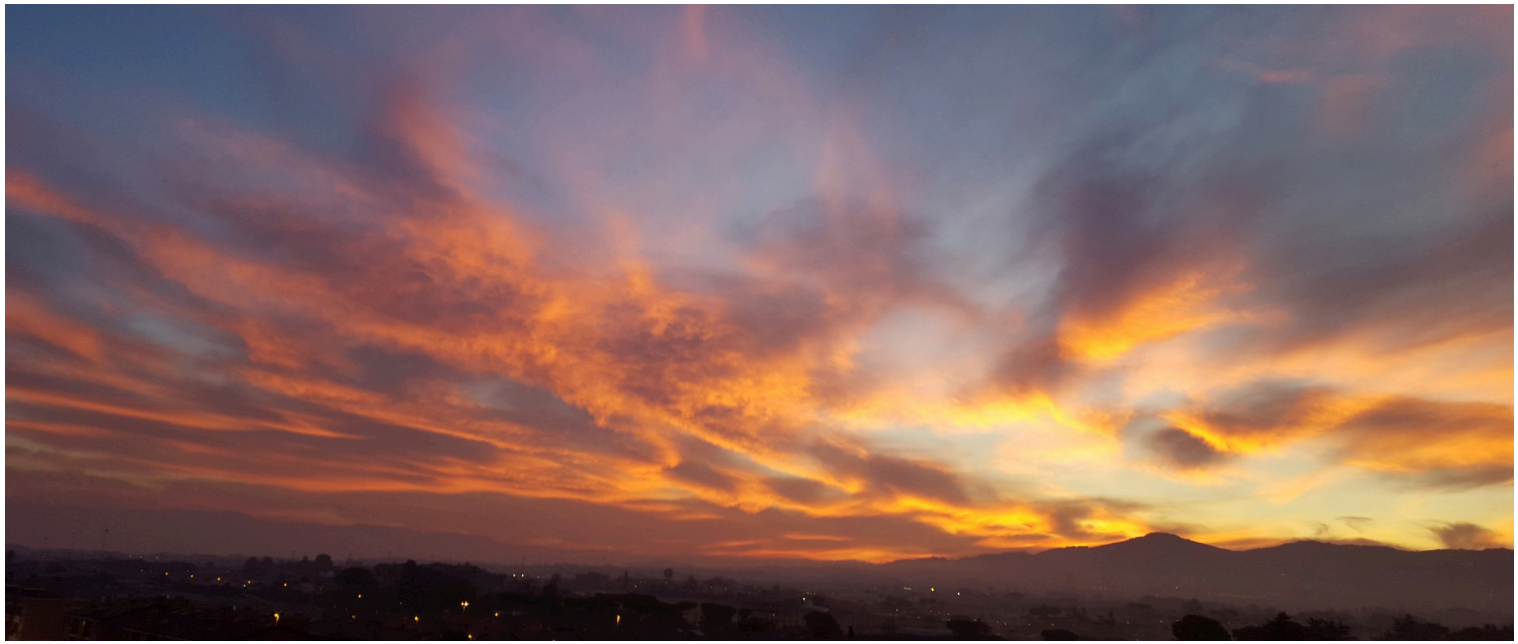
Status of KLOE-2

Antonio Di Domenico
Dipartimento di Fisica, Sapienza Università di Roma
and INFN sezione di Roma, Italy

on behalf of the KLOE-2 collaboration



LNF Scientific Committee meeting
Frascati, 23 November 2015

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 $\phi \to \pi^0 e^+e^-$	Draft paper (*)
Dalitz plot analysis of $\eta \to \pi^+\pi^-\pi^0$	Draft paper
Hadron Vacuum Polarization in $e^+e^- \to \mu^+\mu^-\gamma$	Draft paper
U boson search in $e^+e^- \to U\gamma$, $U \to \pi^+\pi^-$	Draft in preparation
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
Measurement of K^+ mass	In progress
Update of QM/CPT test with KSKL$\to \pi+\pi-\pi+\pi-$	In progress

- «KLOE-2 operation» paper under preparation

(*) Main author hired by software company causing some delay

PhD Theses

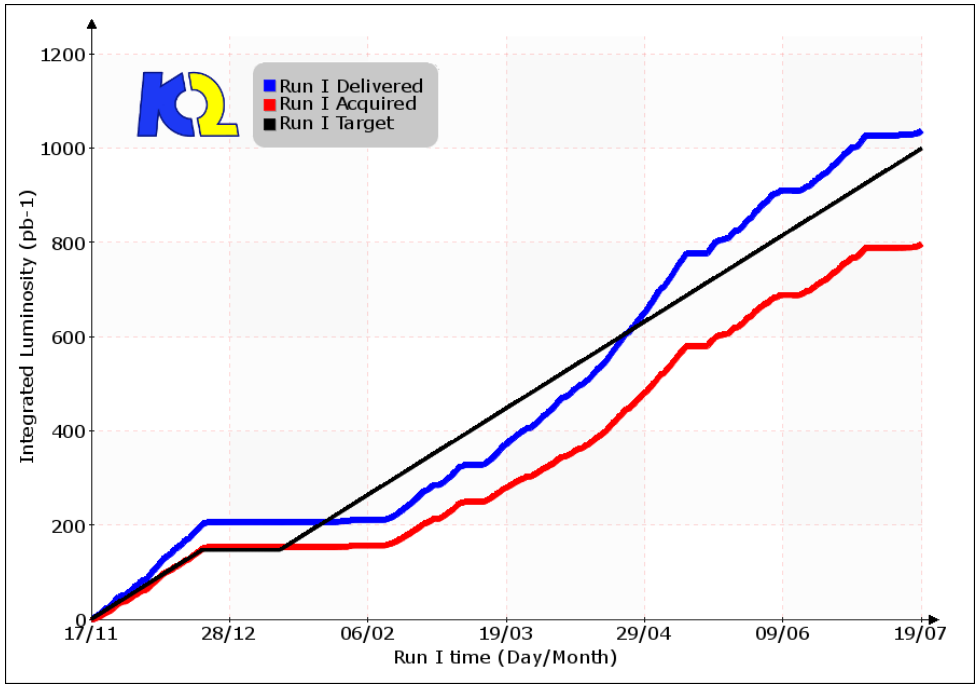
Discrete symmetries tests with kaons at KLOE-2	A. Selce (*) Università Rome Tre, Italy
Measurement of the $K_S \rightarrow \pi^+\pi^-\pi^0$ branching fraction	A. Di Cicco Università Rome Tre, Italy
Light quark masses from Dalitz plot study of $\eta \rightarrow 3\pi$ decay	Li Caldeira-Balkestahl Uppsala 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

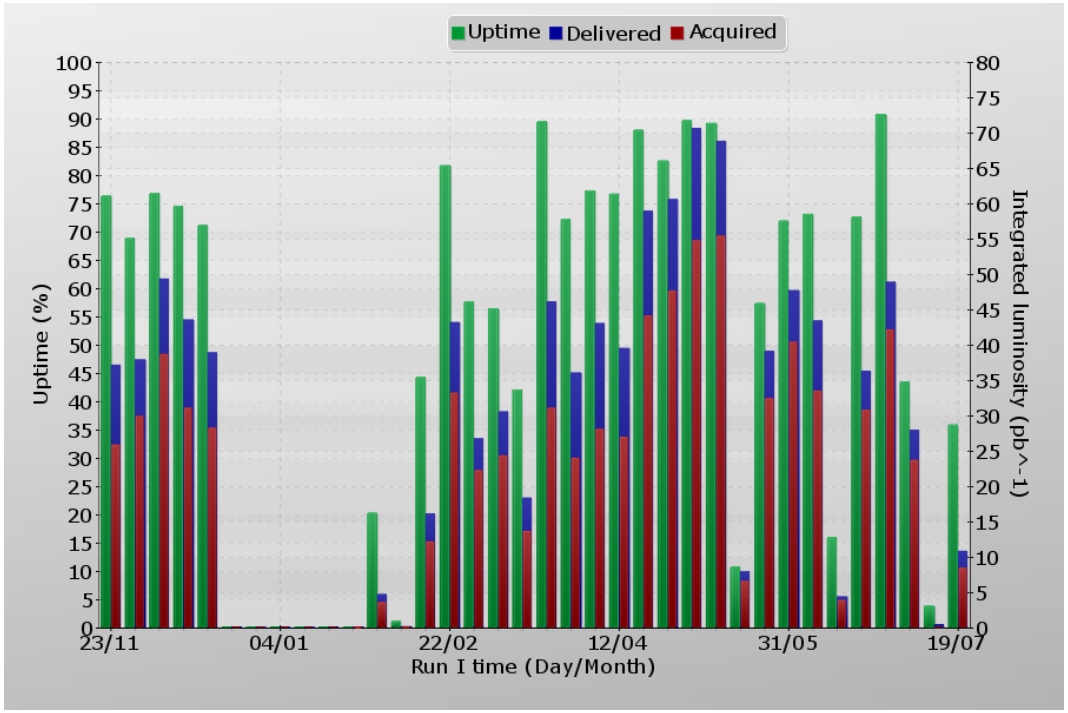
(*) just started

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%)

