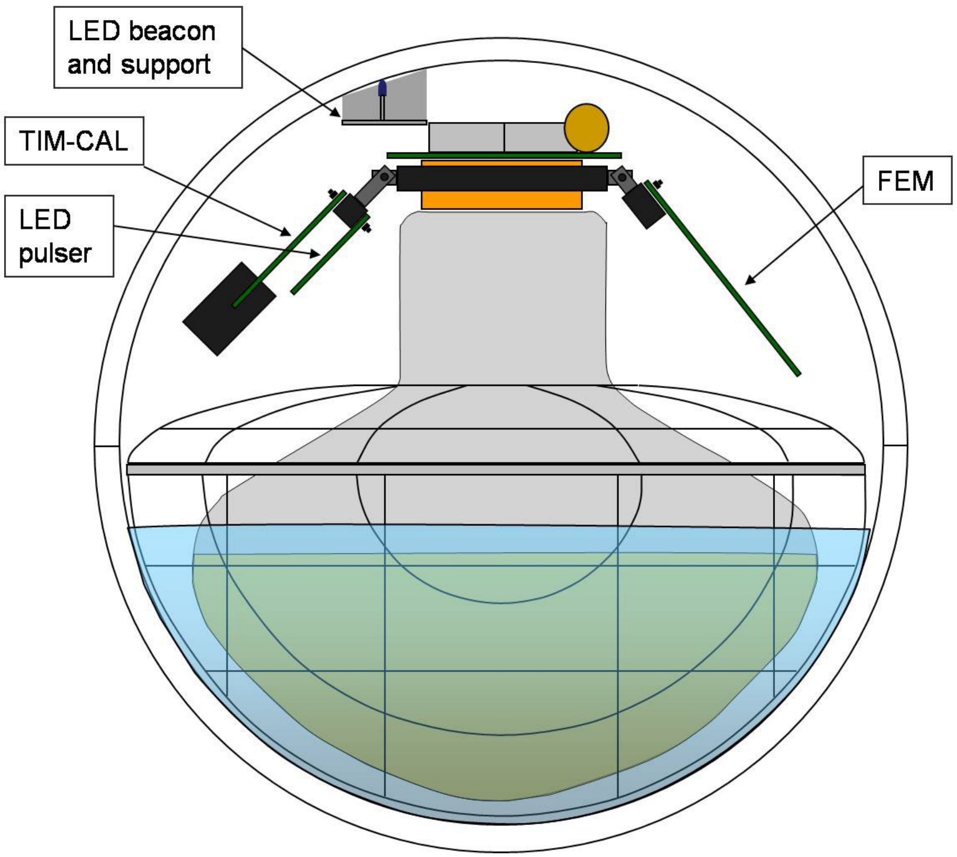
- Context and last result of data analysis reminder
- Technical description of the analysis software

Timing measurement in the detector



- LED of the OM 11 was used (runs 681 684 & 687)
- LED mean wavelength at 470 nm
- LED flash at 2 kHz

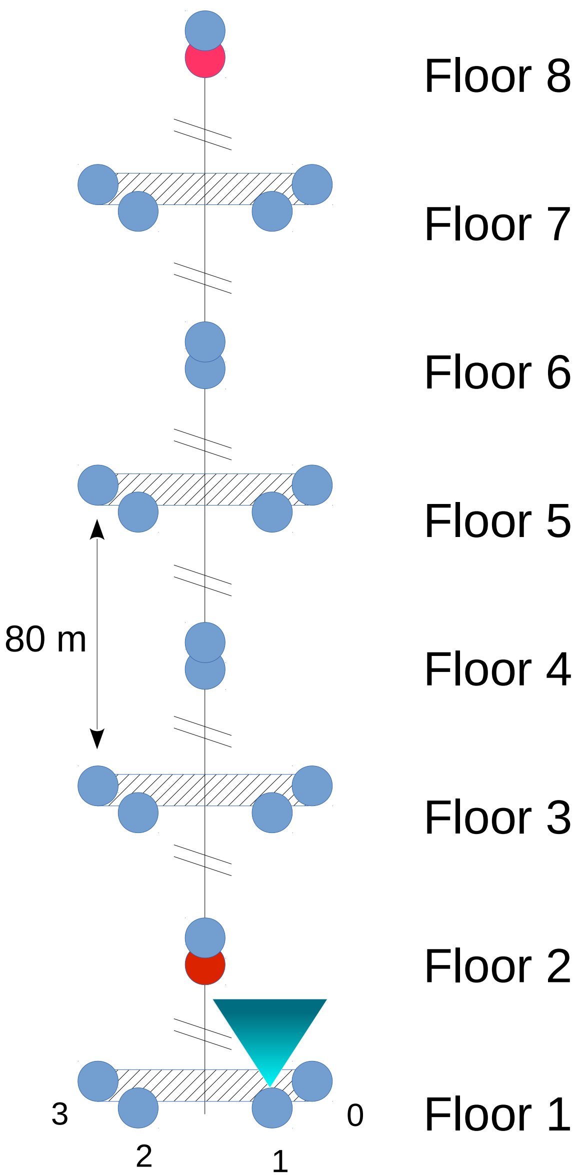
=> peaks observables within a modulo 500 us timing plot

