Status of KLOE-2

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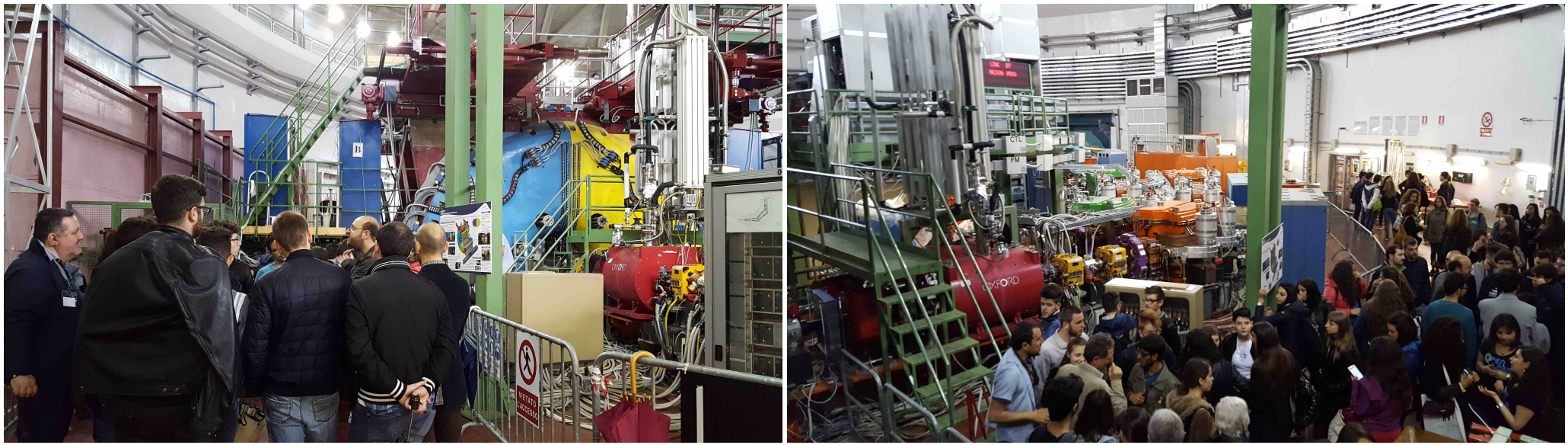
on behalf of the KLOE-2 collaboration



LNF Scientific Committee meeting
Frascati, 23 May 2016

Publications

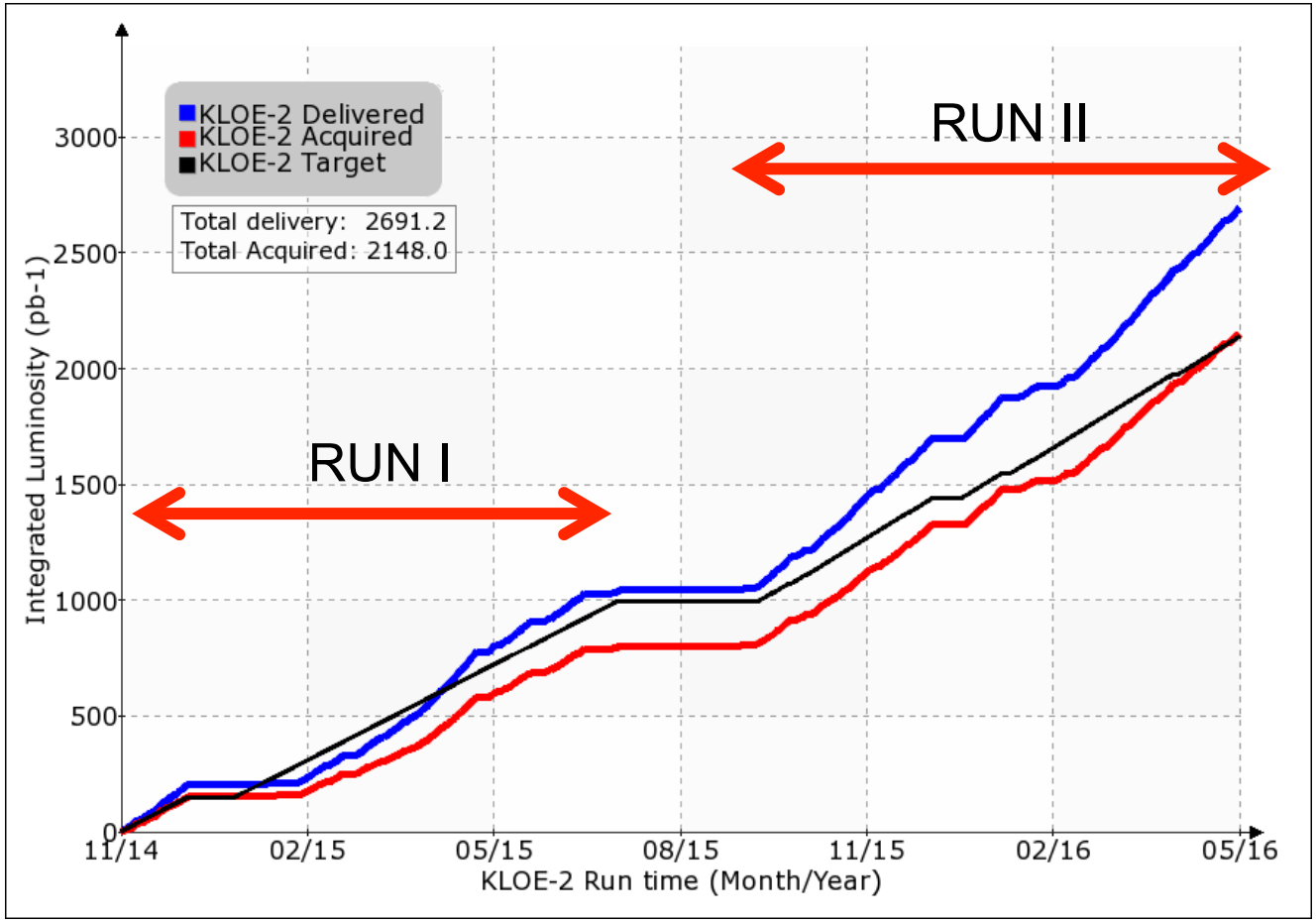
U boson search in $e^+e^- \to U\gamma$, $U \to e^+e^-$	PLB 750 (2015) 633
Search for dark higgsstrahlung process	PLB 747 (2015) 365
BR and Transition Form Factor of $\phi \to \eta e^+e^-$	PLB 742 (2015) 1
BR and Transition Form Factor of $\phi \to \pi^0 e^+e^-$	**PLB 757 (2016) 362** ←
Dalitz plot analysis of $\eta \to \pi^+\pi^-\pi^0$	**JHEP 1605 (2016) 019** ←
Hadron Vacuum Polarization in $e^+e^- \to \mu^+\mu^-\gamma$	Draft paper
U boson search in $e^+e^- \to U\gamma$, $U \to \pi^+\pi^-$	**PLB 757 (2016) 356** ←
CPT test with $\phi \to K_S K_L \to 3\pi^0\, \pi l\nu, \pi\pi\, \pi l\nu$	In progress
BR and charge asymmetry in $K_S \to \pi e\nu$	In progress

- «KLOE-2 operation» paper under preparation

PhD Theses

Discrete symmetries tests with kaons at KLOE-2	A. Selce Università Rome Tre, Italy
Measurement of the $K_S \to \pi^+\pi^-\pi^0$ branching fraction	A. Di Cicco Università Rome Tre, Italy
Light quark masses from Dalitz plot study of $\eta \to 3\pi$ decay (defended Jan.2016)	Li Caldeira-Balkestahl Uppsala University, Sweden
Study of ω decays	Lena Heijkensjold Uppsala University, Sweden
Study of transition form factors and decays of light mesons at KLOE	Bo Cao Uppsala University, Sweden
Lepton charge asymmetry measurement for K_S with the KLOE detector	D.Kaminska Jagiellonian University, Krakow, Poland
A direct test of T symmetry in the neutral K meson system at KLOE-2	A. Gajos Jagiellonian University, Krakow, Poland

Run II: integrated Luminosity



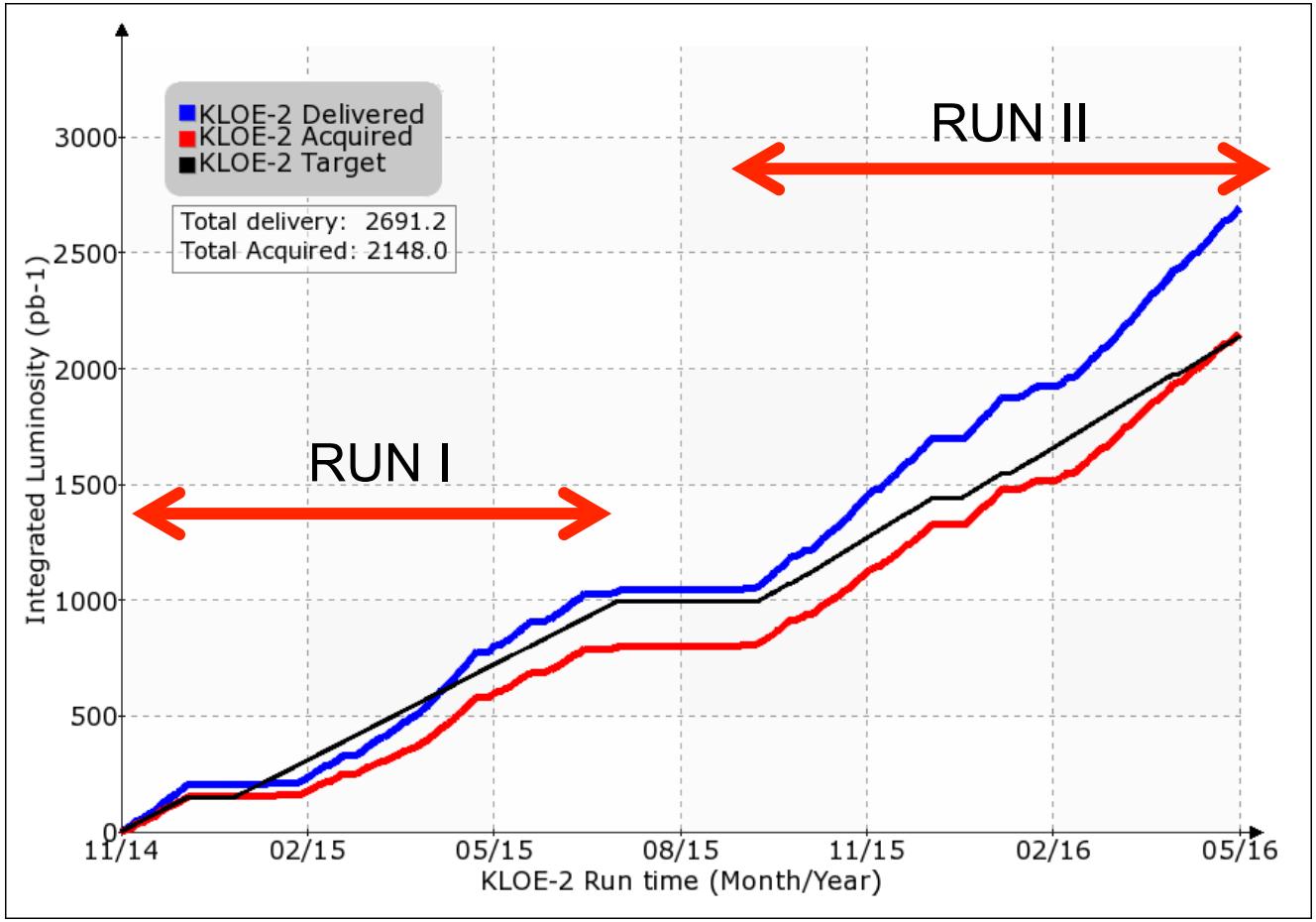
RUN-II started on
28 September 2015

Intermediate luminosity milestone:
L delivered = 2.5 fb^{-1}
by 15 July 2016

This milestone has been set as the minimal requirement to achieve in a "reasonable" amount of time the goal of the experiment, i.e. to acquire <u>at least</u> 5 fb^{-1}.