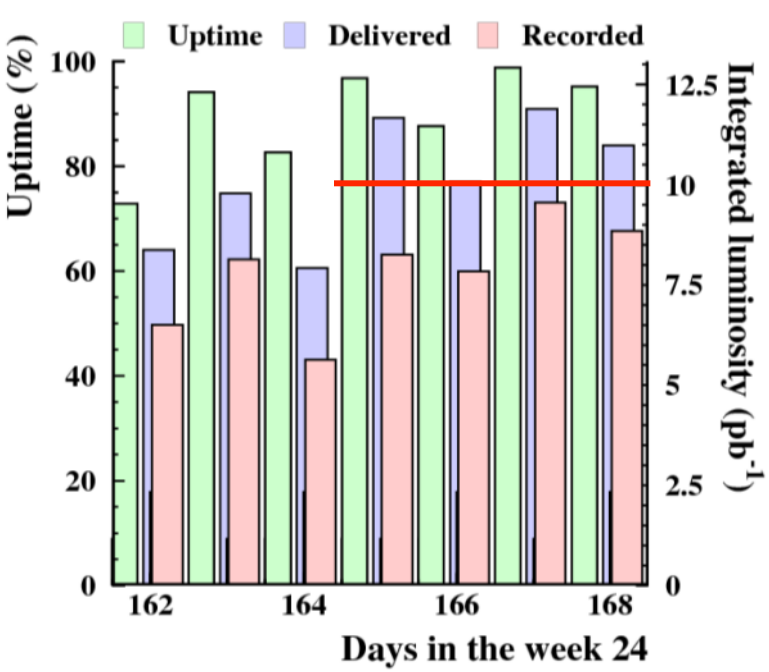
weekly performance

Run I: April-May performance

week 24: 27 April - 3 May

71 pb^{-1} delivered

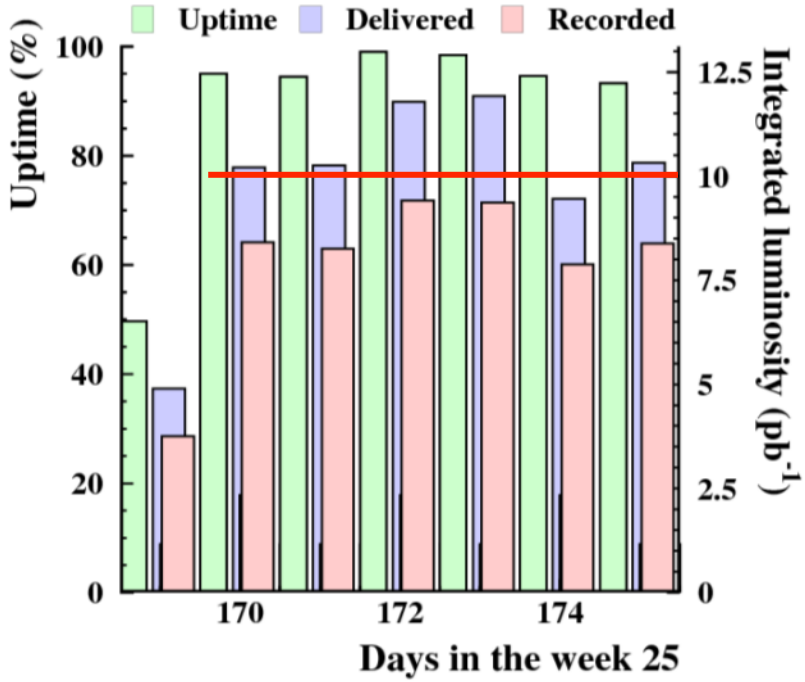
55 pb^{-1} recordered



week 25: 4 May - 10 May

69 pb^{-1} delivered

56 pb^{-1} recordered

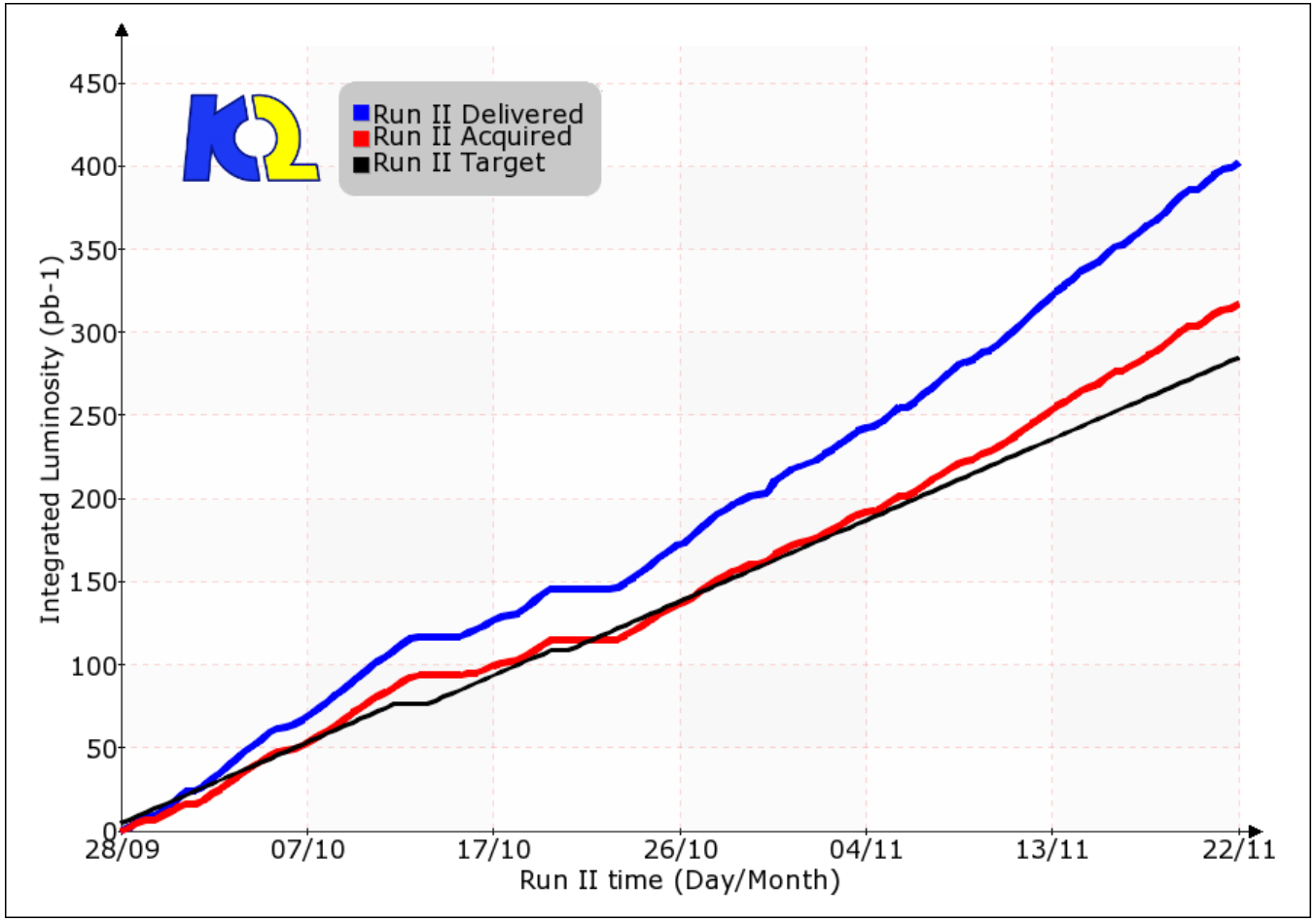


Best DAΦNE performance:

Peak luminosity: ~2 x 10^{32}

maximum daily integrated luminosity (delivered): ~12 pb^{-1}

Run II: integrated Luminosity



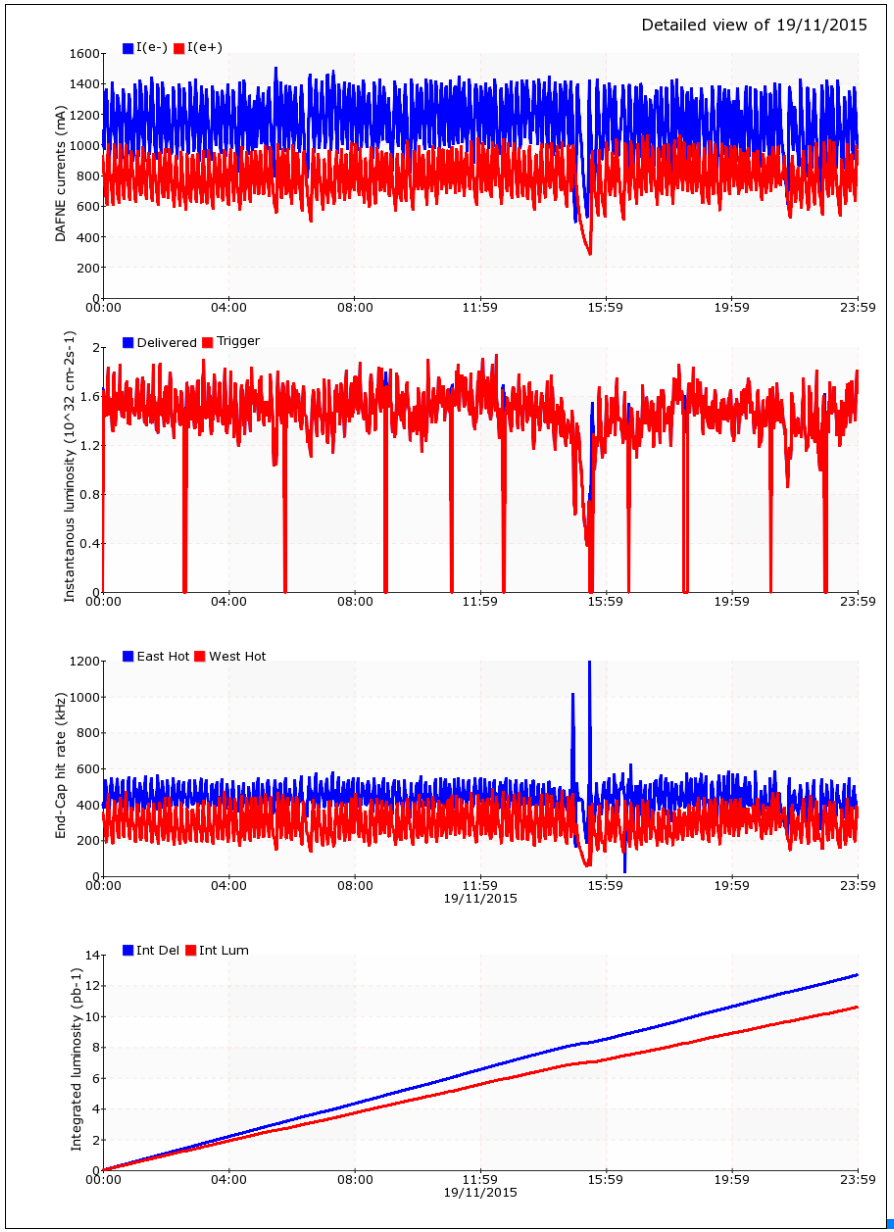
RUN-II started on
28 September 2015

Next luminosity milestone:
to reach a total L delivered
of 2.5 fb^{-1} by 15 July 2016 :

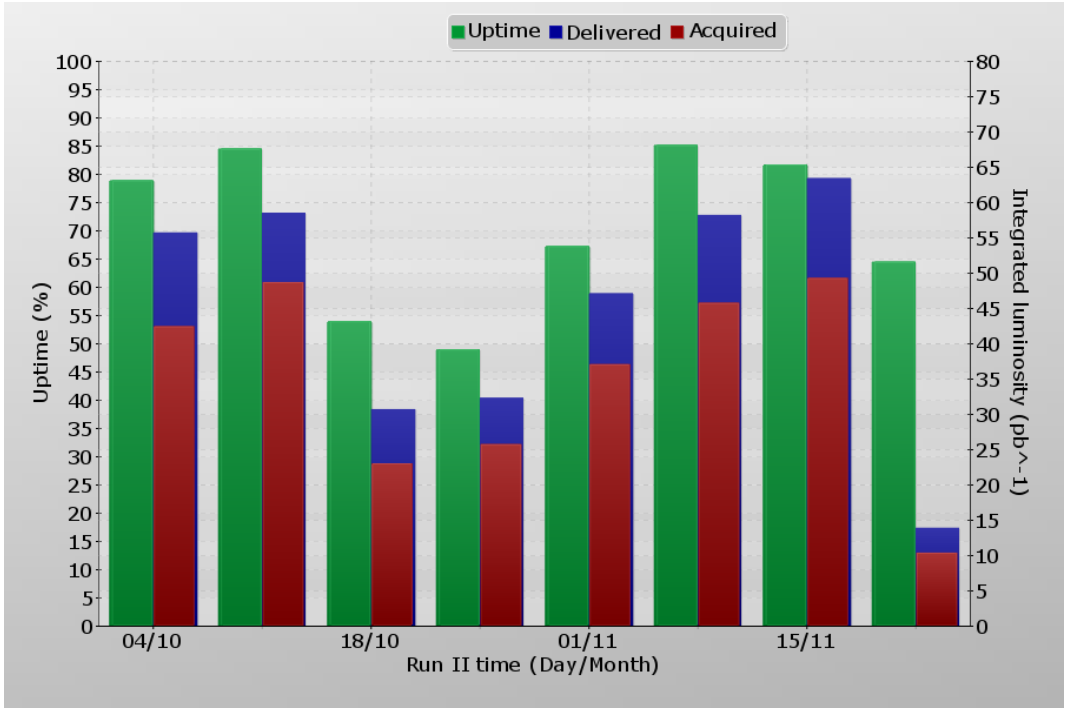
This milestone has been set
as the minimal requirement
to achieve in a "reasonable"
amount of time the goal
of the experiment, i.e.
to acquire <u>at least</u> 5 fb^{-1}.