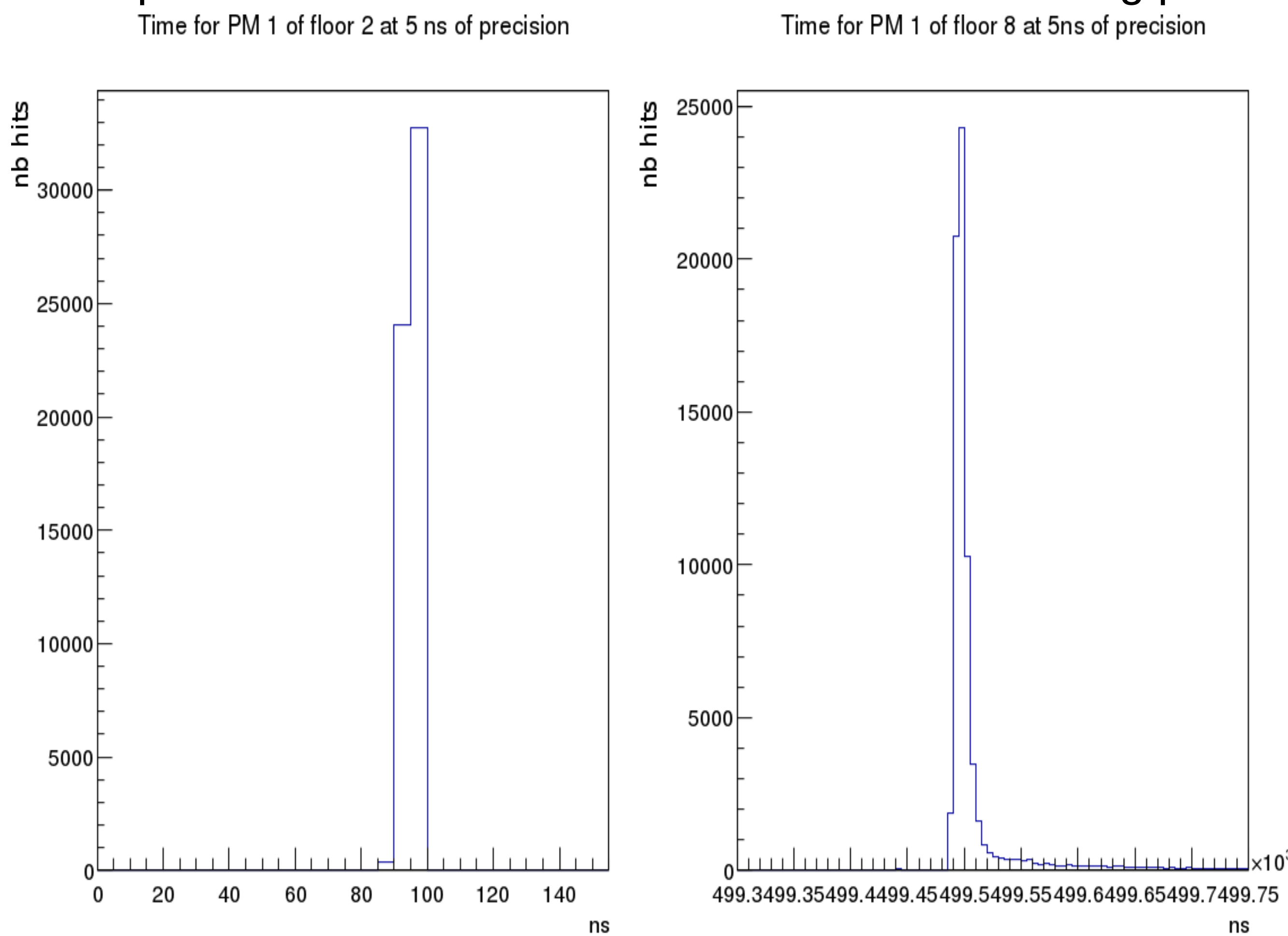


Timing measurement in the detector

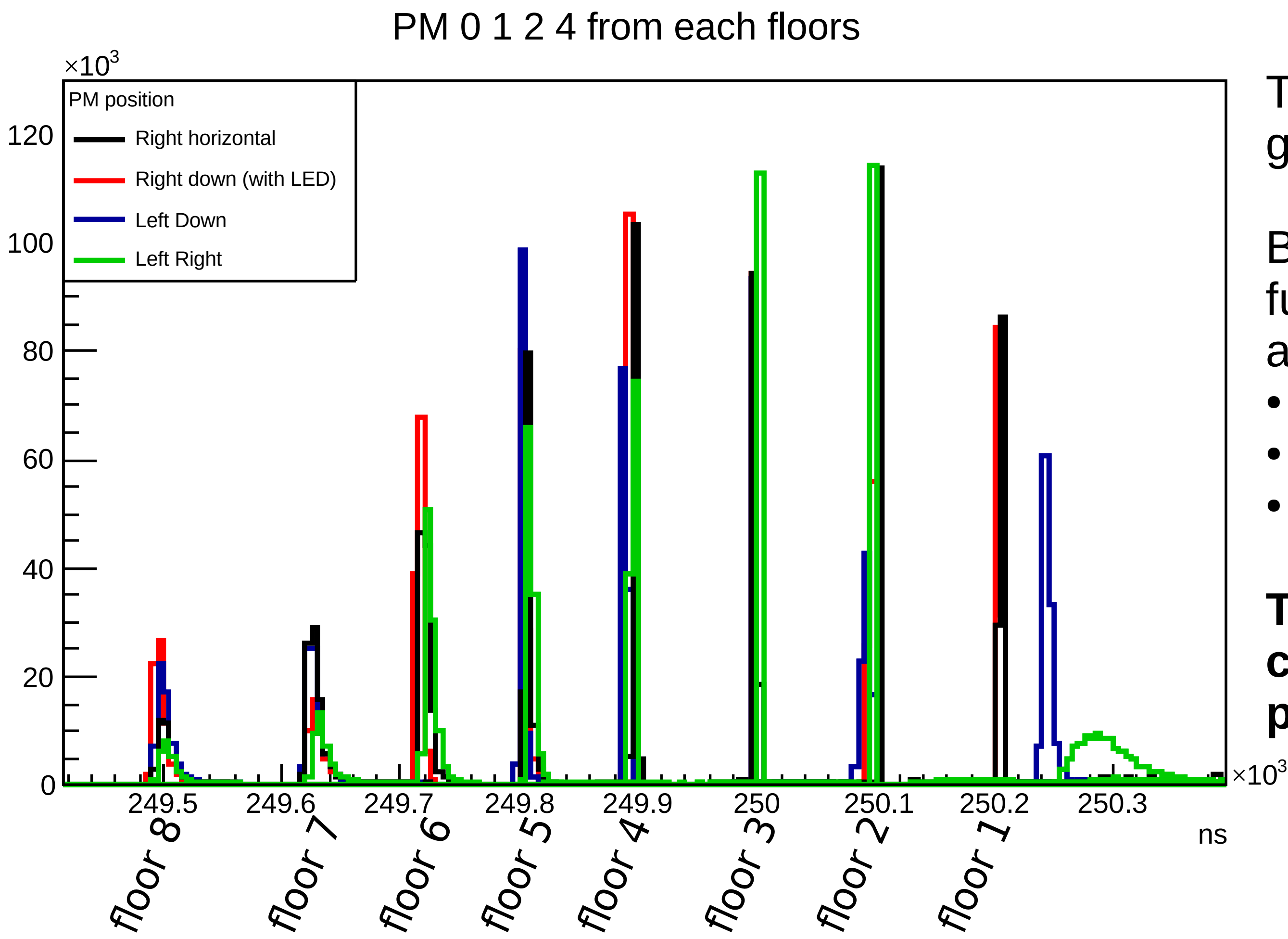
- LED of the PM 11 was used (runs 681 684 687 1359)
- LED mean wavelength at 470 Hz
- LED flash at 2 kHz (and 500 Hz for OM time check)

=> peaks observables within a modulo 500 us timing plot





Timing plotting for all floors



The distribution gives a good time distribution.