Best DAΦNE performance:
Peak luminosity: ~2.2 x 10^{32}
maximum daily integrated luminosity (delivered): ~13 pb^{-1}

Run II: integrated Luminosity



RUN-II started on
28 September 2015

Intermediate luminosity milestone:
L delivered = 2.5 fb^{-1}
by 15 July 2016

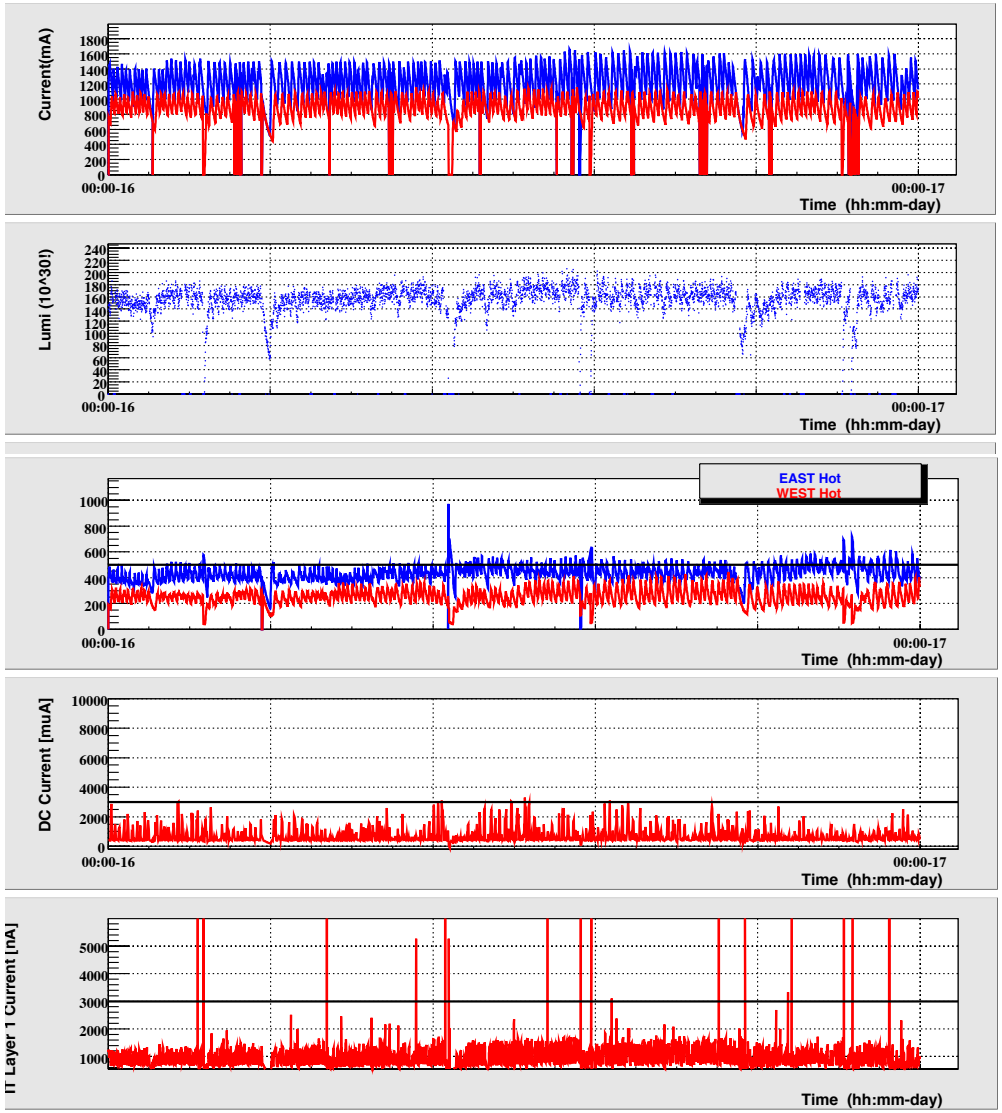
FULFILLED

~2 months in advance

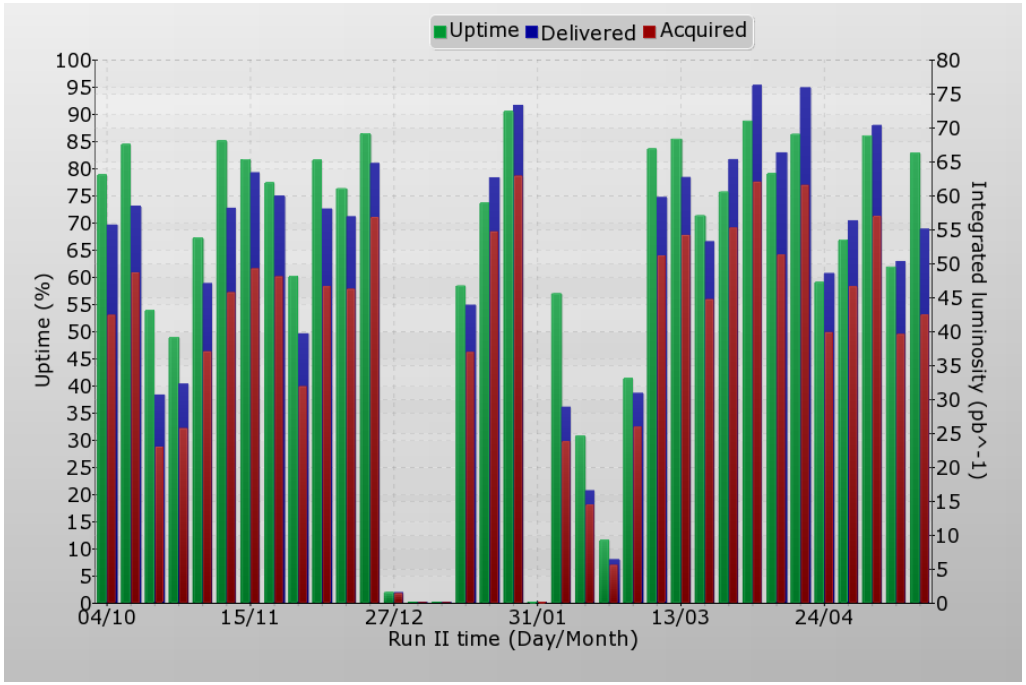
This milestone has been set as the minimal requirement to achieve in a "reasonable" amount of time the goal of the experiment, i.e. to acquire at least 5 fb^{-1}.

Best DAΦNE performance:
Peak luminosity: ~2.2 x 10^{32}
maximum daily integrated luminosity (delivered): ~13 pb^{-1}

Run II: best performance



Best day:
integrated luminosity (delivered): ~13.3 pb^{-1}
integrated luminosity (acquired): ~11.0 pb^{-1}



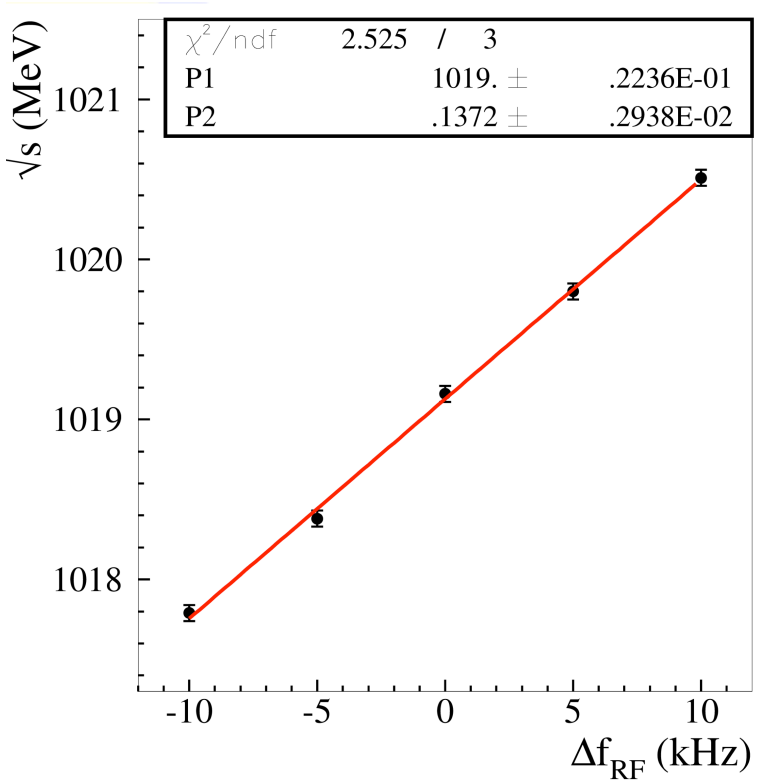
weekly performance

Status of KLOE-2 operation and detector

Energy scan

DAFNE performed an energy scan shifting the central RF frequency:

$$\frac{\Delta p}{p} = -\frac{1}{\alpha_c}\frac{\Delta \nu_{RF}}{\nu_{RF}}$$



$$\mathcal{C}_{RF} = 0.137 \pm 0.003 \frac{\mathrm{MeV}}{\mathrm{kHz}}$$

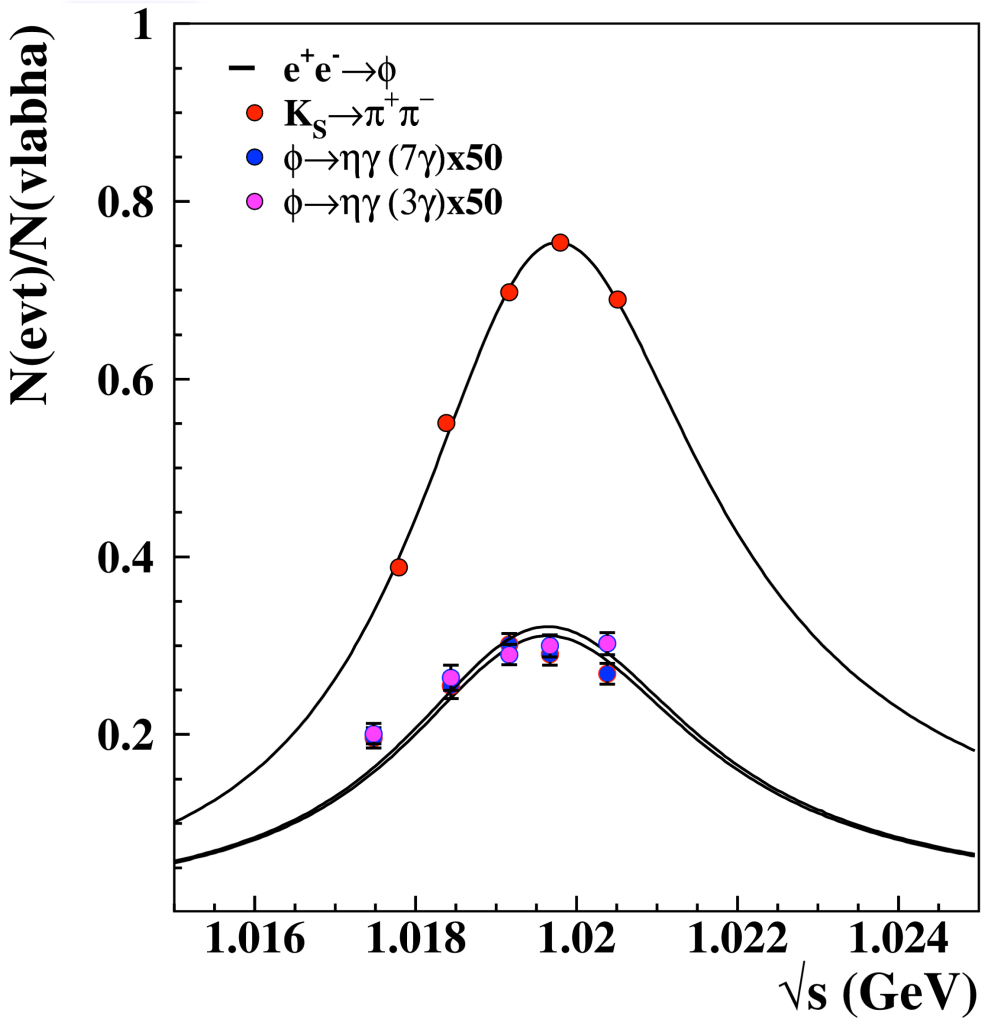
Energy scan

- $\phi \rightarrow$ KSKL with KS$\rightarrow \pi^+\pi^-$, $\pi^0\pi^0$
- $\phi \rightarrow \eta\gamma$ with $\eta \rightarrow \gamma\gamma$ and $\eta \rightarrow 3\pi 0$

Event counts normalized with very large angle Bhabha scattering events used to measure the luminosity.
Fit includes all the energy dependence in the line shape, radiative correction and beam energy spread (300 keV).
Free parameters: absolute normalization for each decay channel and the ϕ mass.

Conclusions:
KLOE absolute $\sqrt{s}$ fine calibration:
-240 keV

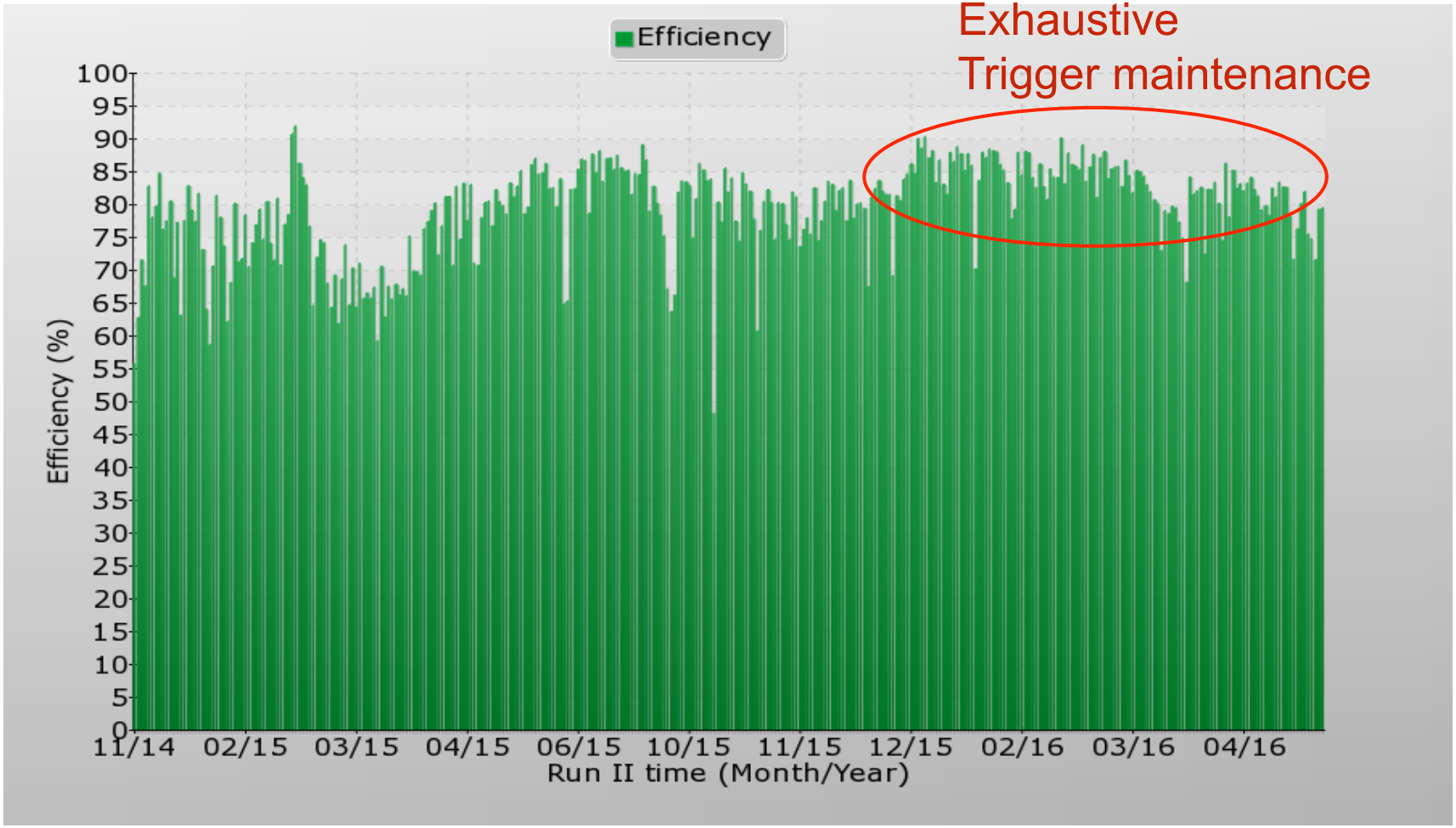
DAFNE: $\sqrt{s}$ has been shifted by
+550 keV to run exactly on ϕ peak



DAQ efficiency optimization

Continuous improvement of data-taking efficiency

In Run-II 82% on average (77% in Run I)

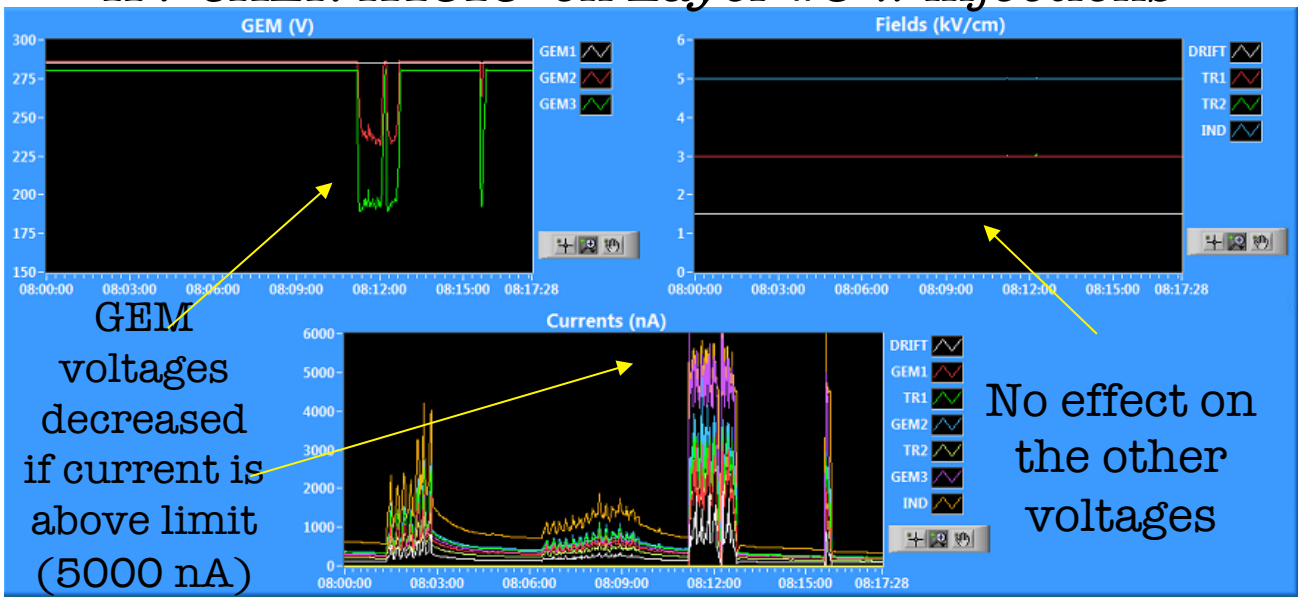


Safe operation of the inner tracker

Since Oct.2015 two main actions to avoid “shorts” occurrence on inner tracker:
1) Optimization of the beam injections by the DAFNE team with online feedback information (DC and IT currents)
2) NEW HV DISTRIBUTION SCHEME OF IT:
(a) passive divider with single current generator channel (installed)
(b) individual floating channels system allows safe operation and single voltages adjustment (CAEN boards arrived and are going to be installed this week)

- A board borrowed from CAEN is successfully under test since November 2015 on layer#3