Best DAΦNE performance:
Peak luminosity: ~2.1 x 10^{32}
maximum daily integrated luminosity (delivered): ~12.7 pb^{-1}

Run II: best performance



Best day:
integrated luminosity (delivered): ~12.7 pb^{-1}
integrated luminosity (acquired): ~10.6 pb^{-1}



weekly performance

Status of KLOE-2 operation and detector

KLOE-2 is fully operational and taking data with all sub-detectors

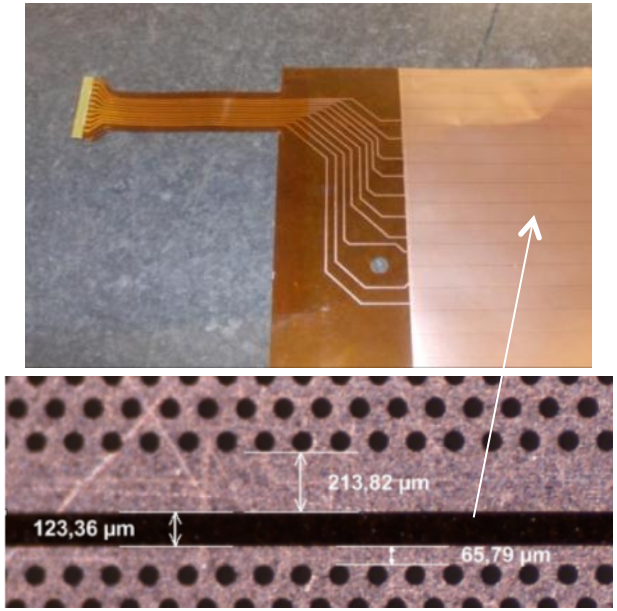
Main open questions since last SC meeting:

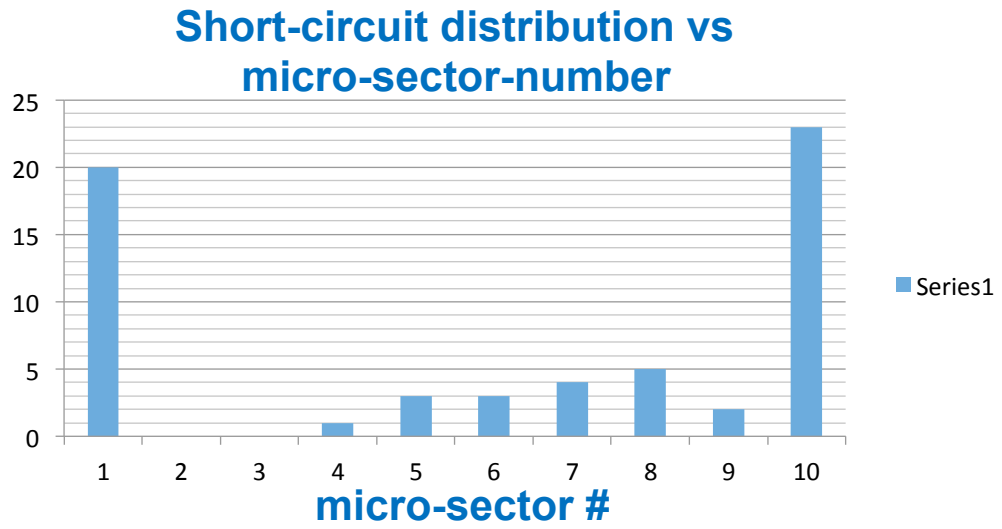
- Lack of spares of the old FEE ADC/TDC boards of the calorimeter
  => CAEN is refurbishing not working boards and has setup a test stand; first repaired boards have been already tested on the detector.
- Safe operation of the inner tracker => see next slides
- Quality of the data in presence of high background => see next slides
- Data throughput => see next slides

Commissioning of all new subdetectors is progressing => see next slides

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>





~5% of global micro-sectors

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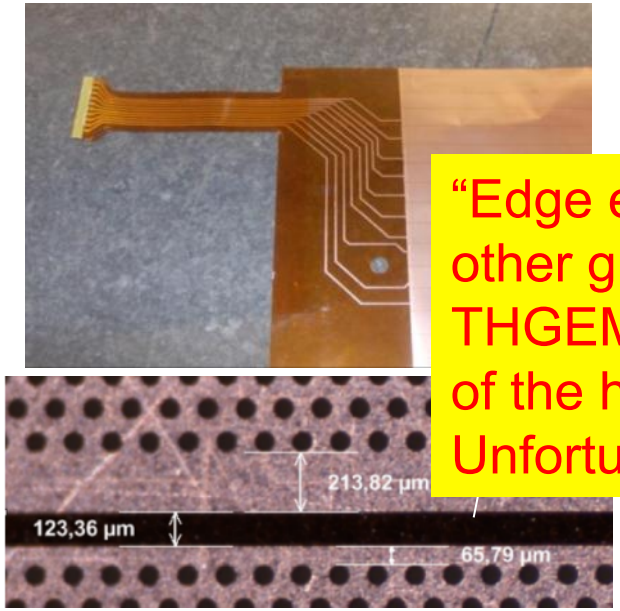
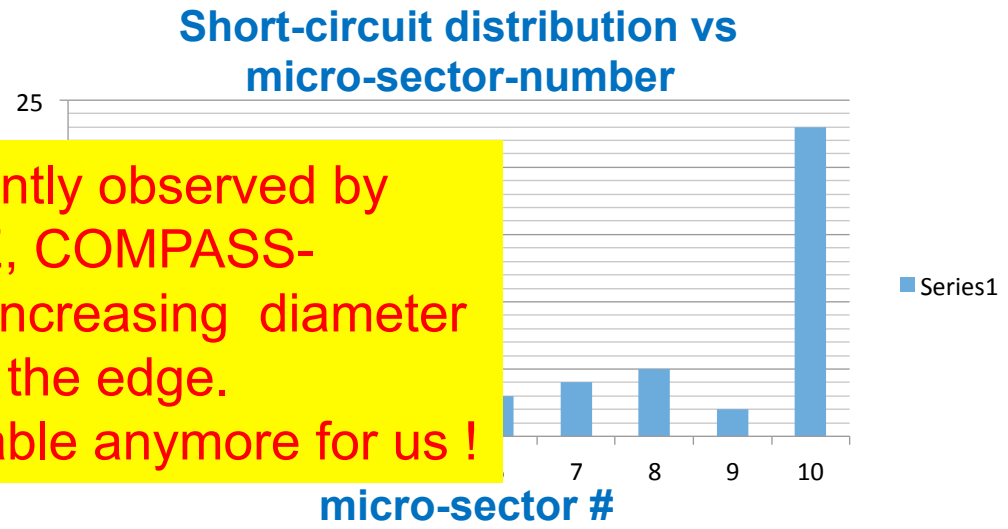


“Edge effect” – recently observed by other groups (ALICE, COMPASS-THGEM) – solved increasing diameter of the holes close to the edge. Unfortunately not viable anymore for us !



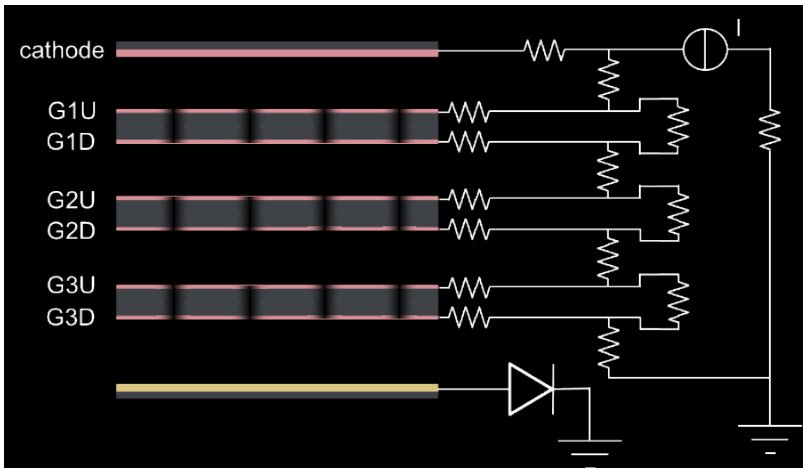
~5% of global micro-sectors

Safe operation of the inner tracker

Two main actions:

1) NEW HV DISTRIBUTION SCHEME:

(a) passive divider with single current generator channel (installed)



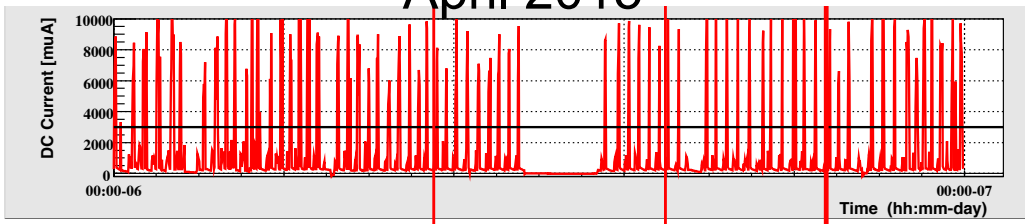
- Safer than individual power supply scheme (common ground) previoulsy used, wrt possible propagation of the discharge between contiguous GEM stages

(b) a dedicated CAEN board with common floating return channels is under test

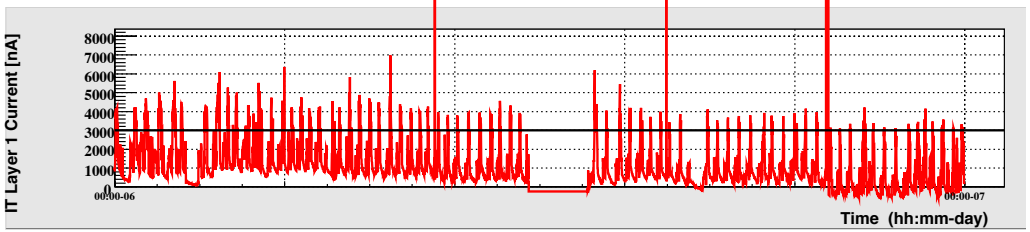
2) Optimization of the beam injections by the DAFNE team with online feedback information (DC and IT currents)

April 2015

DC

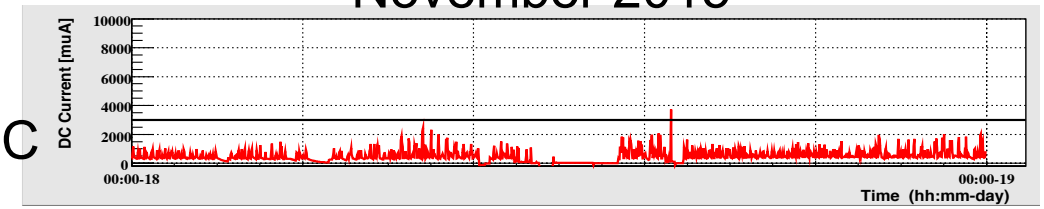


IT



November 2015

DC



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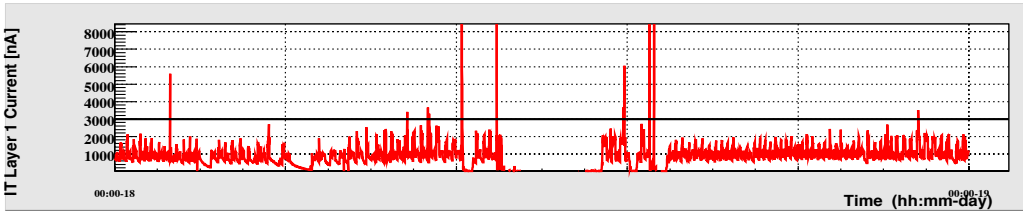