But the intensities in function of distance are not as expected

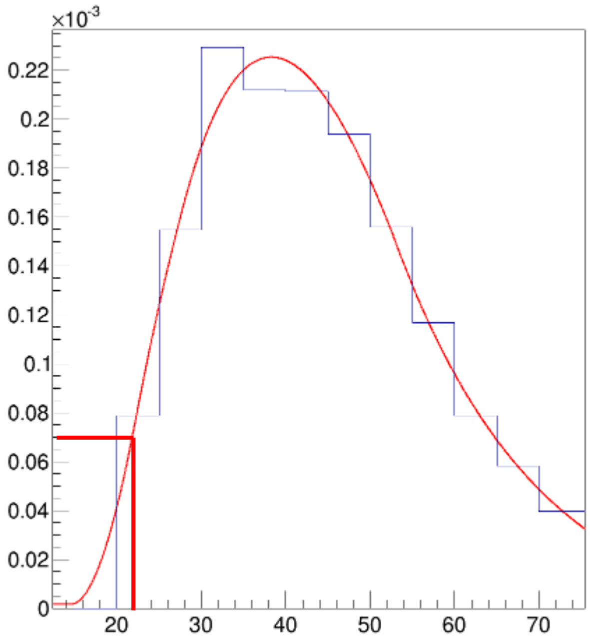
- LED positioning ?
- LED homogeneity ?
- Floor to floor shadow

The timing profile only can be used for the water properties studies

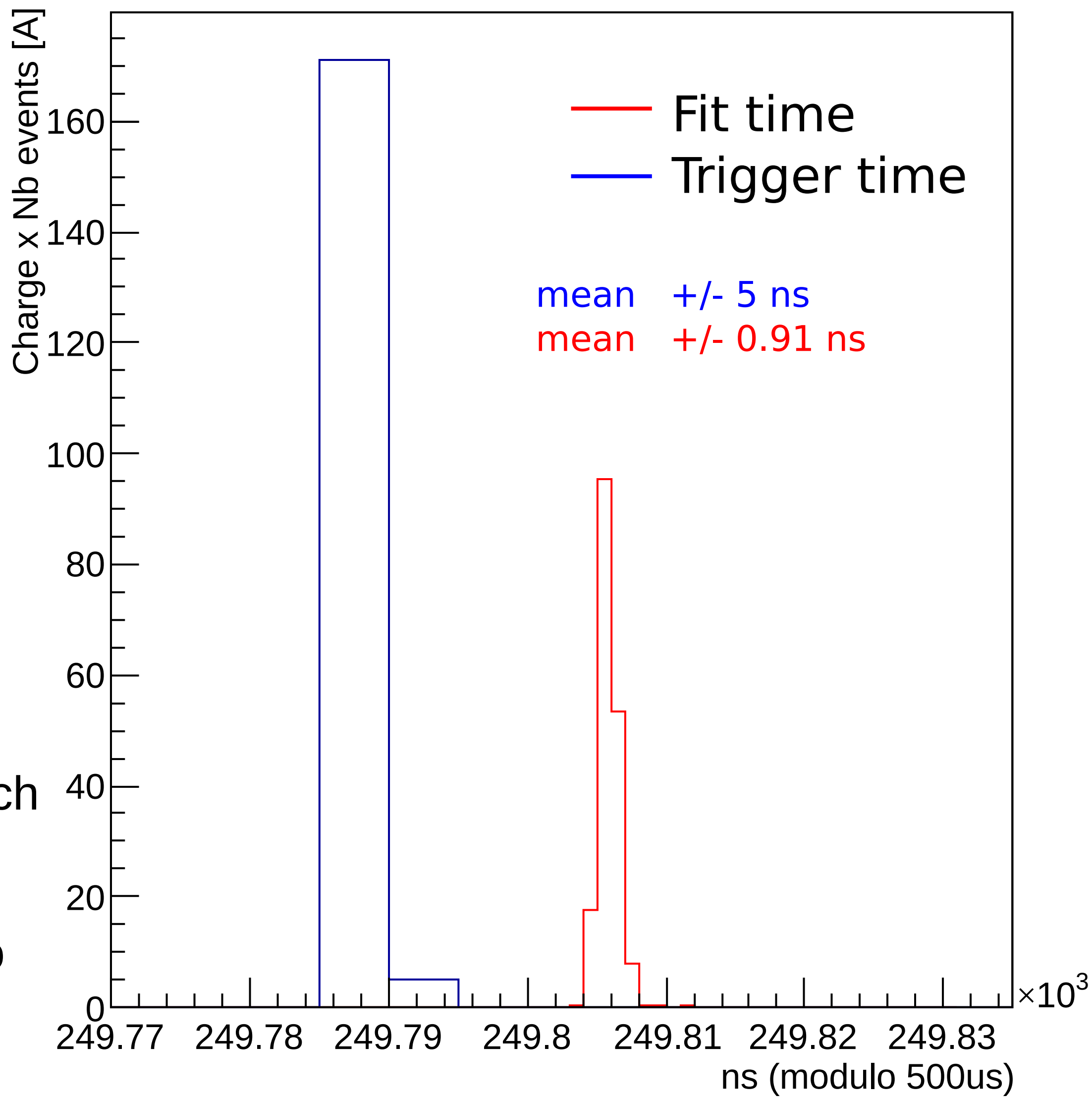
Fit function time improvement

Pmt pulse

30 %



Global timing for PM 41, time extracted from trigger time and fiting



Given by a 3 parts mathematical approach
Permit to take in account the full pulse

Can decrease the resolution from 5 ns to less than 1 ns (see examples)

Timing results with pulses at 1 ns of resolution

Floor number (N)	Measured propagation time with floor 1 (floor N-1)	Theoretical time with floor 1 (floor N-1)	Differential time with floor 1 (floor N-1)
1	0 +/- 0.5	0	0
2	174 (174) +/- 0.9	186 (186)	12 (12)
3	354 (179) +/- 0.5	371 (185)	17 (5)
4	550 (195) +/- 0.4	558 (187)	8 (-9)
5	740 (189) +/- 0.3	744 (186)	4 (-4)
6	929 (188) +/- 0.5	931 (187)	2 (-2)
7	1113 (182) +/- 0.72	1118 (187)	5 (-6)
8	1302 (175) +/- 0.75	1305 (187)	6 (1)

The fitting confirm the last results. It brought a better error to the measure.