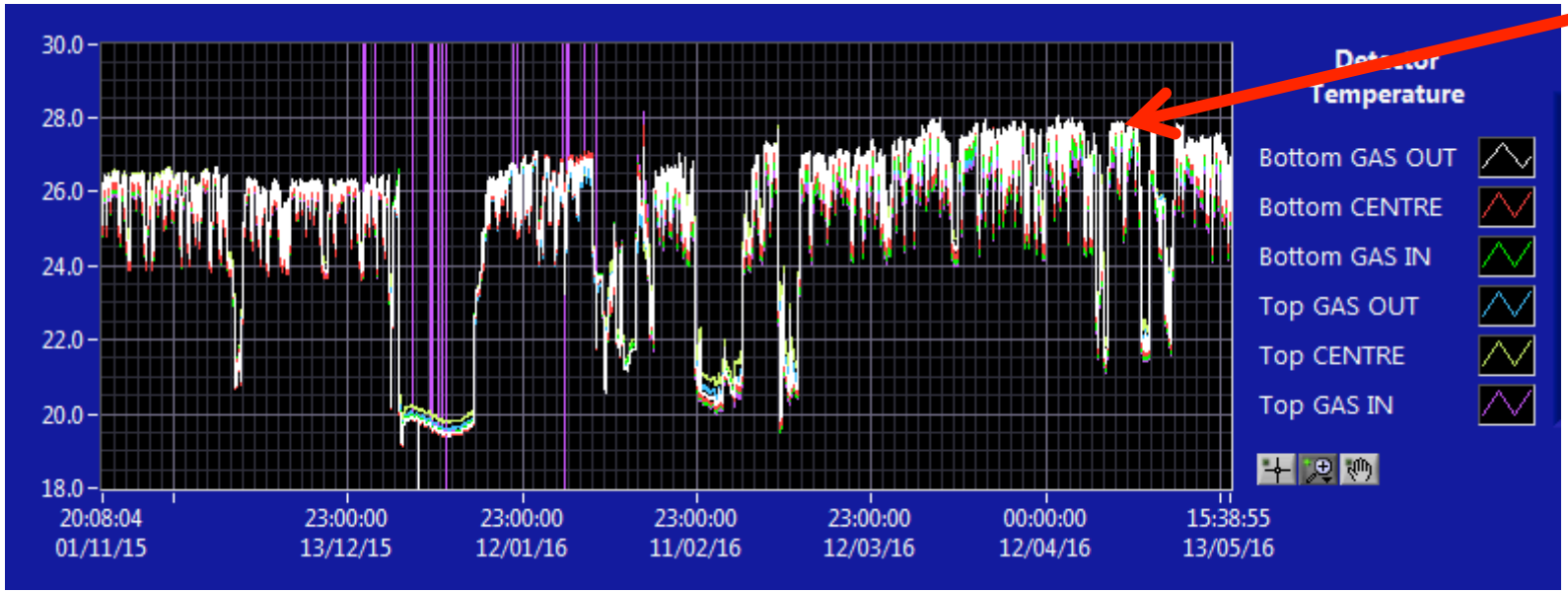
HV CAEN A1515 on Layer #3 w injections



Safe operation of the inner tracker

- The operating temperature of the inner tracker constantly increased along the run due to the improved DAFNE machine performance.
- The limit for the safe operation on the inner tracker has been almost reached.
- A (minor) modification of the water cooling scheme of the interaction region with the insertion of a dedicated chiller in the circuit is necessary.
- Installation during the maintenance week (this week) by the DAFNE crew.

28°C



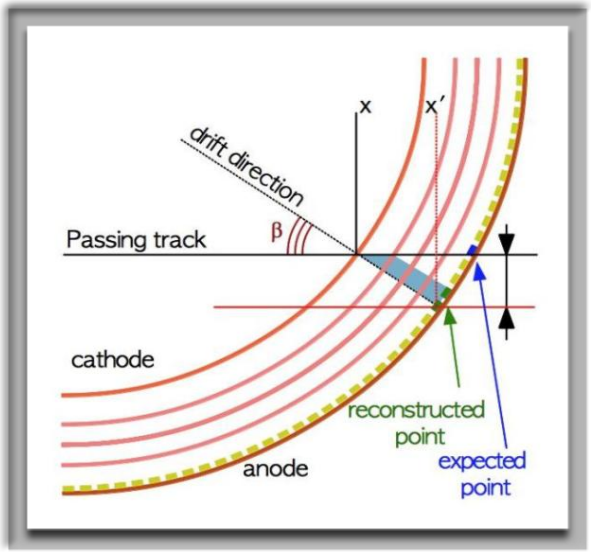
IT Calibration (I)

1. NON-RADIAL TRACKS

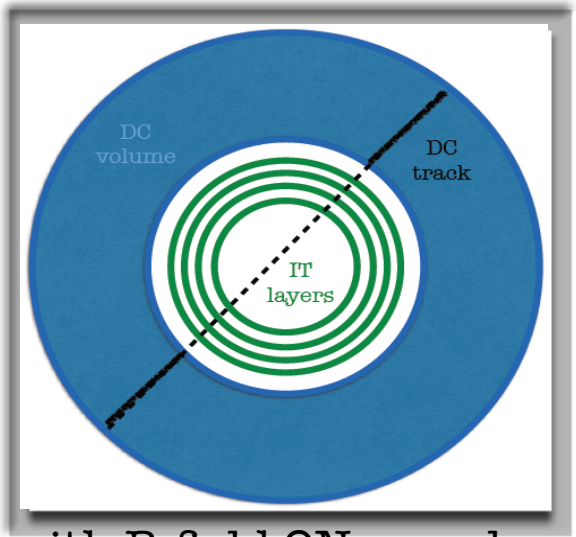
The angle formed by a track and the radial E-field direction introduces: **shift & spread**

2. MAGNETIC FIELD

0.52 T B-field orthogonal to Triple-GEMs E-fields: **shift** $\Delta x(\alpha_L)$ and **larger spread of the electron cloud**



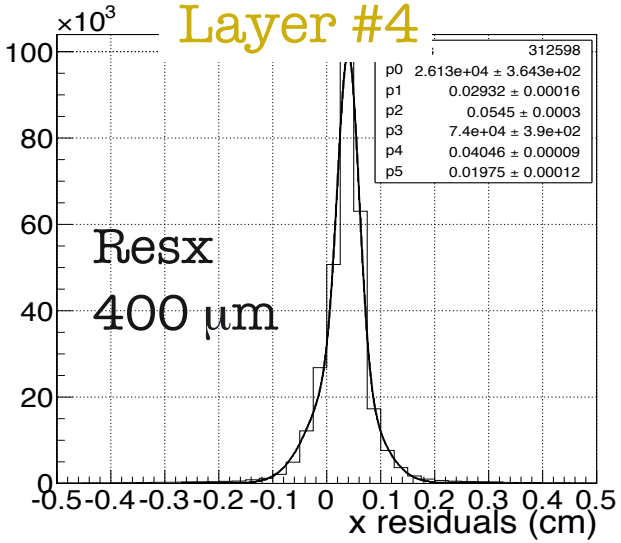
- Cosmic-ray muon data acquired with B-field OFF
  - Calibration of Non-radial track effect
  - Select DC tracks crossing IT at 2 points
  - Corrections as a function of track parameters
  - Shifts and rotations to align the IT

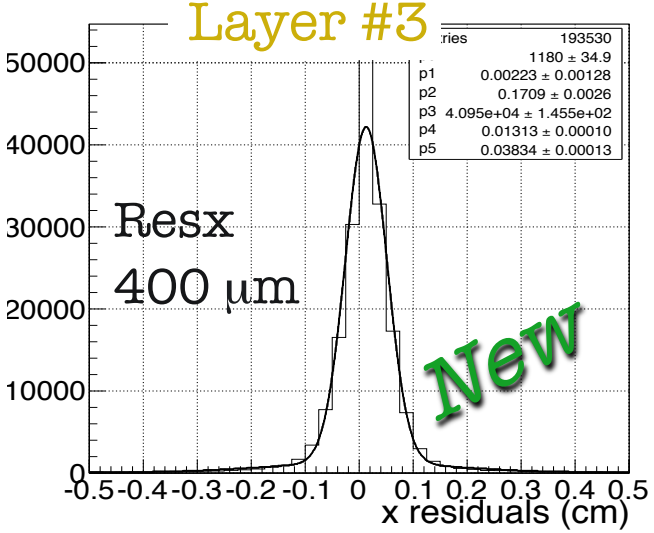


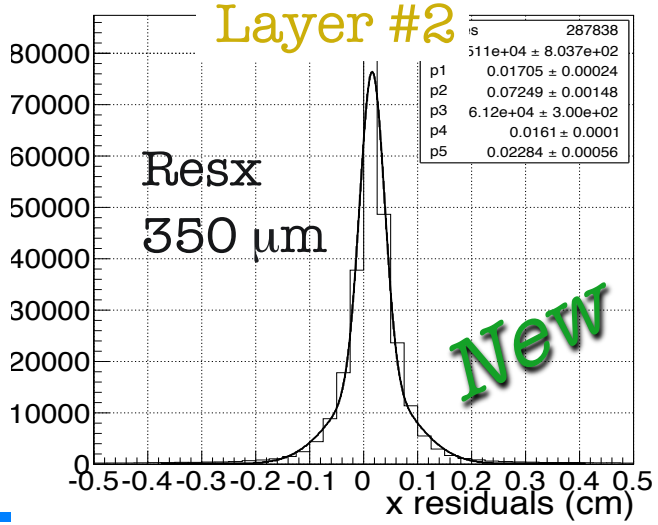
- Cosmic-ray muon data acquired with B-field ON
  - Calibration of Non-radial track & B-field effects
  - Corrections, Shifts and rotations from B-field OFF sample
  - Study and apply B-field effects corrections
- Bhabha scattering events
  - Calibration of Non-radial track & B-field effects
  - Corrections , Shifts and rotations from cosmic-ray muons with B-field ON sample
  - Benchmarking IT+DC integrated reconstruction all corrections inserted

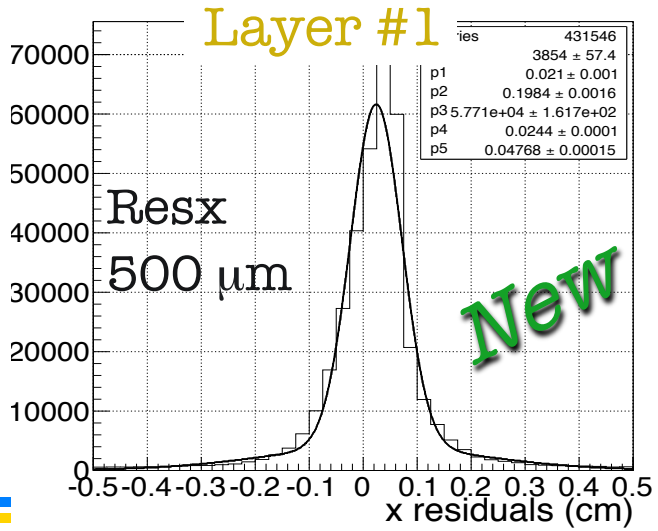
IT Calibration (II)