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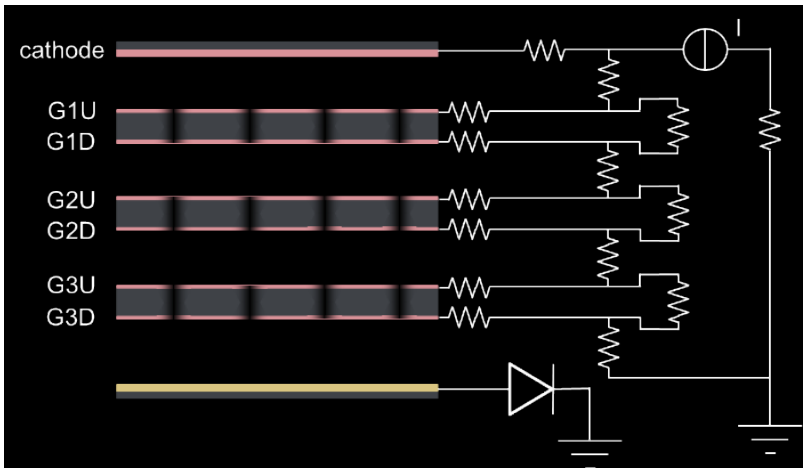

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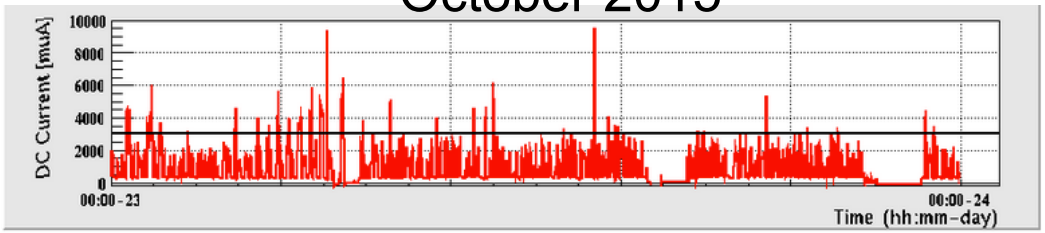

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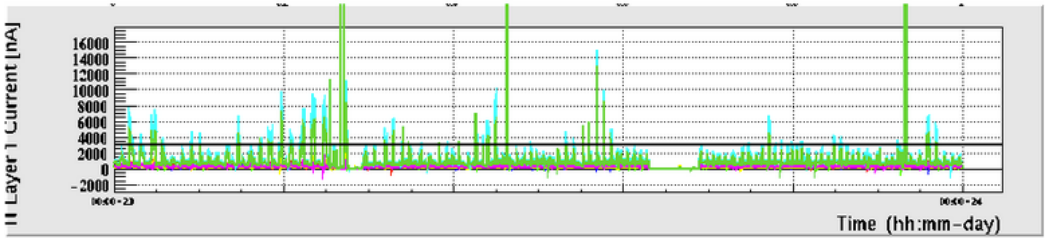

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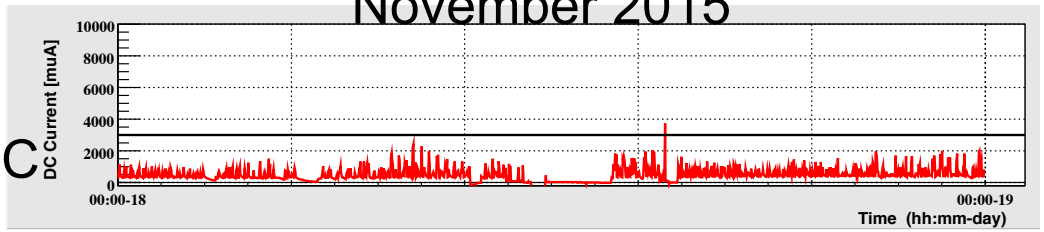

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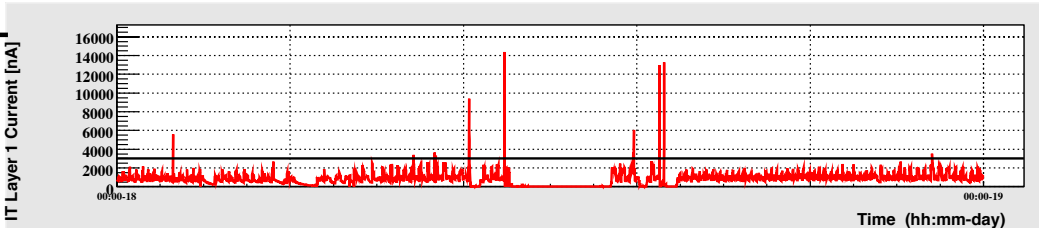

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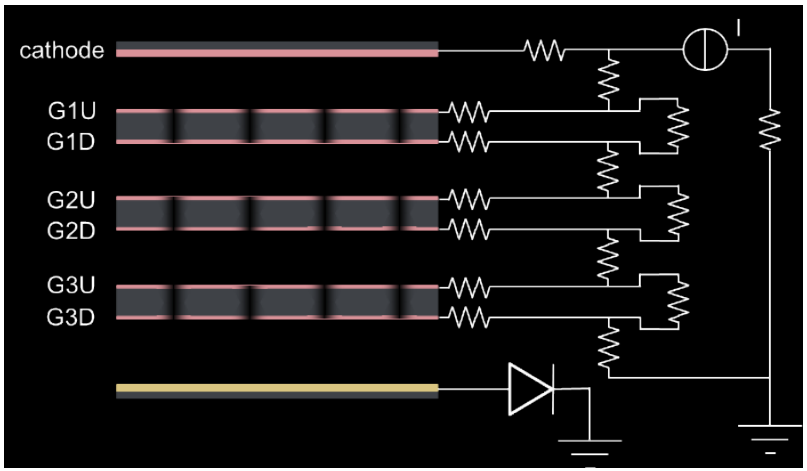

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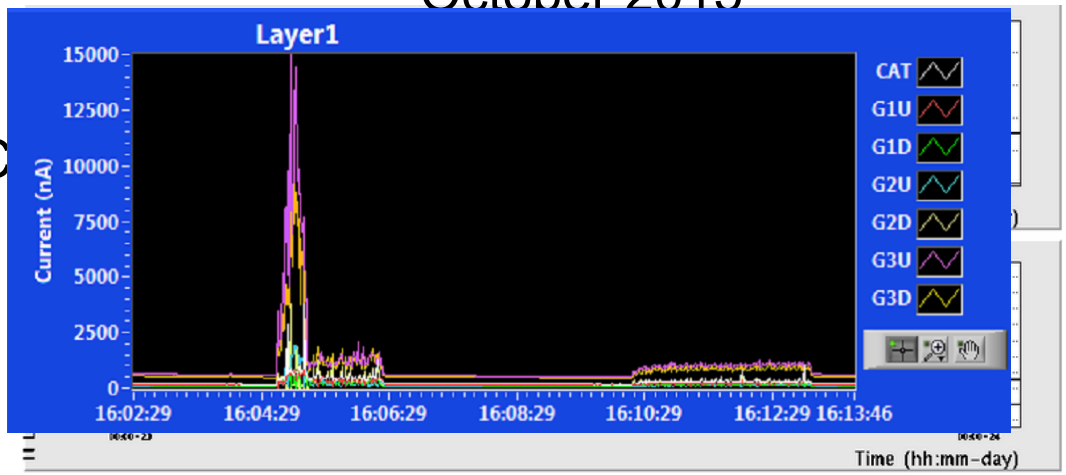

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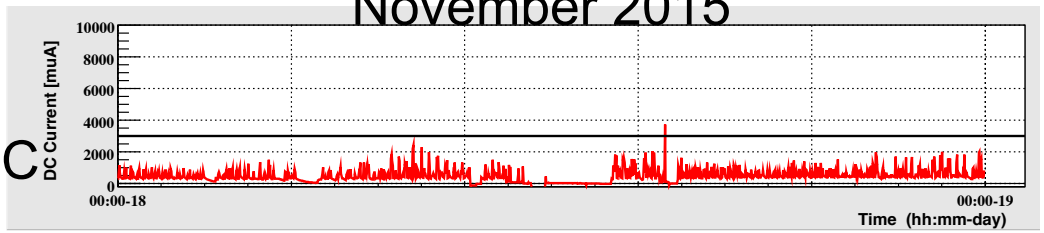

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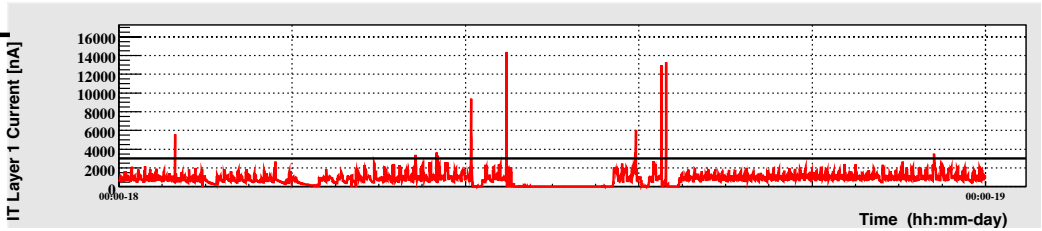

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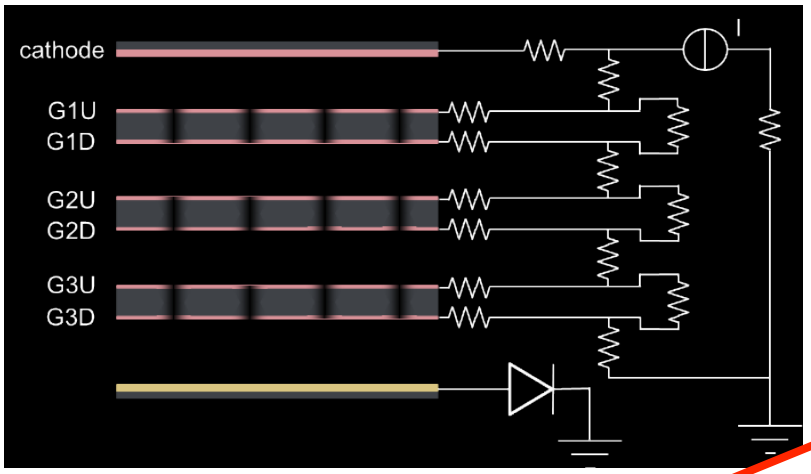

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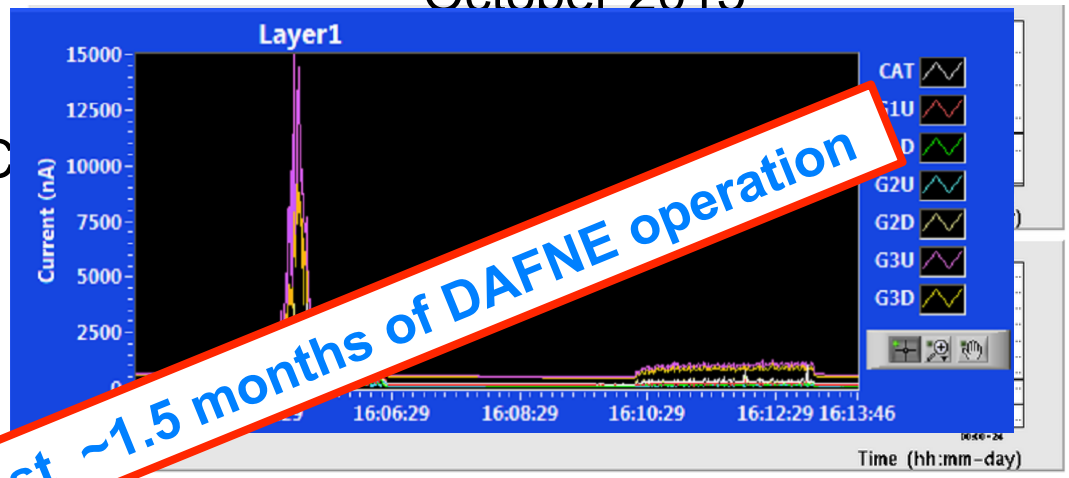
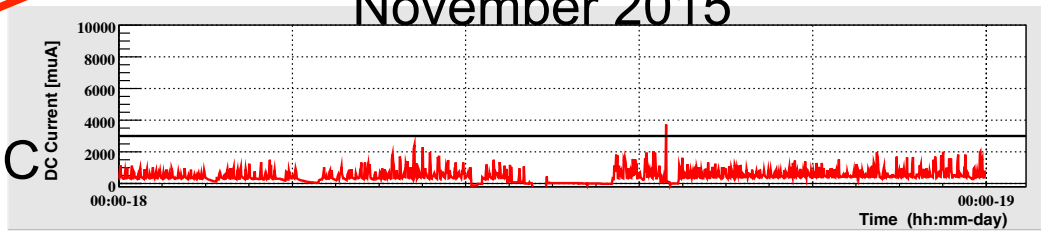