As a cross check a lower intensity run was used for first floors. It correspond to

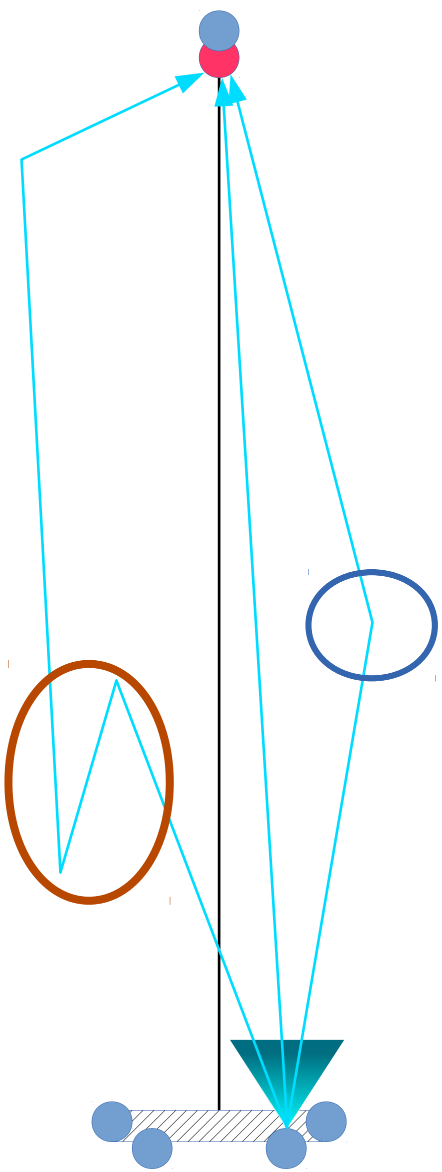
Floor number (N)	Propagation time with floor N-1
2	172 +/- 1.1
3	180 +/- 0.9
4	197 +/- 0.8

2.5 ns <=> 20 cm

Scattering process

$$b_P = 1.34\, \nu_S \left(\frac{550\, nn}{\lambda}\right)^{1.7} + 0.312\, \nu_l \left(\frac{550\, nm}{\lambda}\right)^{0.3}$$

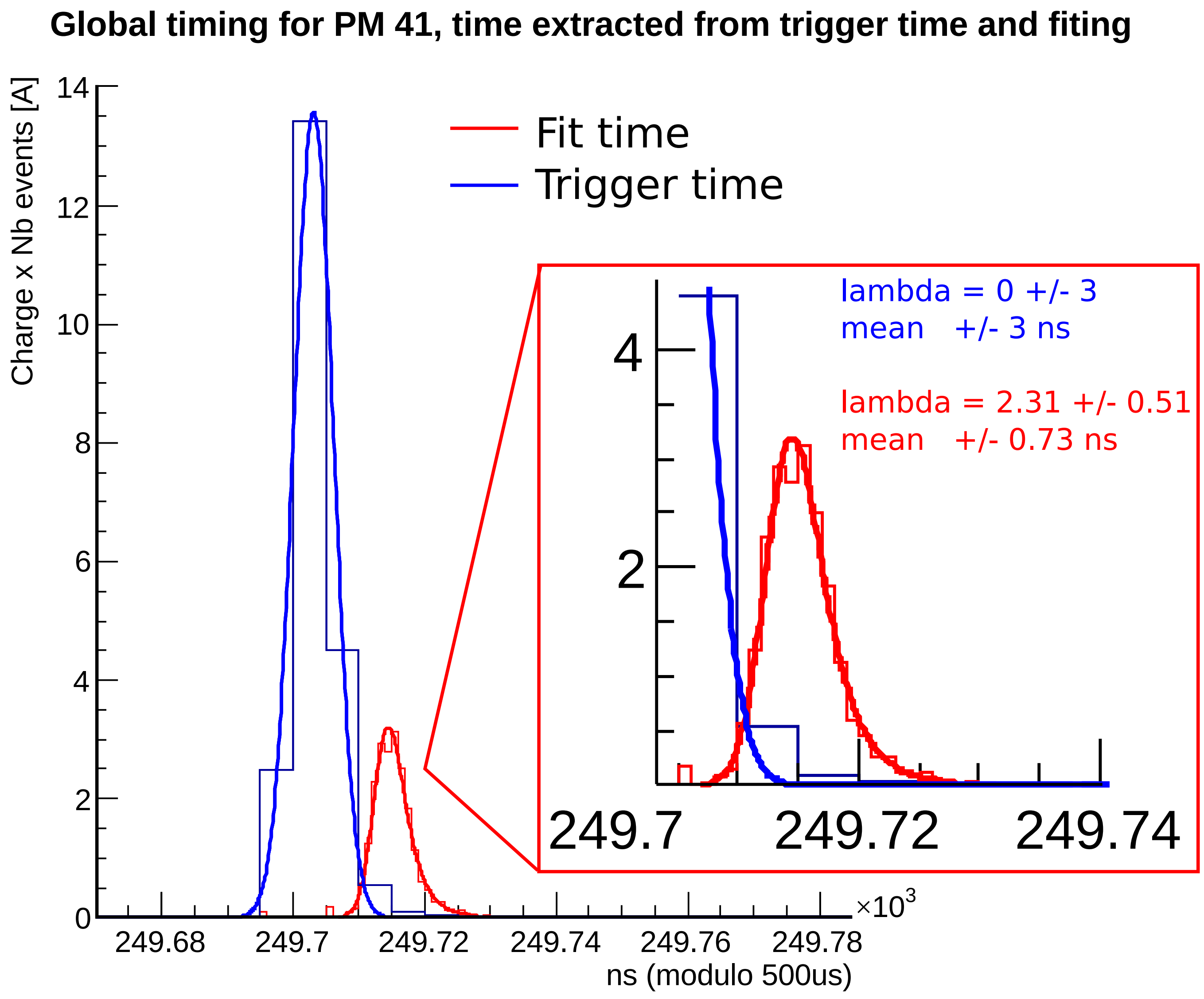
Clancy W. James
Km3 internal note



- 2 components to the scattering :
  - On molecule (isotropic angular distribution)
  - On particles (Forward going angular distribution)
- The both processes depend on the wavelength on a different exponent.
- They imply a delay in time arriving
  - In function of distance
  - In function of wavelength

Need to know the timing to deduce the water properties.
The fit method can help to extract the timing delay to the ns.