- Preliminary results for all layers using Bhabha scattering events



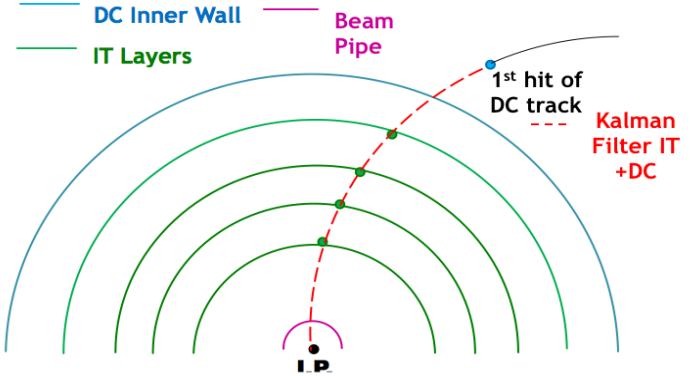




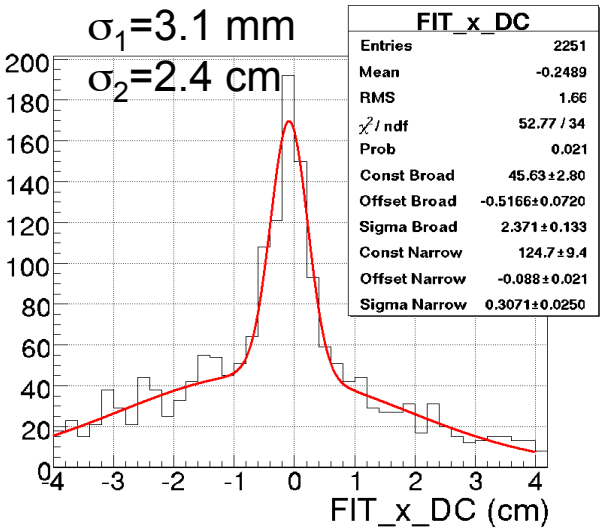


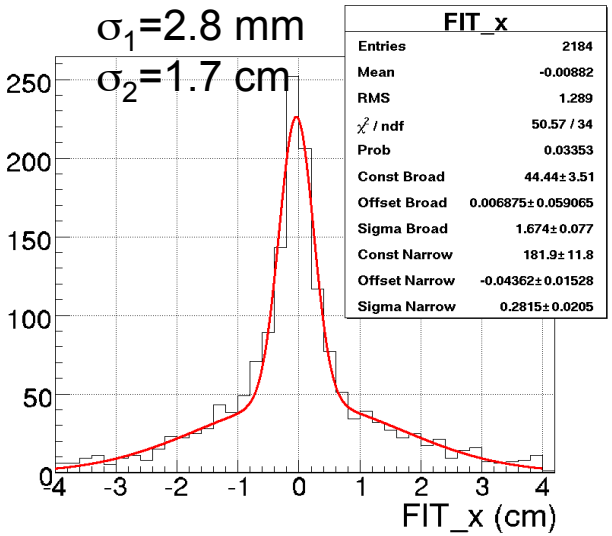
Integrated IT+DC tracking

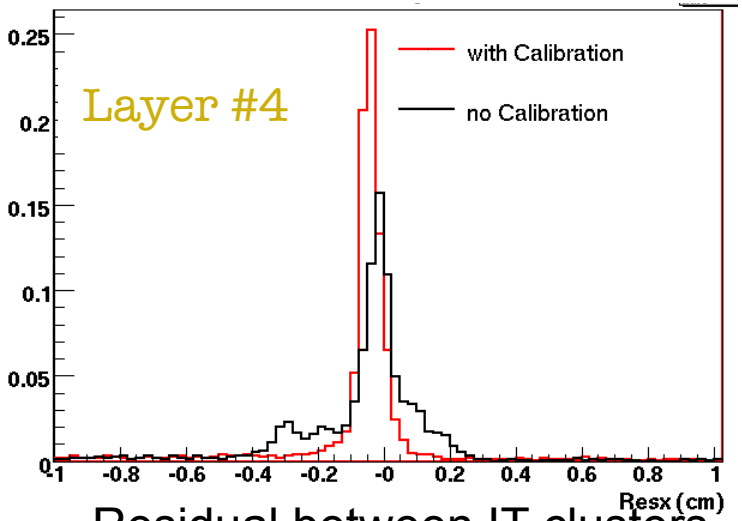
- Starting with DC tracks
- IT Clusters reconstructed are added
- IT+DC Kalman filter
- Updating track parameters
- Bhabha scattering events used as benchmark



- Using the first IT calibration, first comparison between IT+DC and DC vertex







- Residual between IT clusters and expected position from Kalman w/wo Calibration

HET calibration

Dedicated runs to study HET total rate

- Bunch structure

HET stations are completely noiseless

Dafne bunch structure reproduced

HET-KLOE synchronization proved

- Luminosity and Touschek particles contribute to counting rates

Rate timeline on HET-e- /HET-e+ follows:

KLOE_TrigRate x (Luminosity+ $a_e I_e^2$)

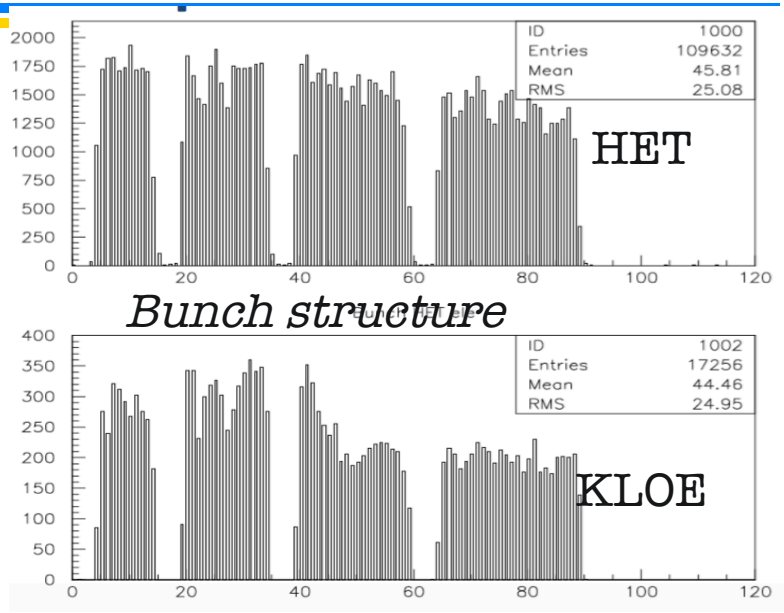
Machine background

maximal relative contribution:

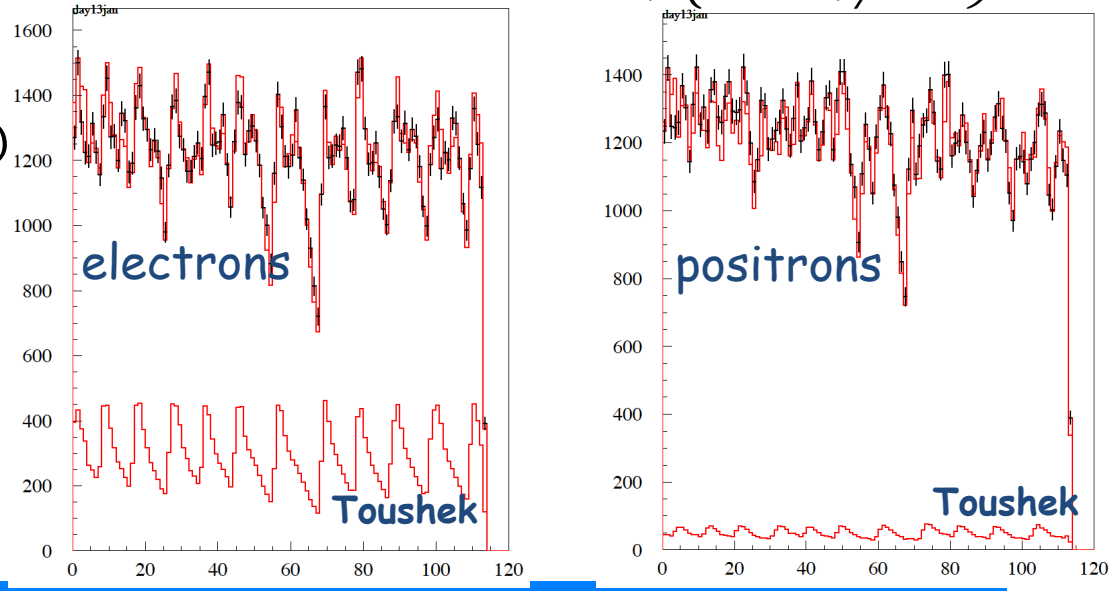
30% e- and 6% e+ beams

- No collision runs

Positron AND electron rate timelines match the I^2 dependence

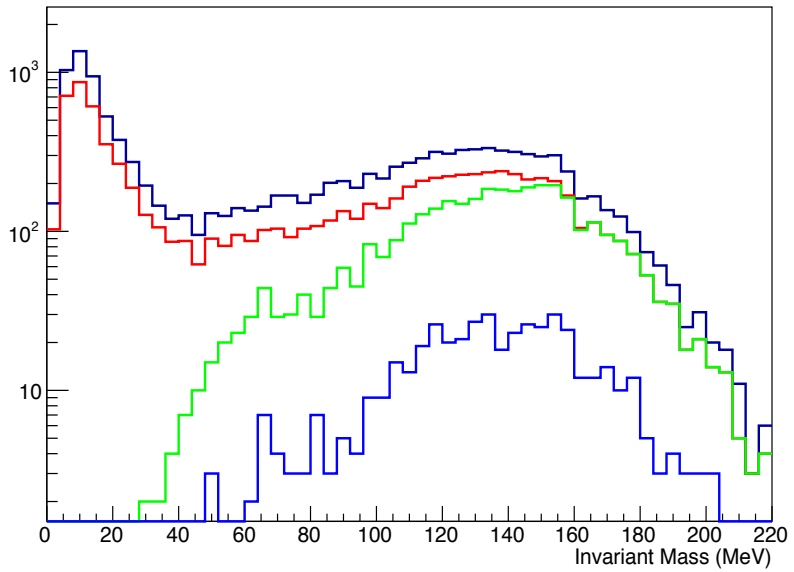


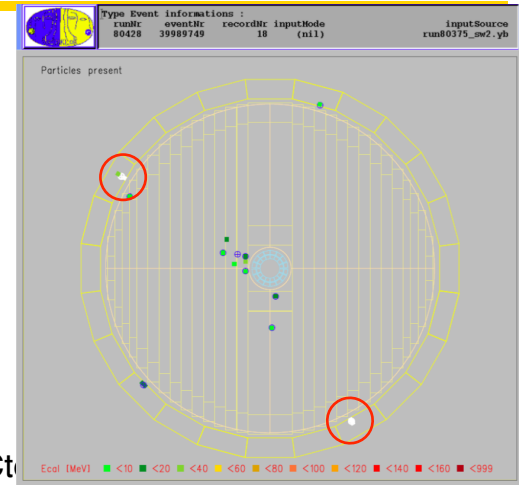
HET Timeline rates (counts/min)