No more "shorts" occurred in the last ~1.5 months of DAFNE operation

November 2015

DC



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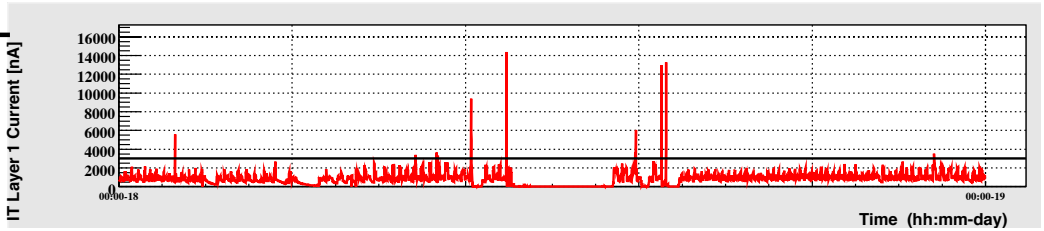
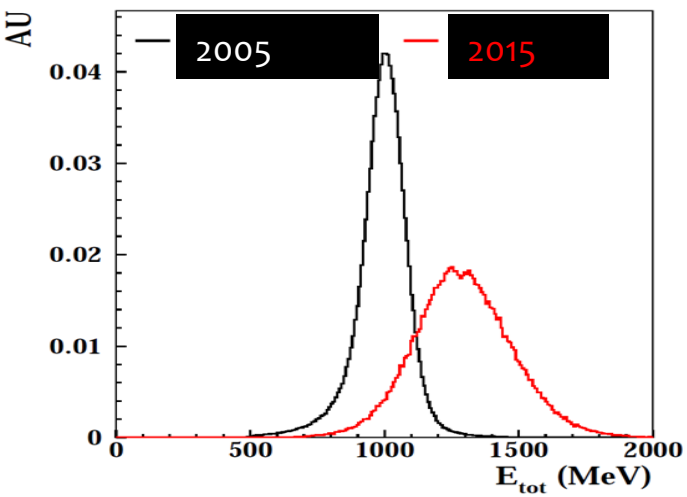
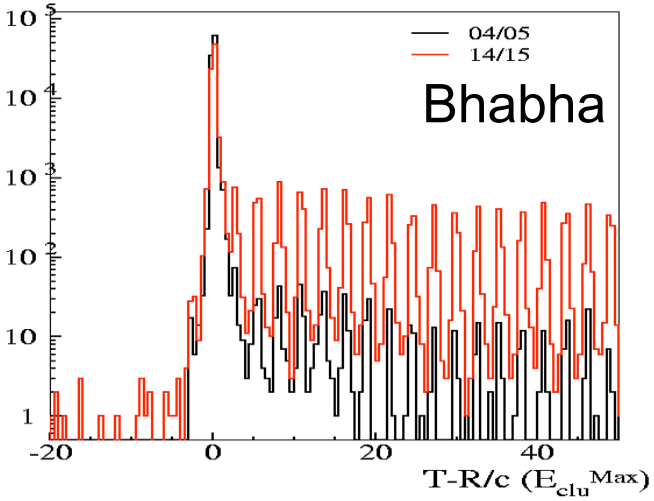


Data composition

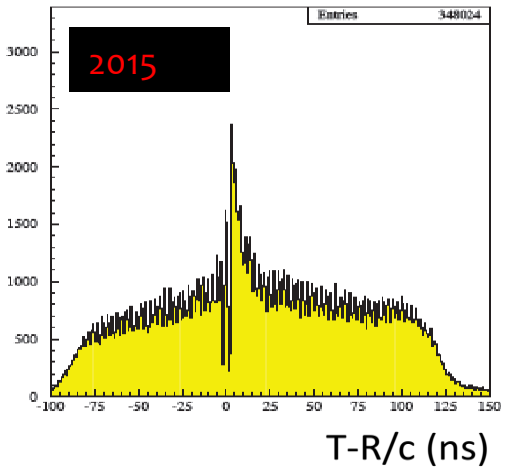


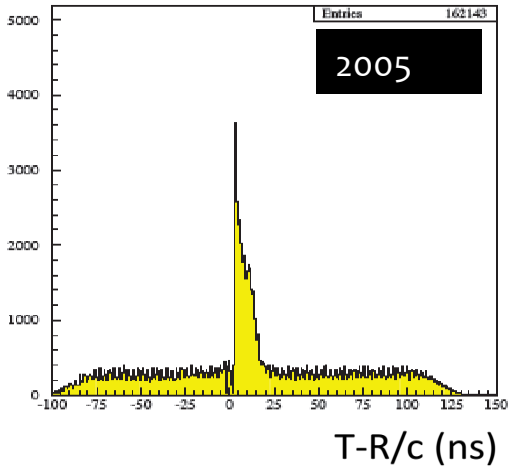
Most of the background hits are not associated in time with the bunch with physics but may affect the T_0 determination



New higher background (6 times wrt 2005) highly contaminates calorimeter data:

- Average EMC cluster multiplicity: 11 (3 in '05)
- Total EMC energy for Bhabhas: 1300 MeV
- Acc. clusters in trigger window: 120% (10% in '05)





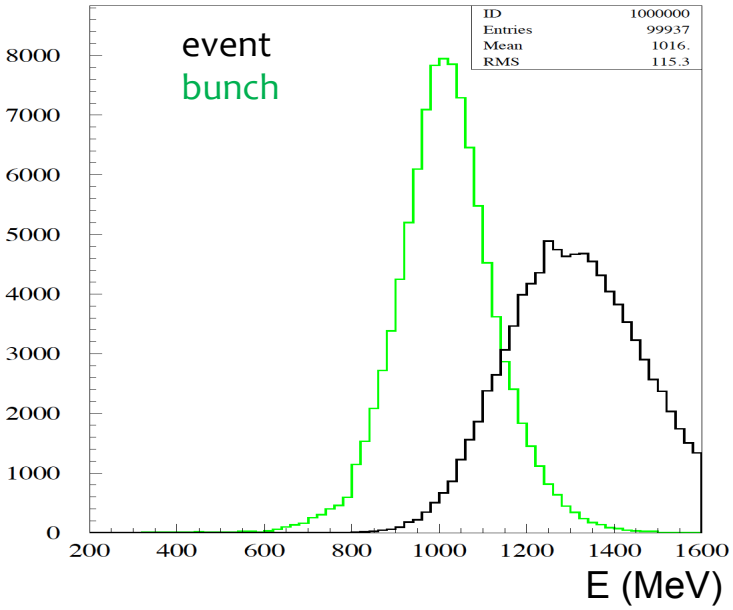
Event composition at L3 ($L = 10^{32}$)

- 300 Hz φ decays
- 2 kHz Bhabha scattering
- 500 Hz Cosmic muons
- 5.5 kHz Intra-bunch interactions (Touschek background)

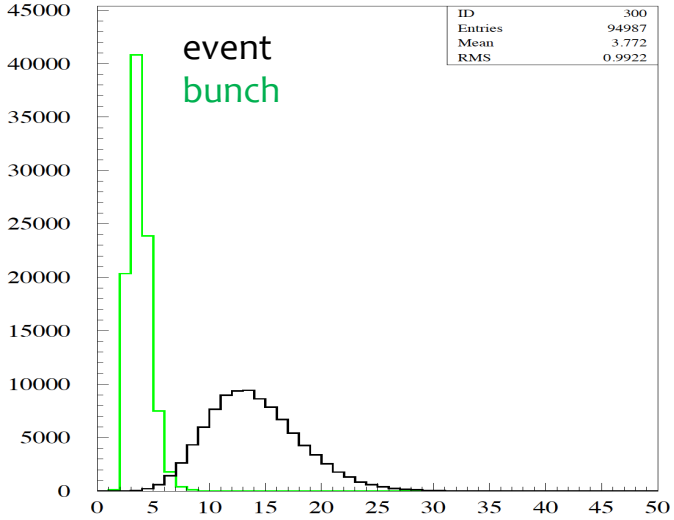
Data selection with "bunching"

With a full exploitation of the timing performance of EMC, it's possible to select the bunch crossing of interest in the event, largely reducing the machine background => in agreement with expected detector performance.

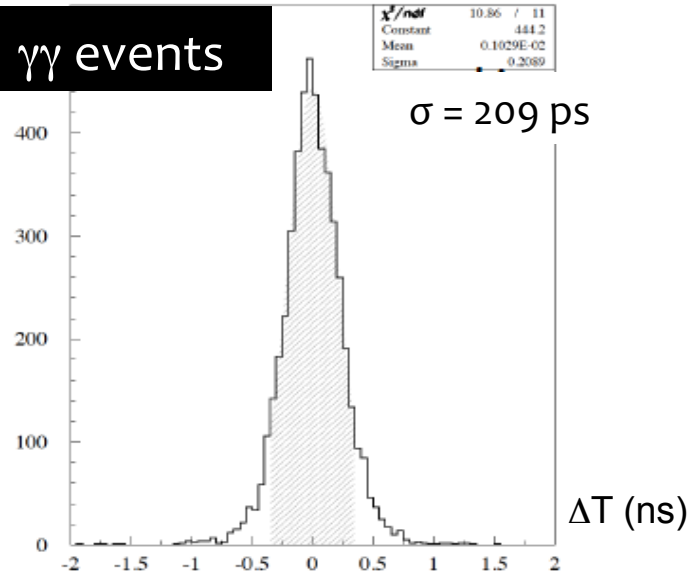
Total EMC Bhabha energy



EMC cluster multiplicity



γγ events



Distribution of the time difference ΔT for the two clusters of maximal energy in the same bunch crossing