Example of fitting: Measure of the scattering

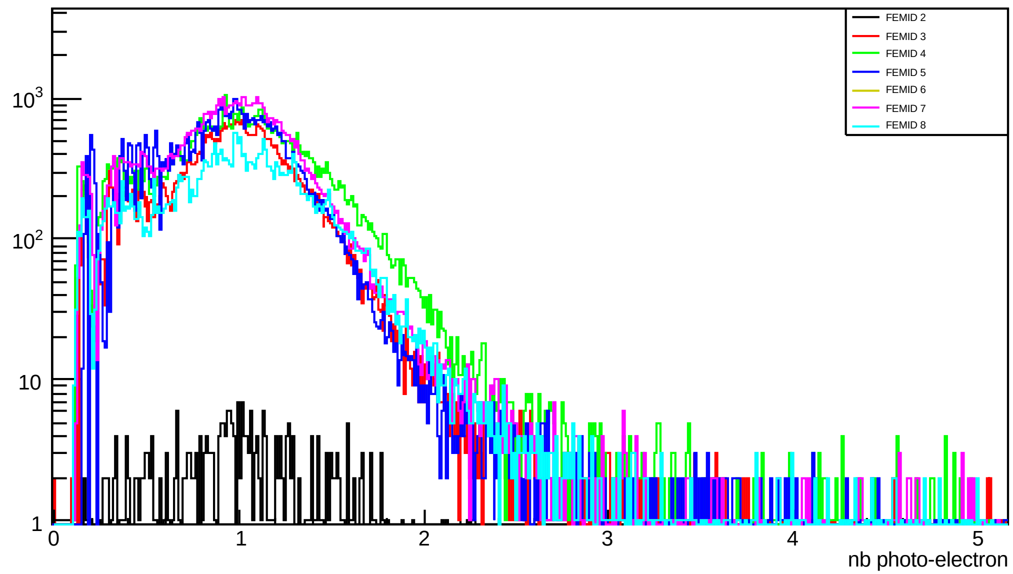


The function fit is a convolution between a Gaussian and an exponential.
Mean is the mean of the Gaussian
Lambda correspond to the “tail length”

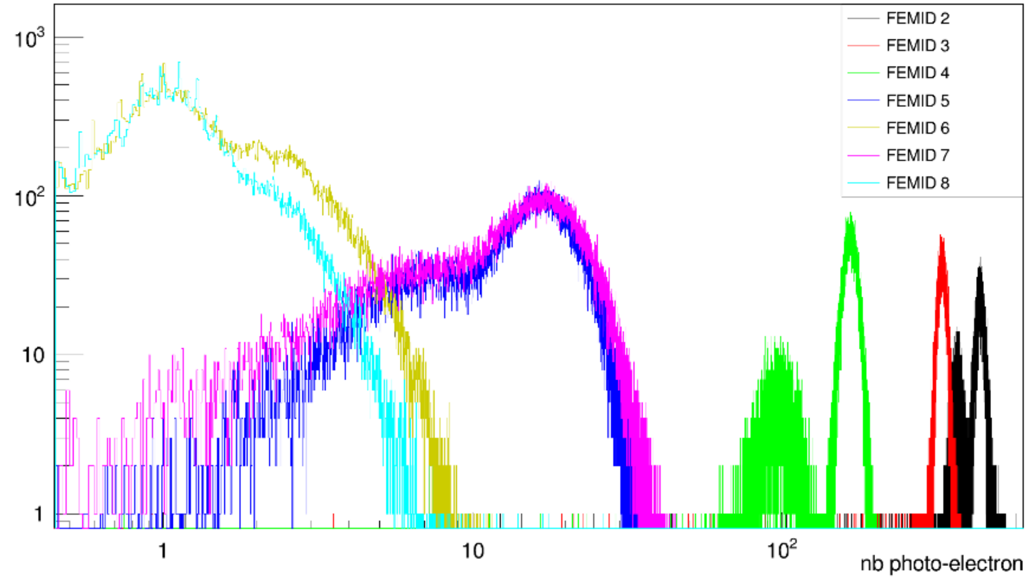
The fitting method allow to extract the scattering information

Secondary measurement : SPE measurement

Nb of photo-electron per floor (BG)

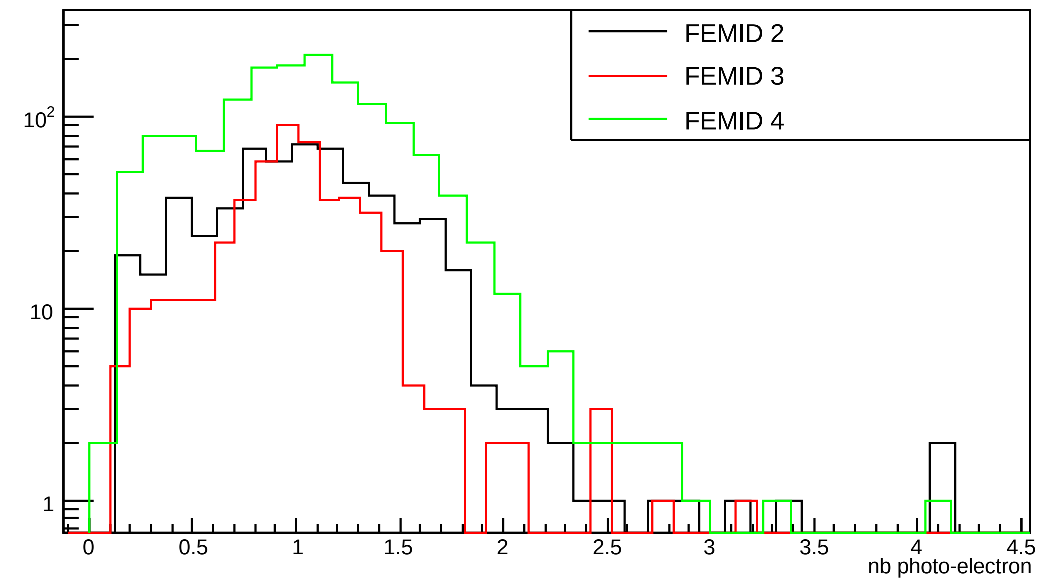


Nb of photo-electron per floor (LED)

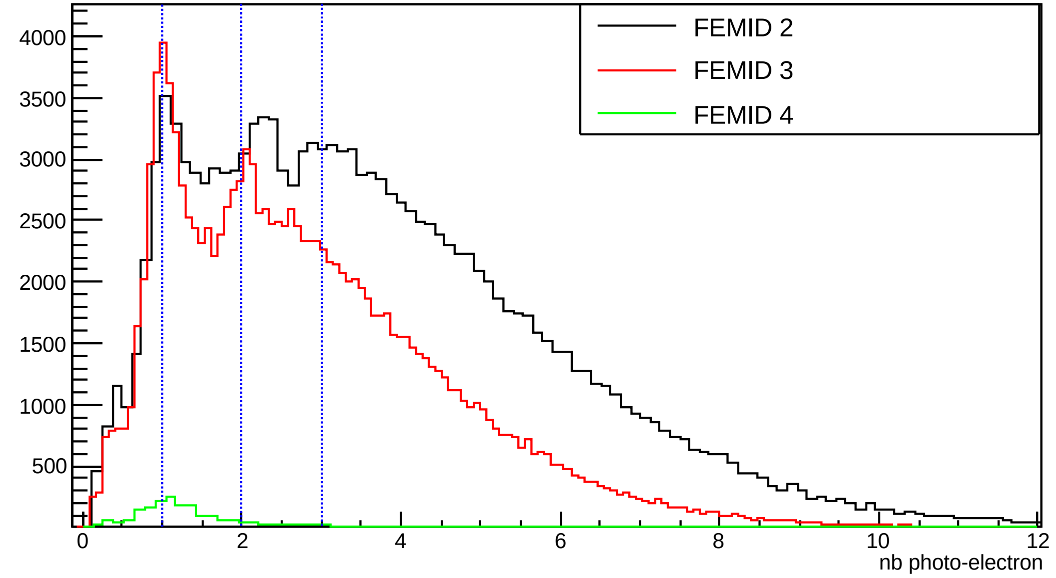


SPE measure low intensity

Nb of photo-electron per floor (BG)