Search for $e^+e^- \rightarrow e^+e^-\pi^0$ with HET double-arm tagging

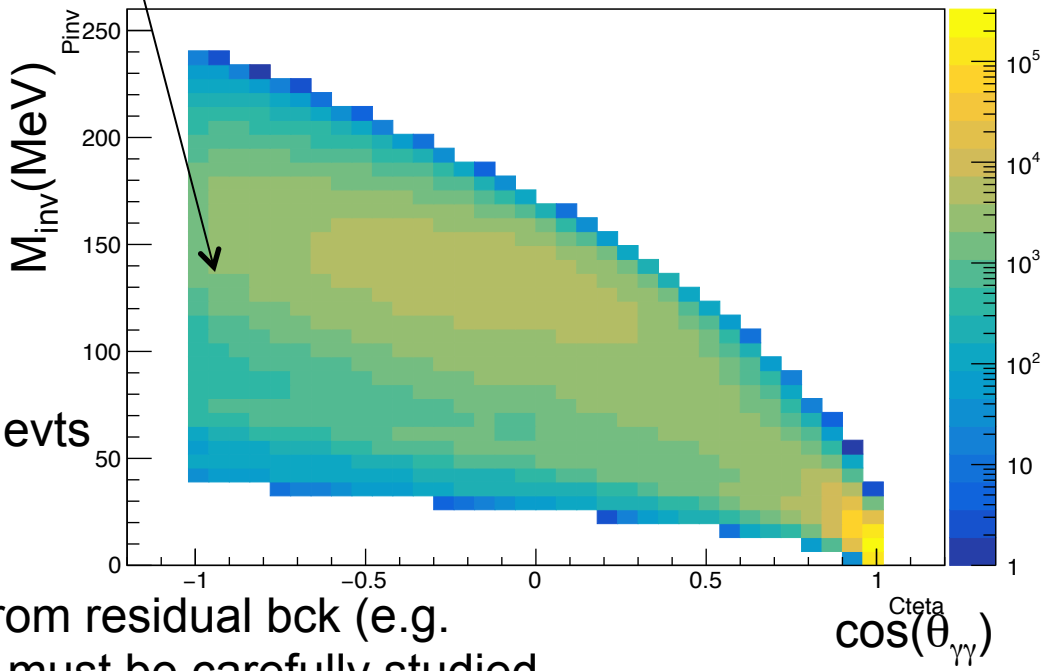
A sample of 325 pb^{-1} is being studied
HET TDCs compatible with KLOE trigger time
(a large contribution from ϕ events in coincidence with the HET due to accidentals can be rejected, e.g. charged kaons)





signal region
$\cos(\theta_{\gamma\gamma}) \sim -1$

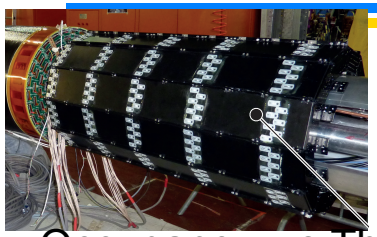
Pinv:Ct



Cuts Used :
$|\Delta T_{HET}|$=+/-1 T_{bunch}+ 2 Clusters in KLOE: 12905 evts
No Tracks : 8733 events
$\cos(\theta_{12}) < 0$: 3481
$\Delta(T_1-T_2) < 150$ ps : 693

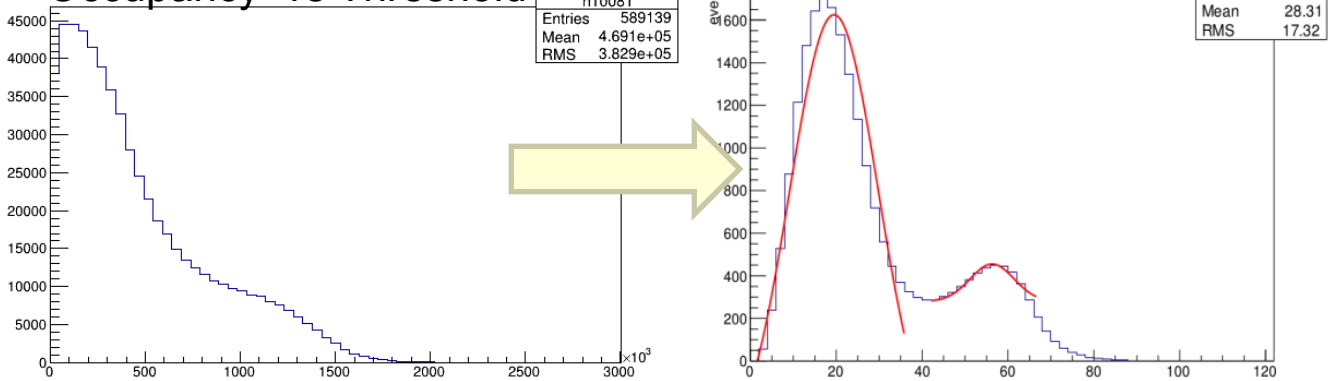
contributions from residual bck (e.g. neutral kaons) must be carefully studied

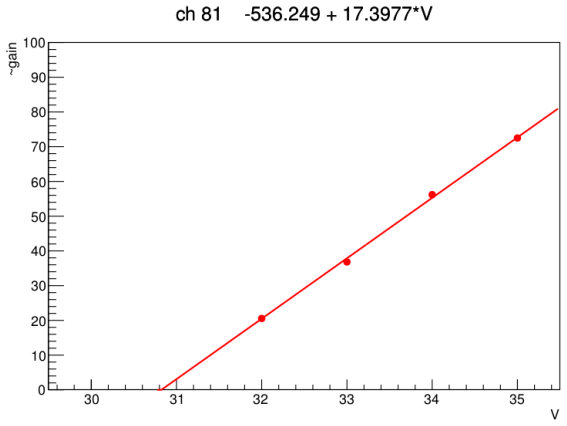
QCALT calorimeters



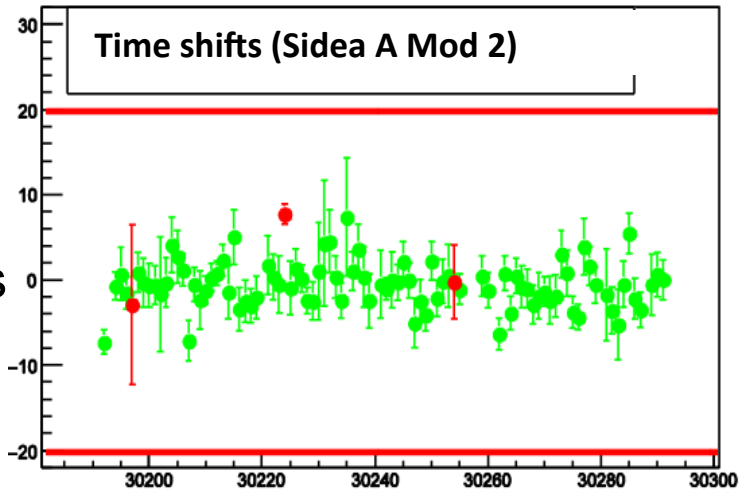
Gain optimization.
Adjusting HV settings to have the 2nd p.e. peak at same threshold for all channels

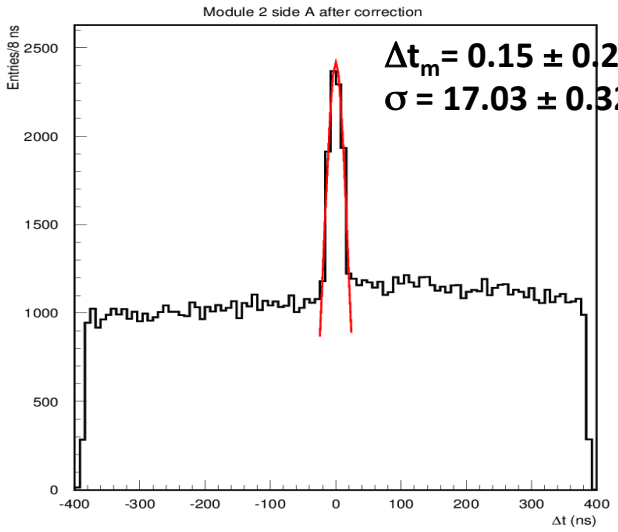
Occupancy vs Threshold



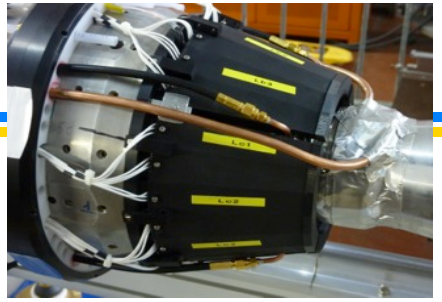


First time calibration with cosmic ray events for all channels





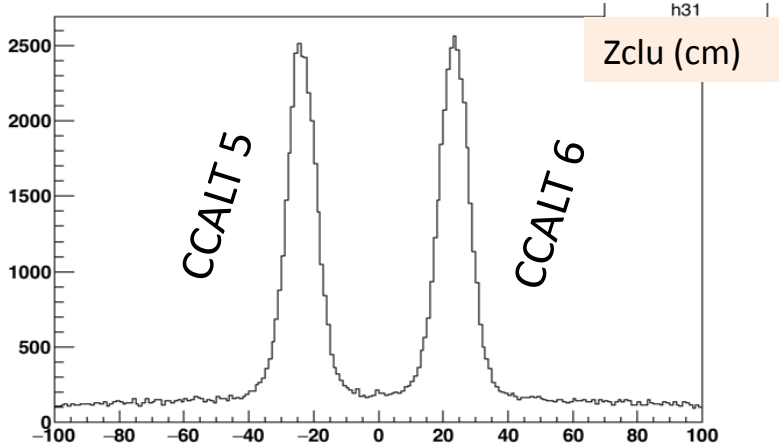
CCALT calorimeters



CCALT: 2 LYSO+SIPM calorimeters. 48 crystals each.