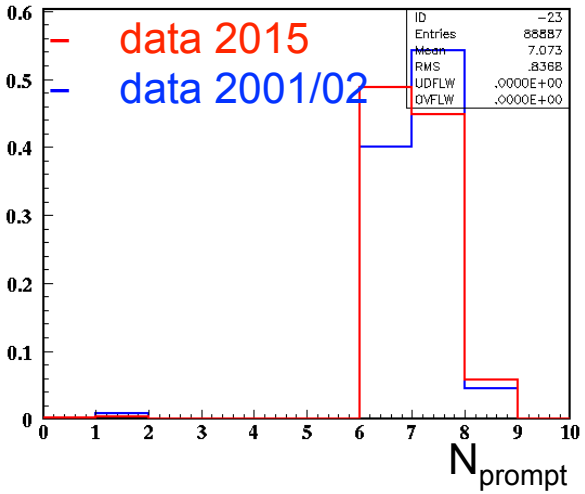
Data quality benchmark

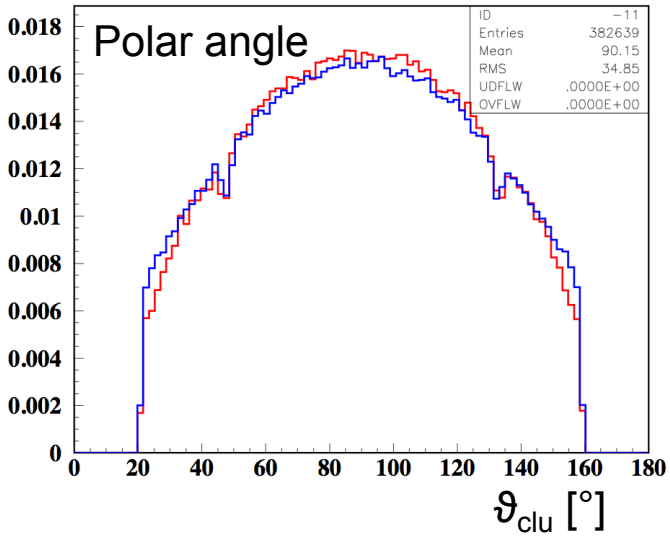
Few examples of benchmark analyses to assess Run I data quality:

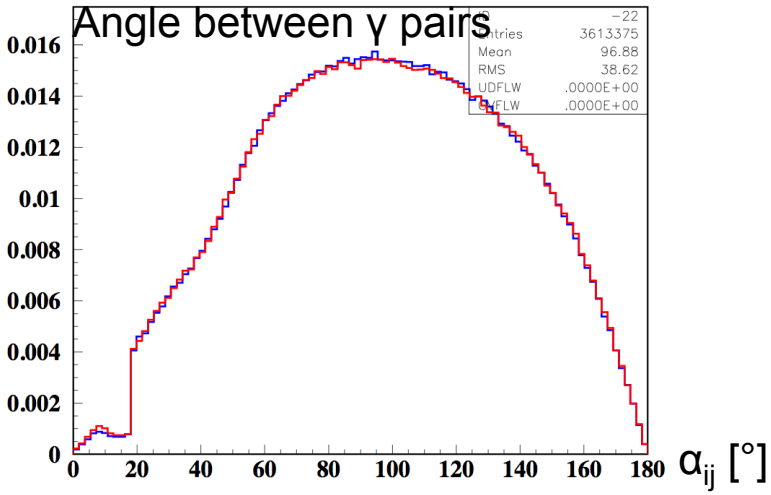
1) $\phi \rightarrow \eta\gamma$ with $\eta \rightarrow 3\pi^0$ (fully neutral channel)
2) $\phi \rightarrow \eta\gamma$ with $\eta \rightarrow \gamma\gamma$ (fully neutral channel) -> in progress
3) Lifetime of K_S with $K_S \rightarrow \pi^+\pi^-$ (charged channel)
4) $K_L \rightarrow 3\pi^0$ (mixed channel) -> in progress

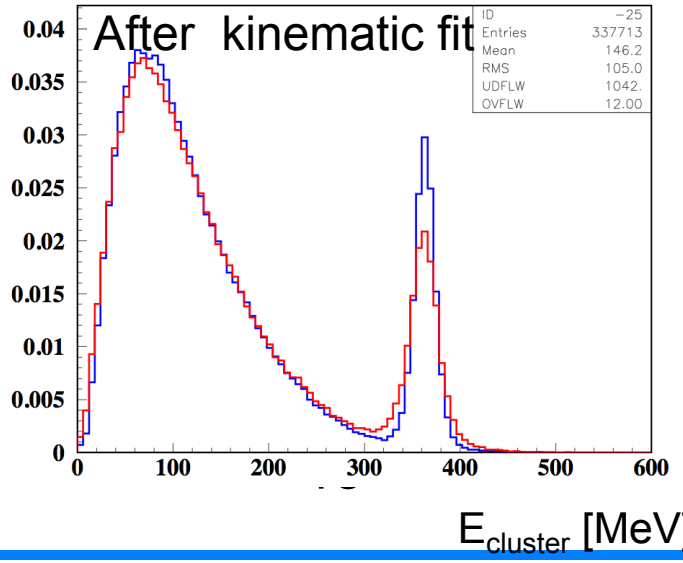
Data quality benchmark (1): $\phi \rightarrow \eta\gamma$ with $\eta \rightarrow 3\pi^0$

- Neutral rad w/ N_{prompt} > 5 clusters
- To select $\phi \rightarrow \eta\gamma$ with $\eta \rightarrow 3\pi^0$ (recoil $\gamma \Rightarrow$ 363 MeV)



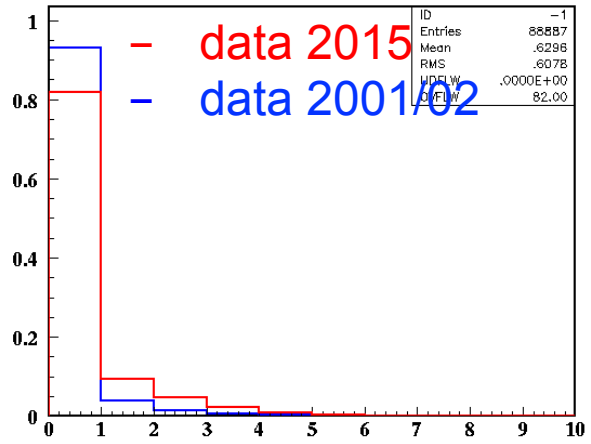




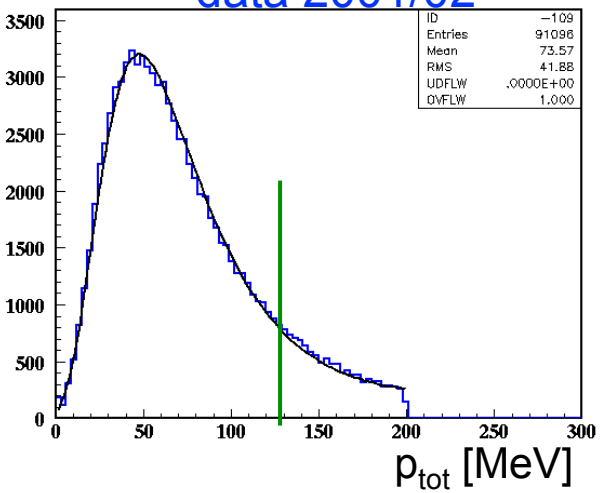


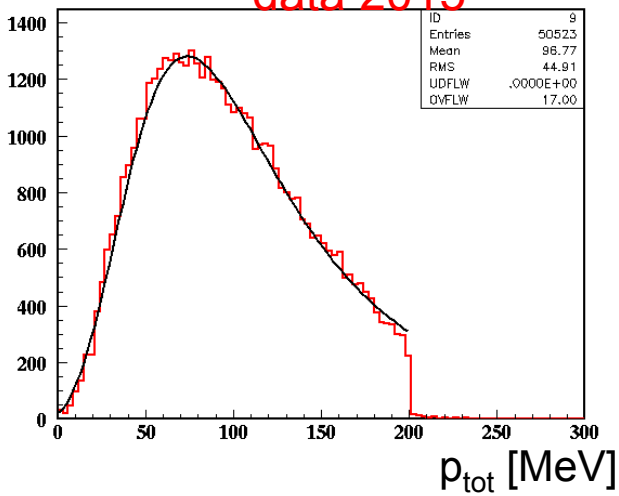
Data quality benchmark (1): $\phi \rightarrow \eta\gamma$ with $\eta \rightarrow 3\pi^0$

- Losses from Event Classification (ECL) Filter cuts



Cut: N_{tracks} (associated to cluster) = 0
⇒ ~ 20% loss





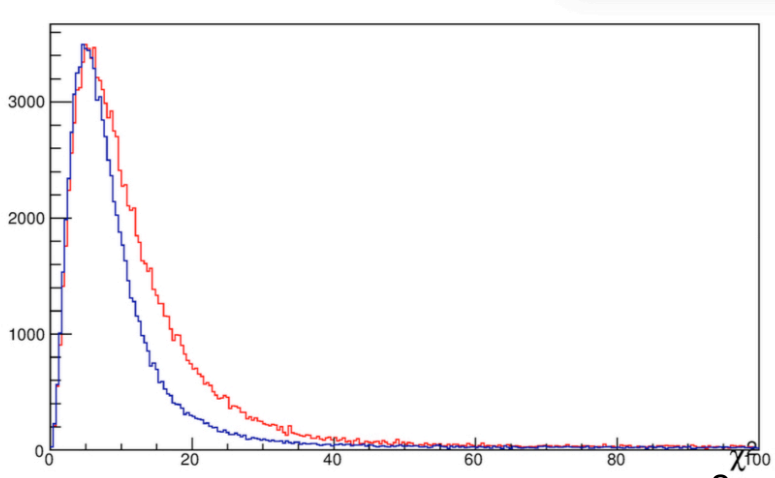
Cut:
p_{tot}(prompt) < 200 MeV
⇒ ~ 12 % loss

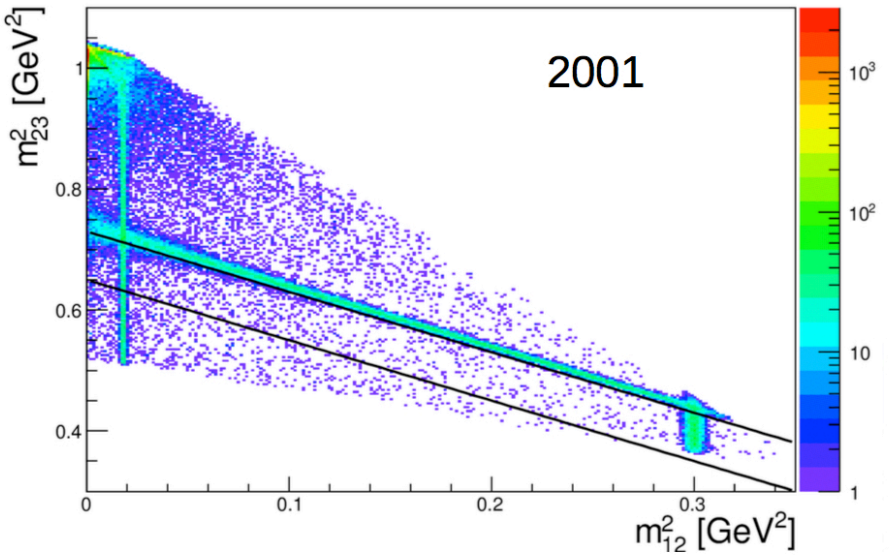
- ECL routine to be modified, by removing the p_{tot} cut and by redefining the N_{tracks} cut
- **A modified ECL routine with "bunching" tech. recovers ~97% of the losses** (prelim.)