Nb of photo-electron per floor (LED)



Analysis conclusion

- The LED can be used for time calibration, even at high light intensity (first floors)
- The fitting method:
  - Improved the resolution to the ns
  - I need the positioning to go further.
- The scattering can be studied, needs the simulation (see tomorrow slides)

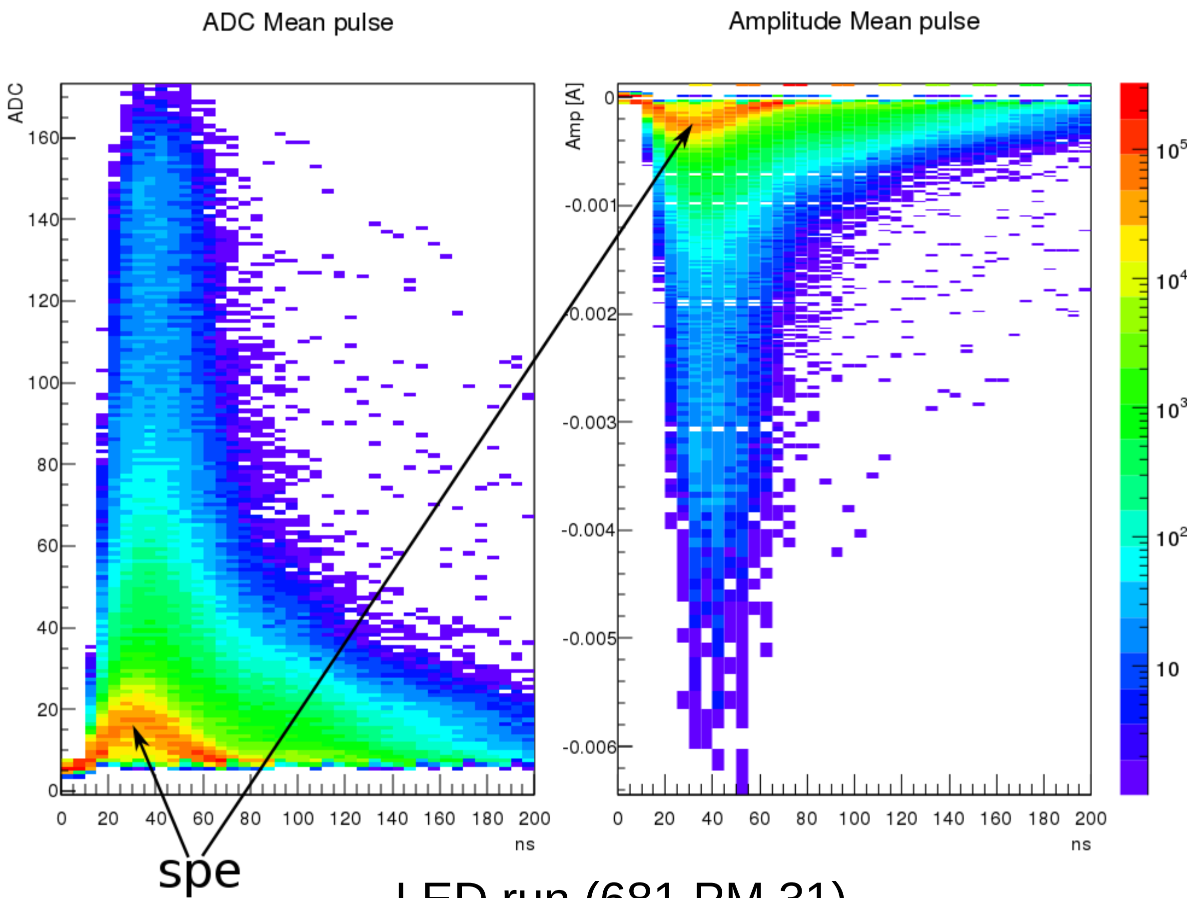
Checked up to 320 m distance

Data Analysis software

- Nreader NReader/documentation
- Started from Tommaso pt data reader
- Has a complete and modulable event model

Features :

- ✓ Read a PTFile and store it;
- ✓ Uncompress the channels. Conversion in a NEvent object model;
- ✓ serialize and save it in multiple formats;
- ✓ Give human readable xml output format;
- ✓ on the fly compression in gz or bz2 format;
- ✓ Very Extensible for the user.



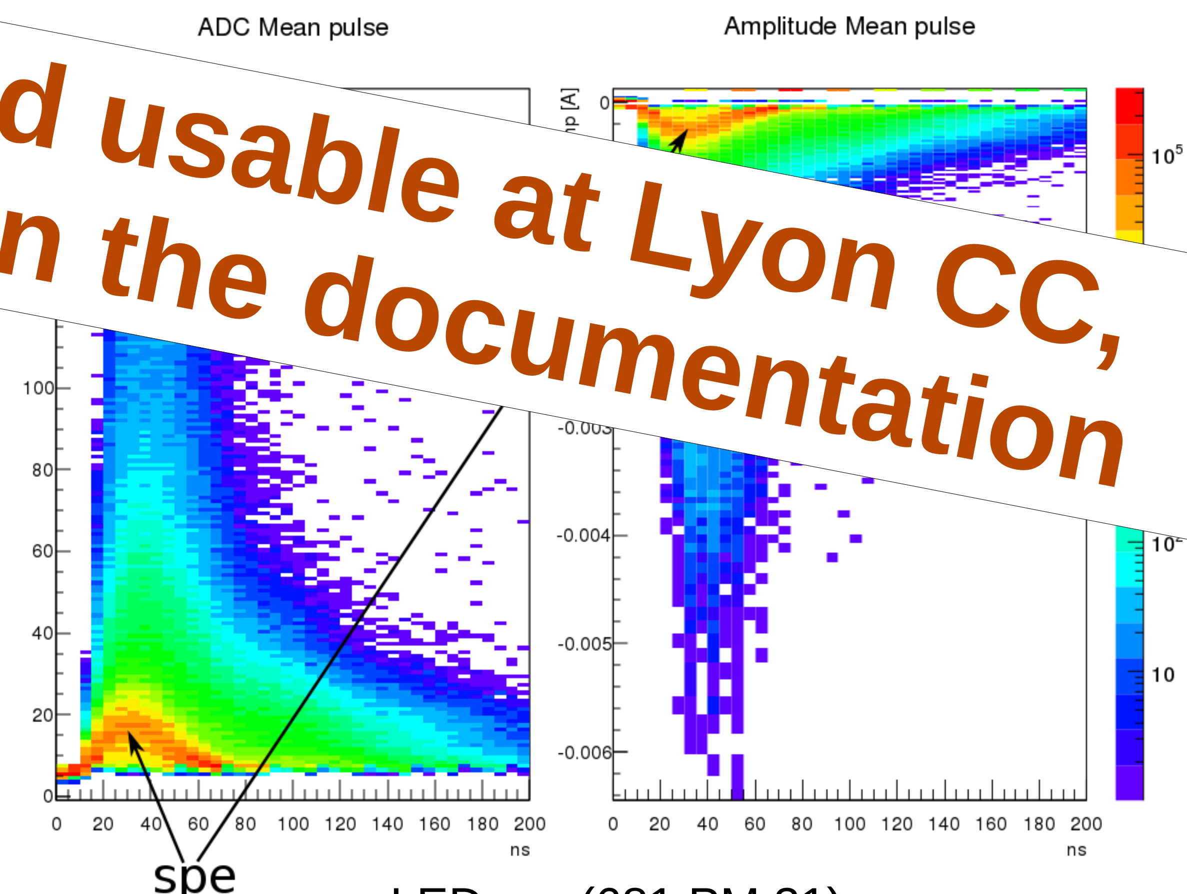
LED run (681 PM 31)