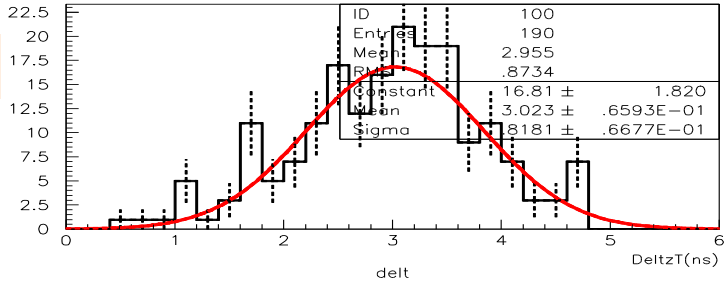
- Tested by wedge (4 crystals each) using cosmic rays selected by EMC with two clusters with a “MIP” energy deposition, pointing longitudinally to CCALT volumes (z<0, z>0).
- Fit the time distribution peaks with:

$$\sum_{i=1}^{9} \frac{P_{i+10}}{\sqrt{2\pi}P_{i+1}} e^{-\frac{(x-P_{20}-i*P_1)^2}{2P_{i+1}^2}}$$

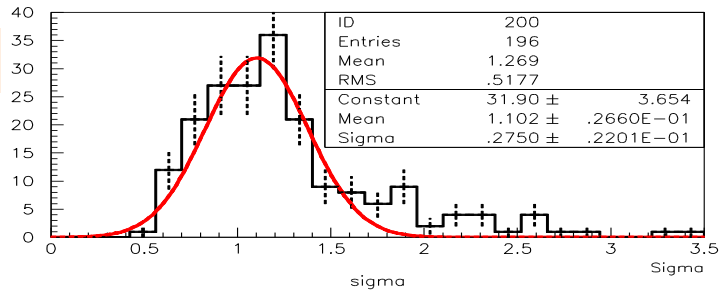


- We extracted RF-period (P_1) and Time resolution

TRF (ns)



Sigma (ns)



- constraining to T_RF=2,71 ns we calibrated TDC bin
- Average values of all sigma is of around 1 ns (0.8 ns) before/after TDC re-scaling

FEE ADC/TDC boards of the calorimeter

Lack of spares of the old FEE ADC/TDC boards of the calorimeter
=> CAEN is refurbishing not working boards and has setup a test stand

10 ADC boards sent to CAEN to clean and refurbish

- 2 did not pass the Pulse and Cosmic tests
- 4 have been working with collisions for few weeks
- 4 are presently properly operating on KLOE

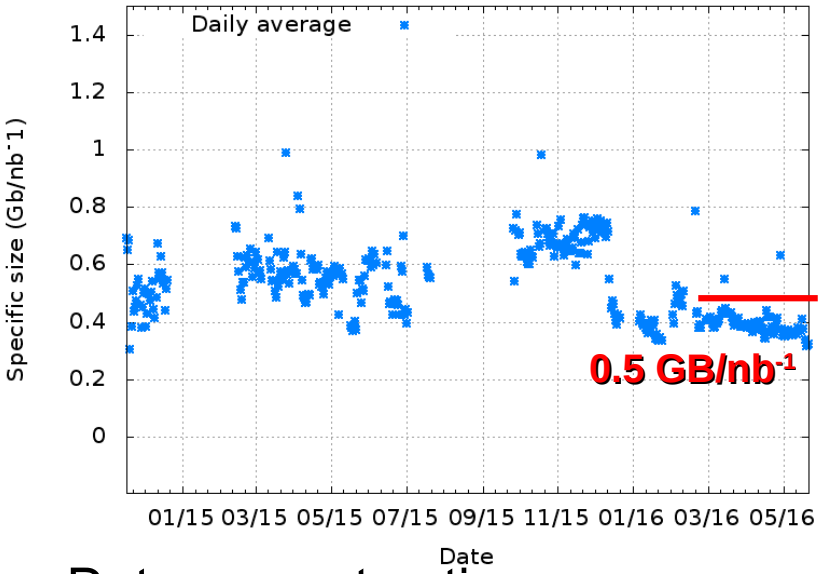
6 TDC boards sent to CAEN to refurbish and clean

- 2 have been declared unrepairable by CAEN for broken components
- 2 did not pass the Pulse and Cosmic test
- 1 has been working with collisions for 3 months
- 1 is presently properly operating in KLOE

Data volume

	Run-I (TB)	Run-II (TB)
Lum (fb^{-1})	0.8	1.34
RAW	427	685
REC	13	118

~35% of data have been reconstructed.



At present Data volume is ~500 TB/fb-1, which brings the total size of raw files at: 3 PB @ 5 fb-1
Reconstructing all with the same Data Volume as now will give: 1PB @ 5 fb-1
Assuming the same data reduction factor as for the old dataset DST and MC can be estimated in 0.4 PB @ 5 fb-1
Total amount of DataVolume: 4.5 PB @ 5 fb-1
~ 1 PB/fb^{-1} (all included: Raw+Reconstructed+MC)

Affordable with the new online/offline machines configuration and the new technology tape drives (10 TB/tape) (see next slides)

Data reconstruction can run simultaneously with the data taking at a rate of 22.3 pb-1/day

The “extra” reconstruction power of the KLOE-2 cluster (10 -15 pb^{-1}/day) can be used to reconstruct in parallel past runs.

Data reduction

Bunching Technique

Full exploitation of EMC timing performance to select the bunch crossing of interest in the event, largely reducing the machine background.

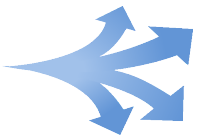
Event rejection: -56% from MC

- Validation with KLOE data: cleaner dataset and lower background level
- Validation of background insertion in MC simulation to improve MC predictivity
- Study the effect of the high level filter on benchmark physics channel: $K_S \to \pi\pi$, $K_L \to \pi e \nu$, $K_L \to 3\pi$ and radiative phi-meson decays

Data Compression

- IBM Tape-Drive allows for HW compression at wire speed with 15% (new 27%) data volume reduction on KLOE raw data
- 30% on reconstructed using zlib on event-by-event level
- KLOE data can be better compressed if single 32 bit words are split in 8 bit chunks and packed in four different streams:

B0a B0b B0c B0d B1a B1b B1c B1d …



B0a B1a …
B0b B1b …
B0c B1c …
B0d B1d …

- First test result for raw files > 50% data reduction & DAQ throughput 16 MB/s / CPU

Computing and storage (I)

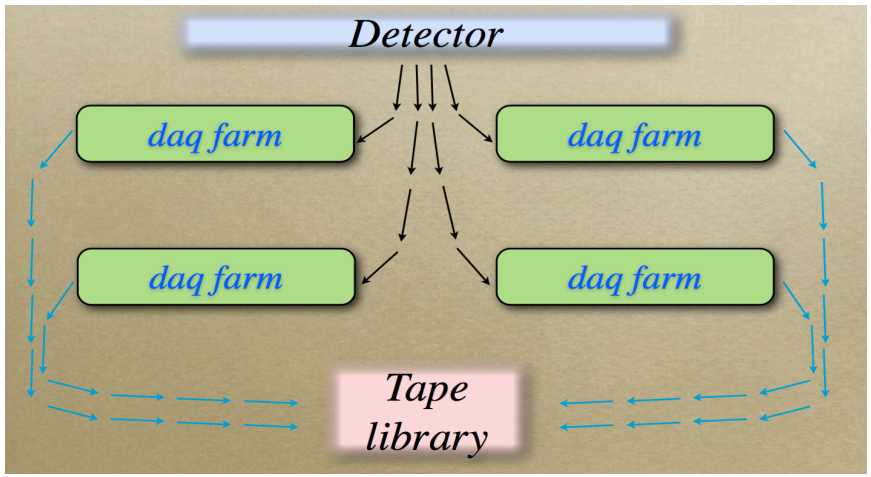
KLOE DAQ Improvement

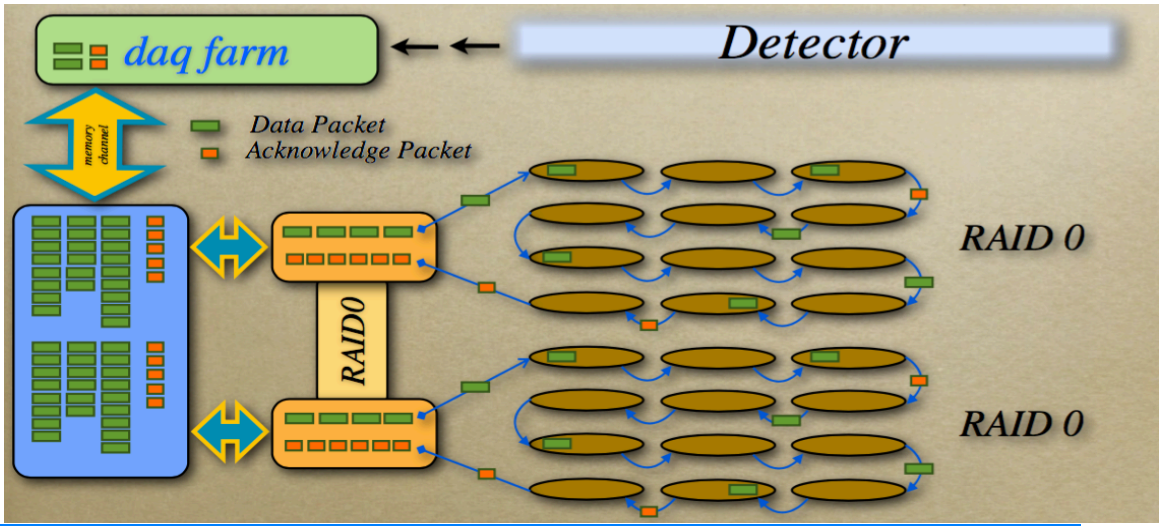
To reduce the data-taking dead-time some offline resources moved to the online cluster (Nov '15)

- Two Power7 substituted three Power6
- P7 hardware partitioning allows us to use a single P7 as two fully independent machines
- Separated Gigabit Ethernet connections for digital acquisition & archiving

8 cores - 32 thread
32 Gigabyte memory
2 Gigabit Ethernet interfaces
Two Way Fiber Channel Card for OS
Two Way SAS Card for /data/farm

- SAS interfaces to reduce busy time and maximize the speed /data/farm filesystem spreaded through 2 SAS interfaces and 24 SAS disks





Computing and storage (II)

Tape Library Improvement

New IBM TS4500 R2

- Drive TS1150 double fiber channel 8Gb and 10TB capacity cartridges without compression
- Single frame and 4 tape drives (max 12). Single robotic arm with a double gripper.
- 550 cartridge slots, 100 cartridges 3595 JD

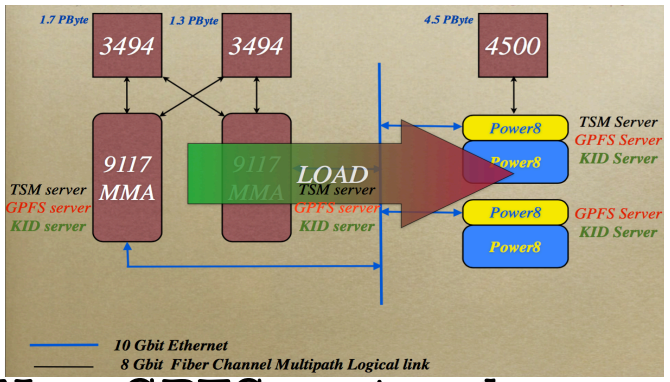
The New Library is working since 24 March

IBM test at LNF done; commissioning just completed

Data-Servers Improvement

10 Core Power8

- 2 Core I/O partition for data moving (Servers)
- 8 Core CPU partition for data reconstruction (Offline)
- CPU and Memory Dynamic Allocation
- New Data-Servers to manage the new disk array (soon) able to serve 600 TB.



New GPFS protocol

New GPFS protocol to enhance the performace into the offline cluster and also into the online cluster.

Conclusions (I)

- Data taking (RUN-II) continues with the KLOE-2 detector fully operational: L delivered up to now >1600 pb^{-1} (Total L~2.6 fb-1)
- July milestone (2.5 fb^{-1}) fulfilled with about 2 months in advance
- KLOE-2 requirement remains more than 5 fb^{-1} of good acquired luminosity in a reasonable amount of time.
- Energy scan successfully performed to calibrate the absolute energy scale
- The inner tracker operates now in a safer mode; alignment and calibration for all layers with cosmic-ray muons and Bhabha scattering events. Benchmarking IT +DC integrated reconstruction with Bhabha scattering events
- HET calibrated with dedicated runs; π^0 candidates observed in double-arm tagged events (325 pb^{-1} analyzed).
- First calibration of QCALT and CCALT.
- DAQ, tape library and data servers improved. New GPFS protocol tested and ready to be implemented.