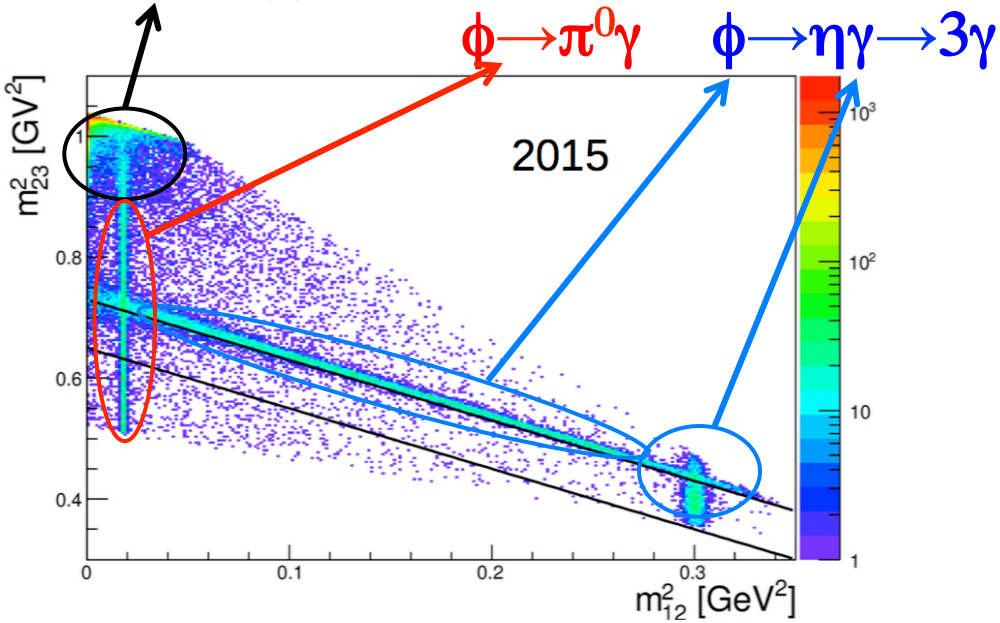
Data quality benchmark (2): $\phi \to \eta\gamma$ with $\eta \to \gamma\gamma$

Work in progress

- E1 < E2 < E3
- Kinfit $\chi^2 < 35$
- Cuts to select eta and pion peaks







Data quality benchmark (2): $\phi \to \eta\gamma$ with $\eta \to \gamma\gamma$

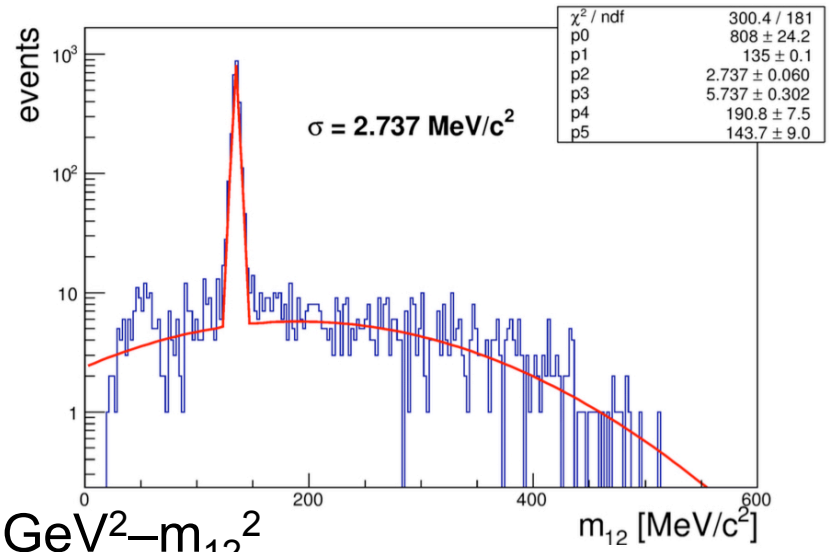
Work in progress

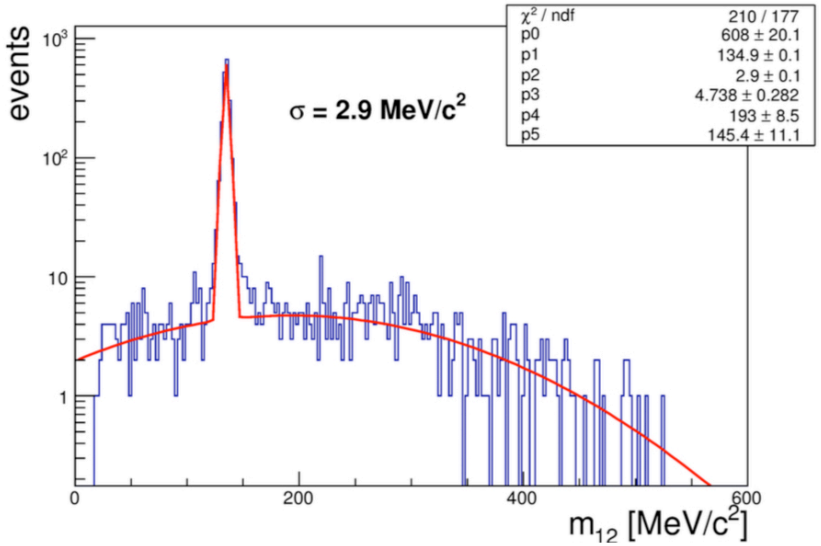
2001

2015

π^0 peak

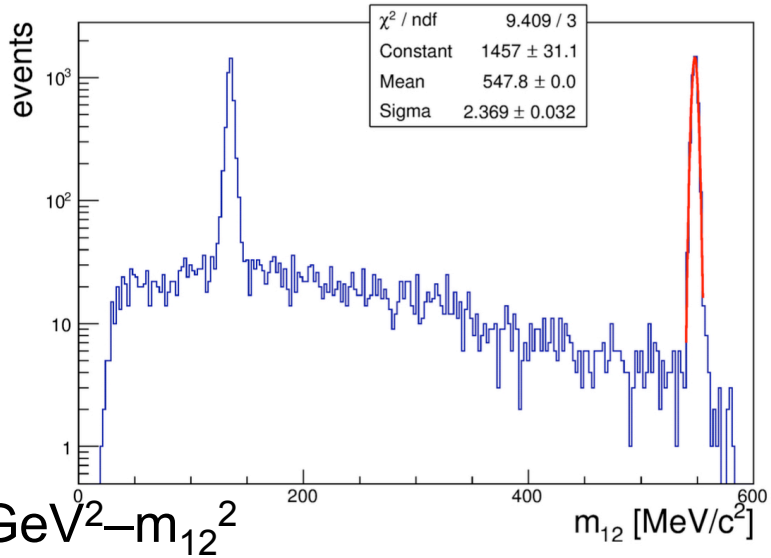
$m_{23}^2 < 0.65\ GeV^2 - m_{12}^2$

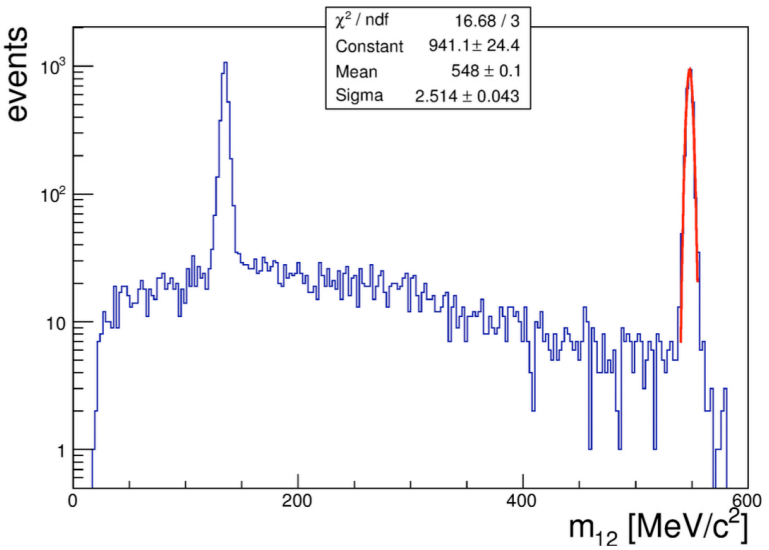




η peak

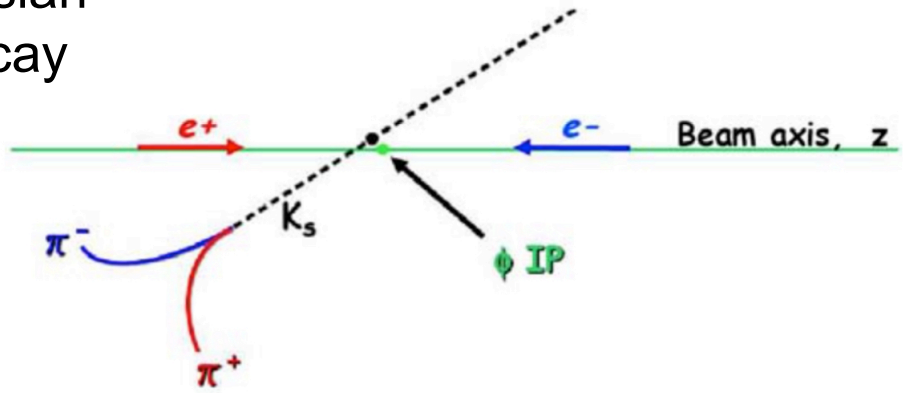
$m_{23}^2 < 0.73\ GeV^2 - m_{12}^2$

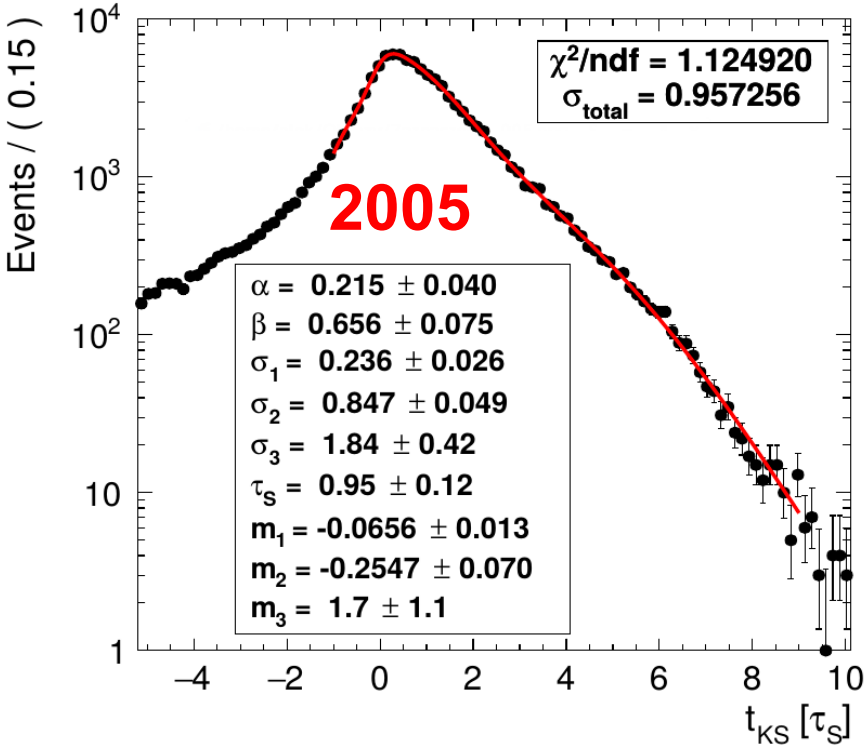


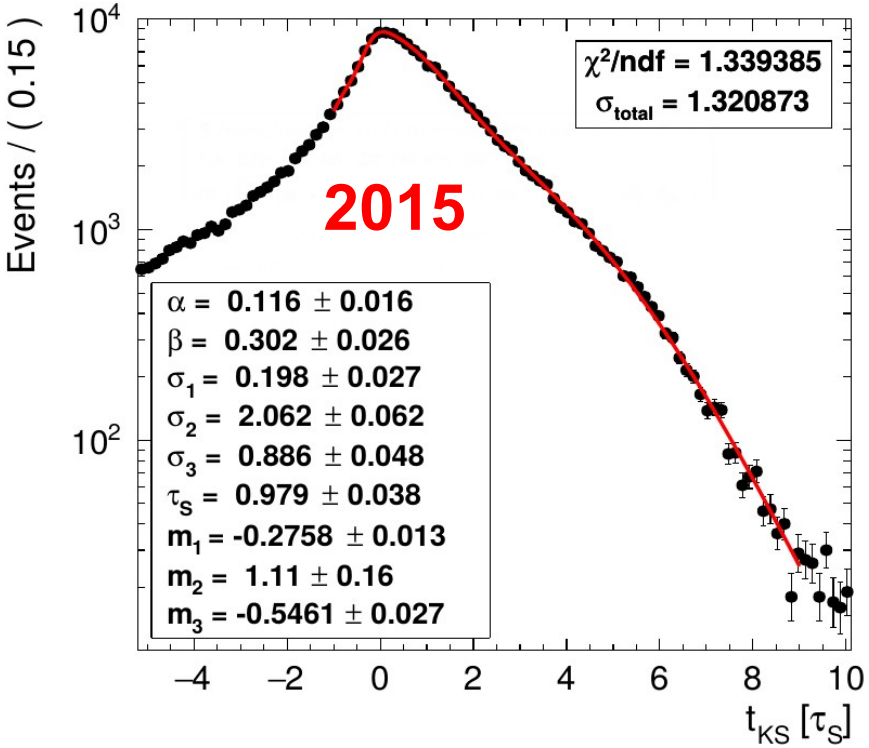


Data quality benchmark (3): K_S lifetime with $K_S \to \pi^+\pi^-$

- Exponential function folded with a triple gaussian
- Time calculated from the projection of the decay length on the KS momentum direction (negative tail due to resolution)
- Better resolution and efficiency expected from IT tracking