Data Analysis software

- Nreader NReader/documentation
- Started from Tommaso pt data reader
- ...e complete and modulable event model

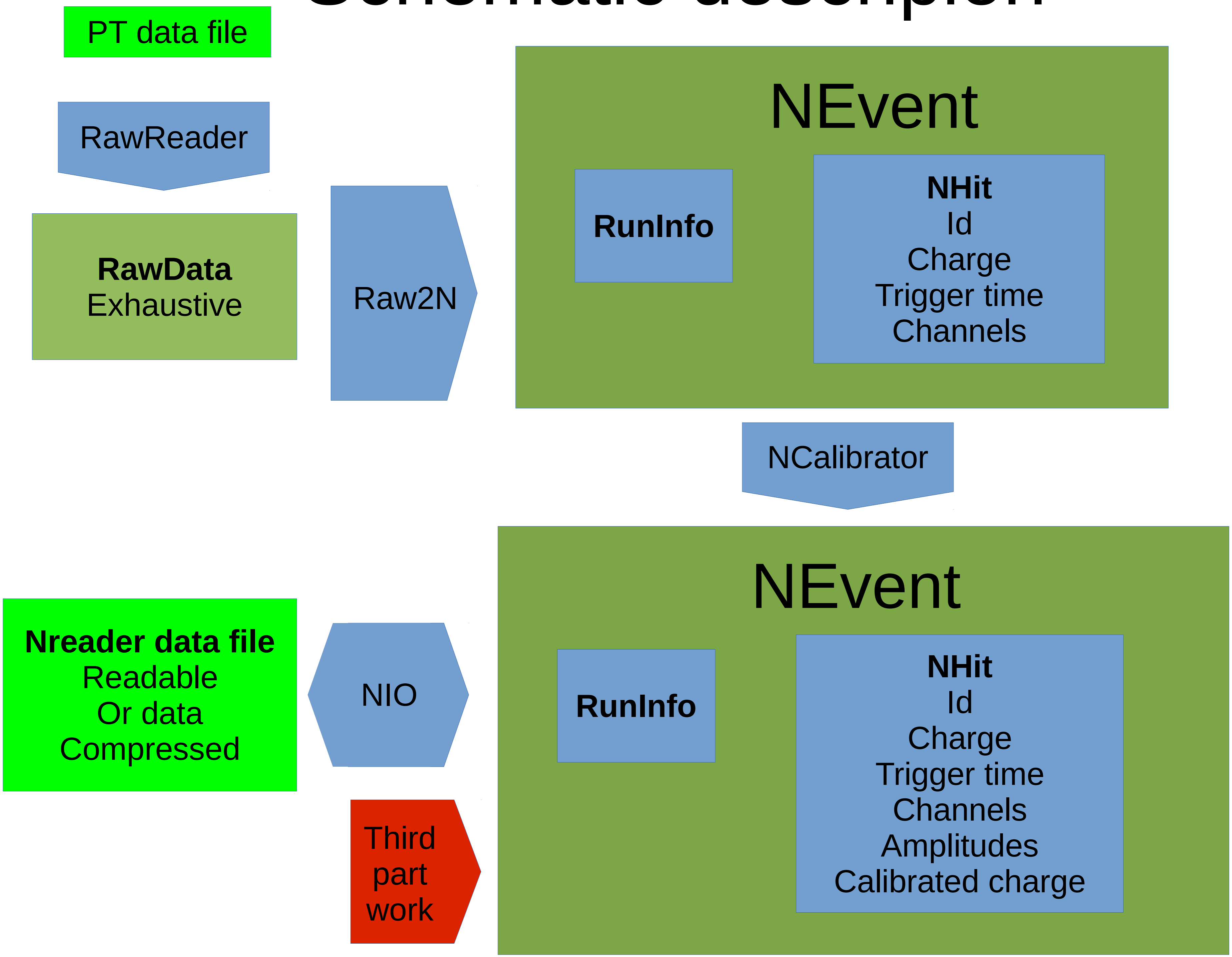
Testable and usable at Lyon CC, check out on the documentation

- ✓ Uncomp...
  Conversion in a NEve...
  model;
- ✓ serialize and save it in multiple formats;
- ✓ Give human readable xml output format;
- ✓ on the fly compression in gz or bz2 format;
- ✓ Very Extensible for the user.



LED run (681 PM 31)

Schematic descripion



Output data and extensibility : The properties and serialization

- Each Nreader data object inherit of Nserializable :
  - Use the boost serialization and filters to save/compress a part of the attributs
  - Has maps of int/double/string to contain extensible data
- Example (from the fitting result saving) :

  hit->SetDoubleProperty (“FitPar1”, Par [1]);

  [continue, save file, reopen]

  Par [1] = hit->GetDoubleProperty (“FitPar1”);

Project on the Analysis software

- Third person use/cross check/complement of the current analysis
- Complete it with finer elements
  - Ideal detector definition
  - Calibrated detector definition (compass/positioning data)
- Try to bind to the track reconstruction ?