Conclusions (II)

- The KLOE-2 manpower issue mitigated by 2 new post-doc positions, 2 post-doc positions as replacement and 1 art.36 position to be filled.
- The new group from Novosibirsk started contributing to the collaboration

- The KLOE-2 Physics program will be reviewed in a dedicated workshop next Fall:

"e+e- Physics at 1 GeV" LNF, 26-28 October 2016

with a full session on 28 devoted to the proposal by Calame, Passera, Trentadue, Venanzoni on the measurement of the hadronic g-2 contribution in the space-like region.

The proposal has been discussed within the KLOE-2 Collaboration, that is in favor of starting the feasibility study and perform the first measurement with KLOE/KLOE-2.

It constitutes a very challenging measurement that needs a dedicated manpower resource.

SPARE SLIDES

High Energy Tagger rates

effective σ_E	HET : single arm	HET: double arm	KLOE : triggerless	KLOE : triggered
Bhabha scattering	484 μb	0.21 μb		
$\gamma\gamma$ X= π^0	2.2 10^{-5} μb	4 10^{-6} μb		1.4 10^{-6} μb

Triggerless mode : events taken with "random" triggers, i.e. irrespectively of the process generating the KLOE trigger (signal or background)

Rate	HET : single arm	HET: double arm	KLOE : triggerless	KLOE: triggered
Bhabha scattering	58080 x 2 Hz	25 Hz	As a consequence ~ 0.2% (0.3% measured) of KLOE trigger rate has 2 single-arm Bhabha+ double-arm Bhabha (~ 20 - 30 Hz)	
$\gamma\gamma$ X= π^0	2.6 10^{-3} x 2 Hz	4.8 10^{-4} Hz		1.7 10^{-4} Hz (double-arm)

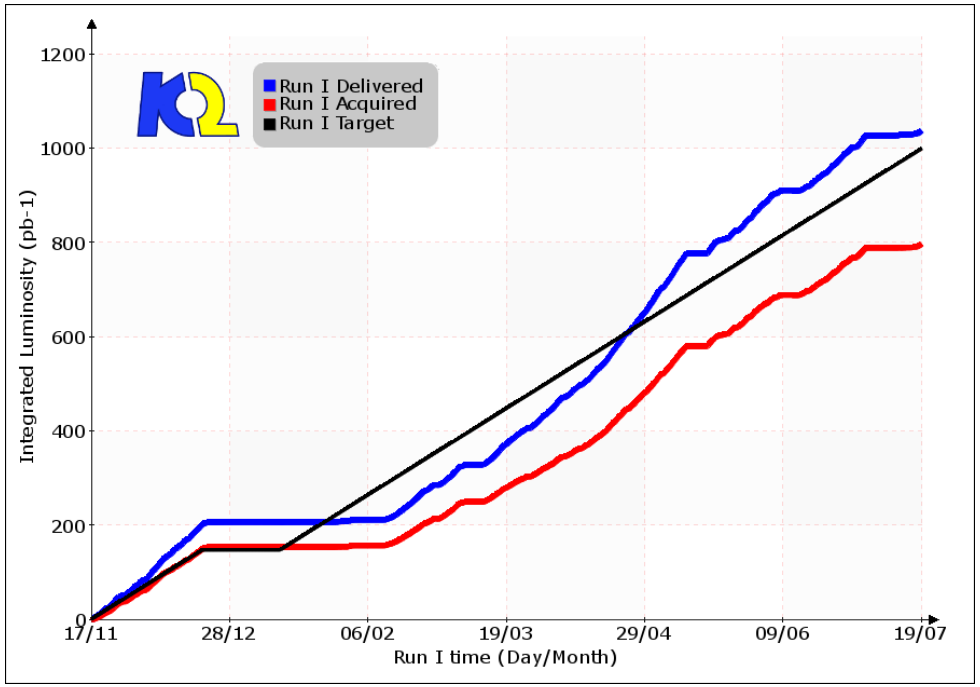
DAQ fixed dead time: 8kHz x 4 μs = 3.2%
Veto at beam injection: 2 Hz x 50 ms x 0.6(fraction inj. time) = 6%
DAFNE bad condition collisions: ~ 5%
KLOE downtime: ~5%

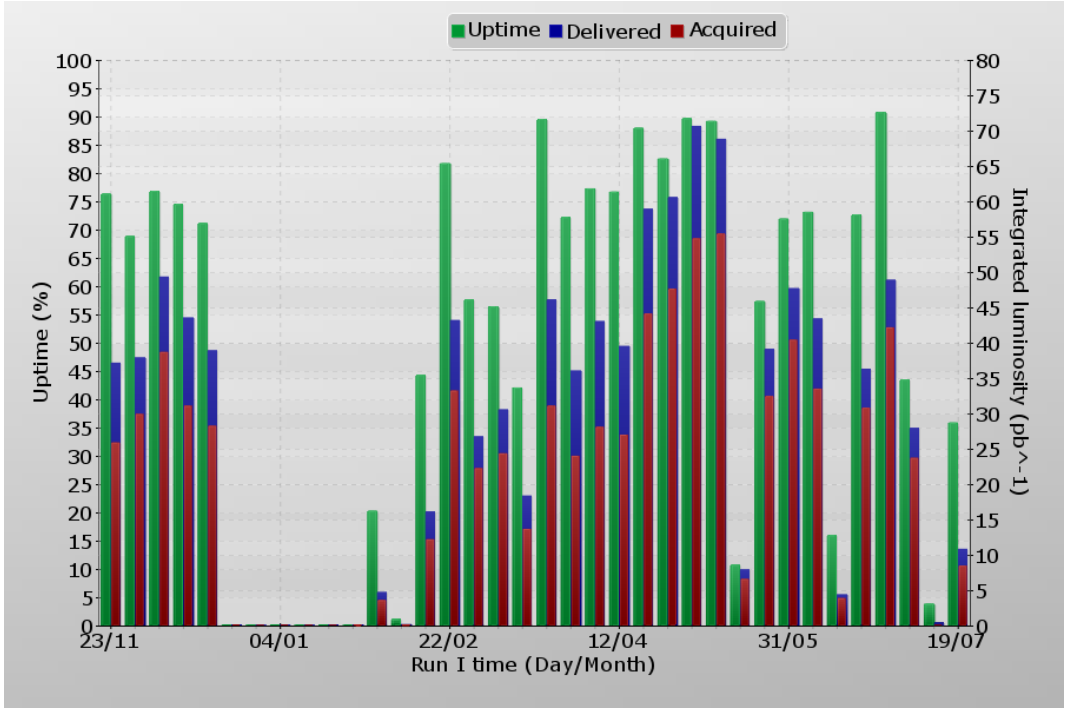
TOTAL INEFFICIENCY: ~20%

Run I: integrated Luminosity summary

KLOE-2 data taking started on
17 November 2014 with the goal of reaching an integrated luminosity of 1 fb^{-1} by 30 June 2015 (**RUN-I**)

Very good performance achieved in April-May





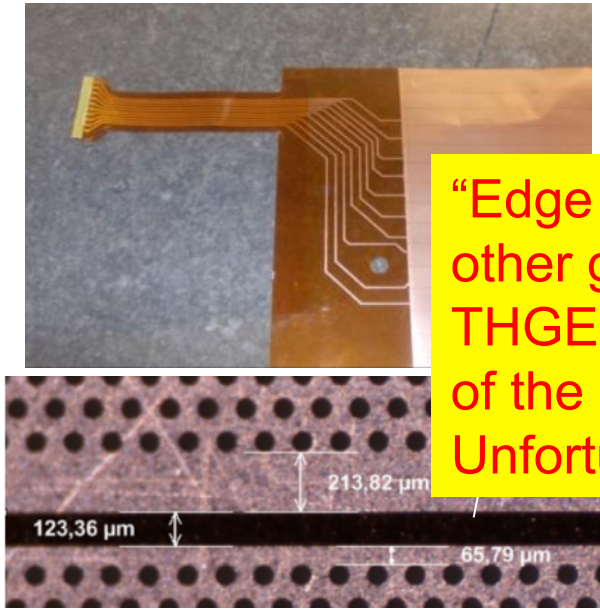
DAFNE delivered: 1030 pb^{-1}

KLOE recorded: 790 pb^{-1} (i.e. 77%)

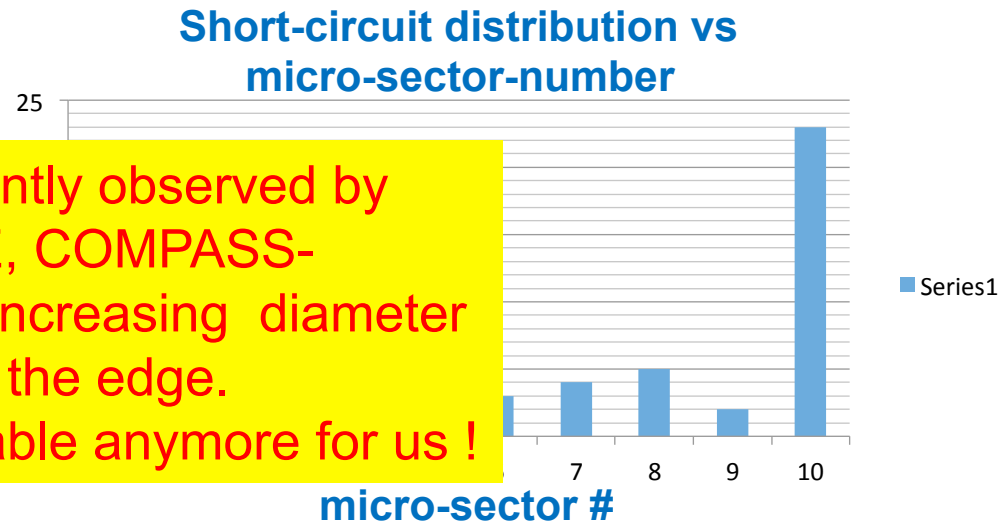
weekly performance

Safe operation of the inner tracker

- The “shorts” occurrence is the main issue found in the running of the IT, enhanced by the relatively high gas gain at which the detector is operated (12 k).
- The “shorts” are mainly triggered by anomalous DAFNE injections or beam losses.
- Each GEM foil is divided in 4 macro-sectors, and each macro-sector is divided in 10 micro-sectors. “Shorts” distribution per GEM foil shows an anomalous accumulation at the edges of the micro-sectors.
- <u>The source of the edge effect has been understood:
sectorization creates distortion of electric field resulting in higher effective gain</u>



“Edge effect” – recently observed by other groups (ALICE, COMPASS-THGEM) – solved increasing diameter of the holes close to the edge. Unfortunately not viable anymore for us !



~5% of global micro-sectors