Timing results with pulses at 5 ns of resolution

Floor number (N)	Fit mean time (gaus on mod 500us distribution)	Diff with floor 1 (floor N-1)	Offset with floor 1 (floor N-1)	Propagation time with floor 1 (floor N-1)	Theoretical time with floor 1 (floor N-1)	Differential time with floor 1 (floor N-1)
1	250,320 +/- 5	0	9	0	0	0
2	250,210 +/- 5	110 (110)	294 (285)	175 (175)	186 (186)	11 (11)
3	250,000 +/- 5	210 (110)	574 (280)	355 (180)	371 (185)	16 (5)
4	249,895 +/- 5	315 (105)	875 (301)	551 (196)	558 (187)	7 (-9)
5	249,802 +/- 3	408 (92)	1157 (282)	741 (190)	744 (186)	3 (-4)
6	249,714 +/- 3	496 (88)	1434 (277)	930 (189)	931 (187)	1 (-2)
7	249,627 +/- 1	583 (87)	1714 (280)	1123 (193)	1118 (187)	-5 (-6)
8	249,493 +/- 1	717 (134)	2034 (320)	1309 (186)	1305 (187)	-4 (1)

As a first approximation the used index for propagation time was taken from the measurement of the group velocity of light in sea water at the ANTARES site (1.38).

As a cross check a lower intensity run was used for first floors. It correspond to

Floor number (N)	Propagation time with floor 1 (floor N-1)
1	170 +/- 5
2	182 +/- 5
3	197 +/- 5

2.5 ns <=> 20 cm

Timing results with pulses at 5 ns of resolution

Floor number (N)	Fit mean time (gaus on mod 500us distribution)	Diff with floor 1 (floor N-1)	Offset with floor 1 (floor N-1)	Propagation time with floor 1 (floor N-1)	Theoretical time with floor 1 (floor N-1)	Differential time with floor 1 (floor N-1)
1	250,320 +/- 5	0	9	0	0	0
2	250,210 +/- 5	110 (110)	294 (285)	175 (175)	186 (186)	11 (11)
3	250,000 +/- 5	210 (110)	574 (280)	355 (180)	371 (185)	16 (5)
4	249,895 +/- 5	315 (105)	875 (301)	551 (196)	558 (187)	7 (-9)
5	249,802 +/- 3	408 (92)	1157 (282)	741 (190)	744 (186)	3 (-4)
6	249,714 +/- 3	496 (88)	1434 (277)	930 (189)	931 (187)	1 (-2)
7	249,627 +/- 1	583 (87)	1714 (280)	1123 (193)	1118 (187)	-5 (-6)
8	249,493 +/- 1	717 (134)	2034 (320)	1309 (186)	1305 (187)	-4 (1)

As a first approximation the used index for propagation time was taken from the measurement of the group velocity of light in sea water at the ANTARES site (1.38).

As a cross check a lower intensity run was used for first floors. It correspond to

Floor number (N)	Propagation time with floor 1 (floor N-1)
1	170
2	182
3	197

2.5 ns <=> 20 cm

Timing results with pulses at 5 ns of resolution

Floor number (N)	Fit mean time (gaus on mod 500us distribution)	Diff with floor 1 (floor N-1)	Offset with floor 1 (floor N-1)	Propagation time with floor 1 (floor N-1)	Theoretical time with floor 1 (floor N-1)	Differential time with floor 1 (floor N-1)
1	250,123 +/- 0.5	0	9	0	0	0
2	250,010 +/- 0.9	111 (111)	294 (285)	174 (174)	186 (186)	12 (12)
3	250,910 +/- 0.5	211 (100)	574 (280)	354 (179)	371 (185)	17 (5)
4	249,805 +/- 0.4	316 (105)	875 (301)	550 (195)	558 (187)	8 (-9)
5	249,713 +/- 0.3	408 (92)	1157 (282)	740 (189)	744 (186)	4 (-4)
6	249,625+/- 0.5	496 (88)	1434 (277)	929 (188)	931 (187)	2 (-2)
7	249,528 +/- 0.72	593 (97)	1714 (280)	1113 (182)	1118 (187)	5 (-6)
8	249,398 +/- 0.75	723 (130)	2034 (320)	1302 (175)	1305 (187)	6 (1)

The fitting confirm the last results. It brought a better error to the measure.

As a cross check a lower intensity run was used for first floors. It correspond to

Floor number (N)	Propagation time with floor 1 (floor N-1)
1	170 +/- 5
2	182 +/- 5
3	197 +/- 5

2.5 ns <=> 20 cm

Timing results with pulses at 5 ns of resolution

Floor number (N)	Measured propagation time with floor 1 (floor N-1)	Theoretical time with floor 1 (floor N-1)	Differential time with floor 1 (floor N-1)
1	0 +/- 5	0	0
2	175 (175) +/- 5	186 (186)	11 (11)
3	355 (180) +/- 5	371 (185)	16 (5)
4	551 (196) +/- 5	558 (187)	7 (-9)
5	741 (190) +/- 3	744 (186)	3 (-4)
6	930 (189) +/- 3	931 (187)	1 (-2)
7	1123 (193) +/- 1	1118 (187)	-5 (-6)
8	1309 (186) +/- 1	1305 (187)	-4 (1)

As a first approximation the used index for propagation time was taken from the measurement of the group velocity of light in sea water at the ANTARES site (1.38).

As a cross check a lower intensity run was used for first floors. It correspond to

Floor number (N)	Propagation time with floor N-1
2	170 +/- 5
3	182 +/- 5
4	197 +/- 5

2.5 ns <=> 20 cm

Timing results with pulses at 5 ns of resolution

Floor number (N)	Measured propagation time with floor 1 (floor N-1)	Theoretical time with floor 1 (floor N-1)	Differential time with floor 1 (floor N-1)
1	0 +/- 5	0	0
2	175 (175) +/- 5	186 (186)	11 (11)
3	355 (180) +/- 5	371 (185)	16 (5)
4	551 (196) +/- 5	558 (187)	7 (-9)
5	741 (190) +/- 3	744 (186)	3 (-4)
6	930 (189) +/- 3	931 (187)	1 (-2)
7	1123 (193) +/- 1	1118 (187)	-5 (-6)
8	1309 (186) +/- 1	1305 (187)	-4 (1)

As a first approximation the used index for propagation time was taken from the measurement of the group velocity of light in sea water at the ANTARES site (1.38).

As a cross check a lower intensity run was used for first floors. It correspond to

Floor number (N)	Propagation time with floor N-1
2	170 +/- 5
3	182 +/- 5
4	197 +/- 5

2.5 ns <=> 20 cm

Raw timing conclusion

- The LED can be used for time calibration, even at high light intensity (first floors)
- Need a method to improve the error in the timing (especially for the < 5 ns FWHM of time distribution)