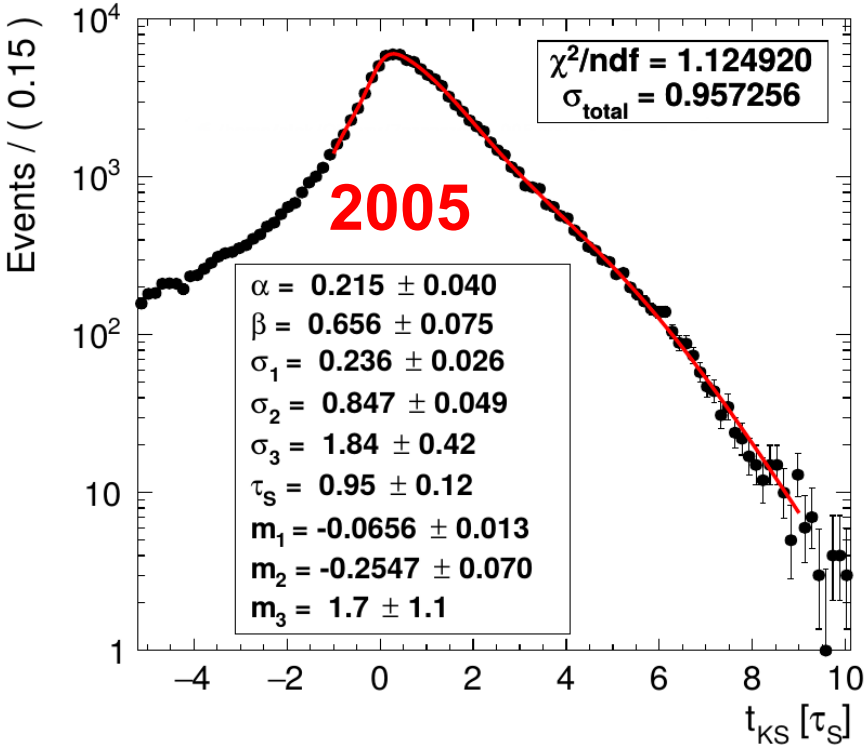


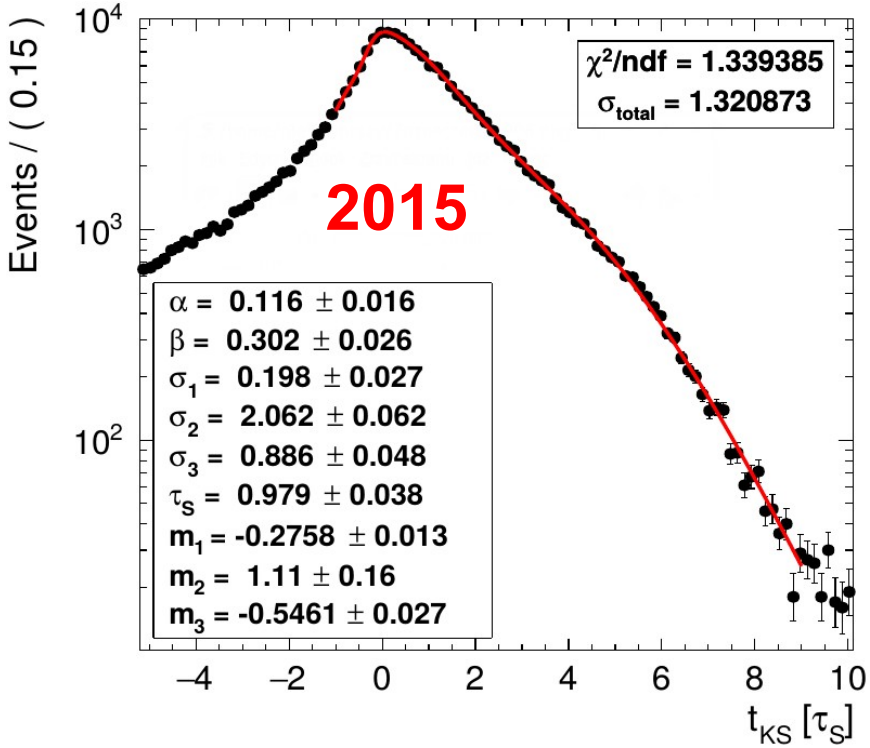




Data quality benchmark (3): K_S lifetime with $K_S \to \pi^+\pi^-$

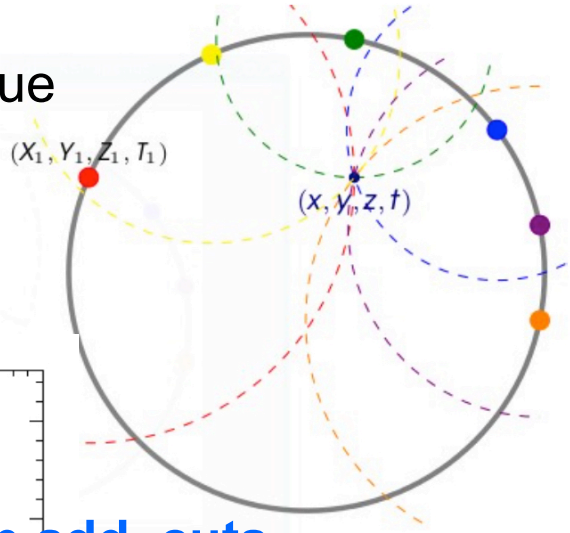
	2005	2015
χ^2/ndf	1.12	1.34
σ_{TOT} (τ_S)	0.96 ± 0.16	1.32 ± 0.05
K_S lifetime (τ_S)	0.95 ± 0.12	0.979 ± 0.038

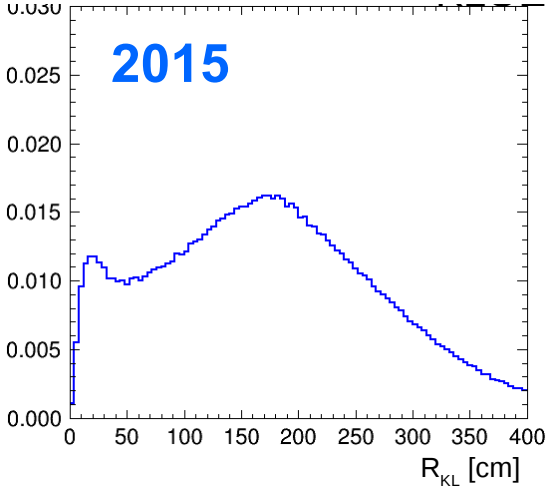


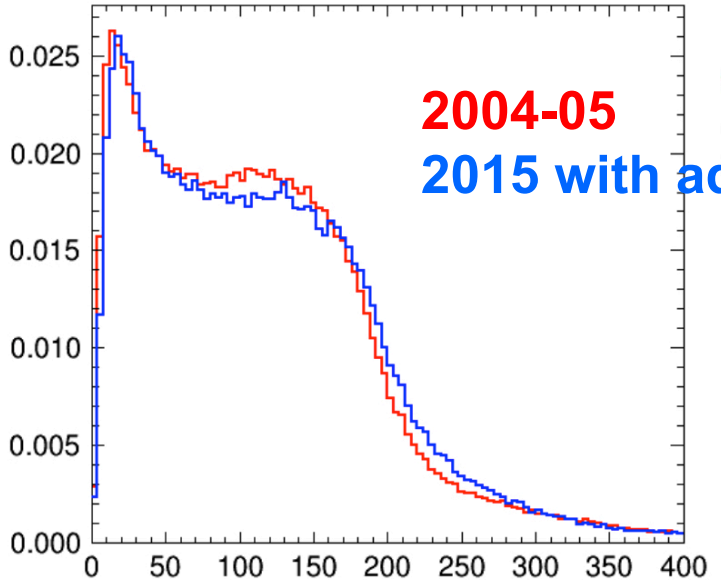


Data quality benchmark (4): $K_L \rightarrow 3\pi^0$

- New method to recostruct the $K_L \rightarrow 3\pi^0$ decay vertex inside the drift chamber volume by using a “GPS” technique (and without a K_L tag from $K_S \rightarrow \pi^+\pi^-$)
- Additional cuts to reject background:
  θ in [20,160] deg and t_{last}-t_{first} < 15 ns
- First step to select:
  $K_L \rightarrow 3\pi^0$, $K_S \rightarrow \pi l \nu$







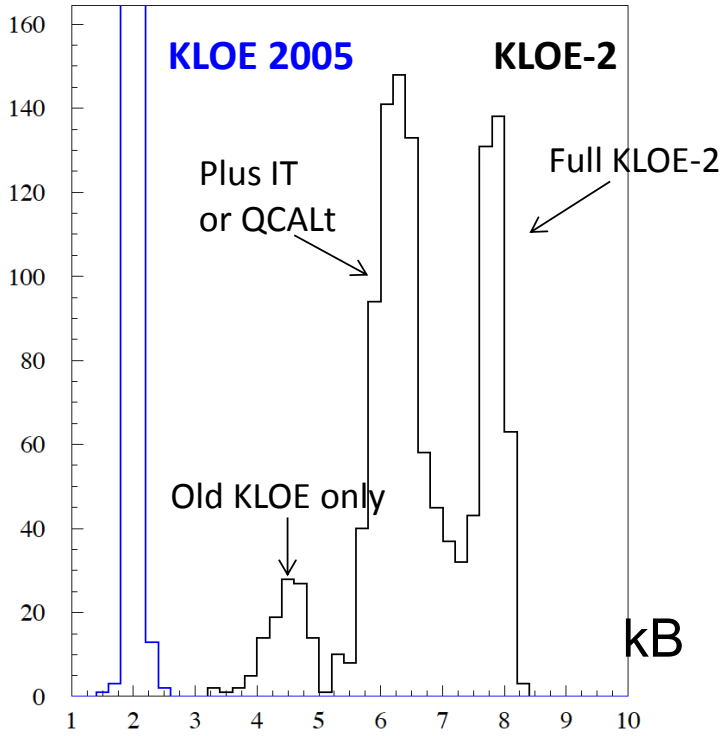
Work in progress

- This is a key ingredient for testing CPT symmetry in transition processes (never done before and possible only at KLOE)

  J. Bernabeu, A.D.D., P. Villanueva: JHEP 10 (2015) 139

Data reduction (I)

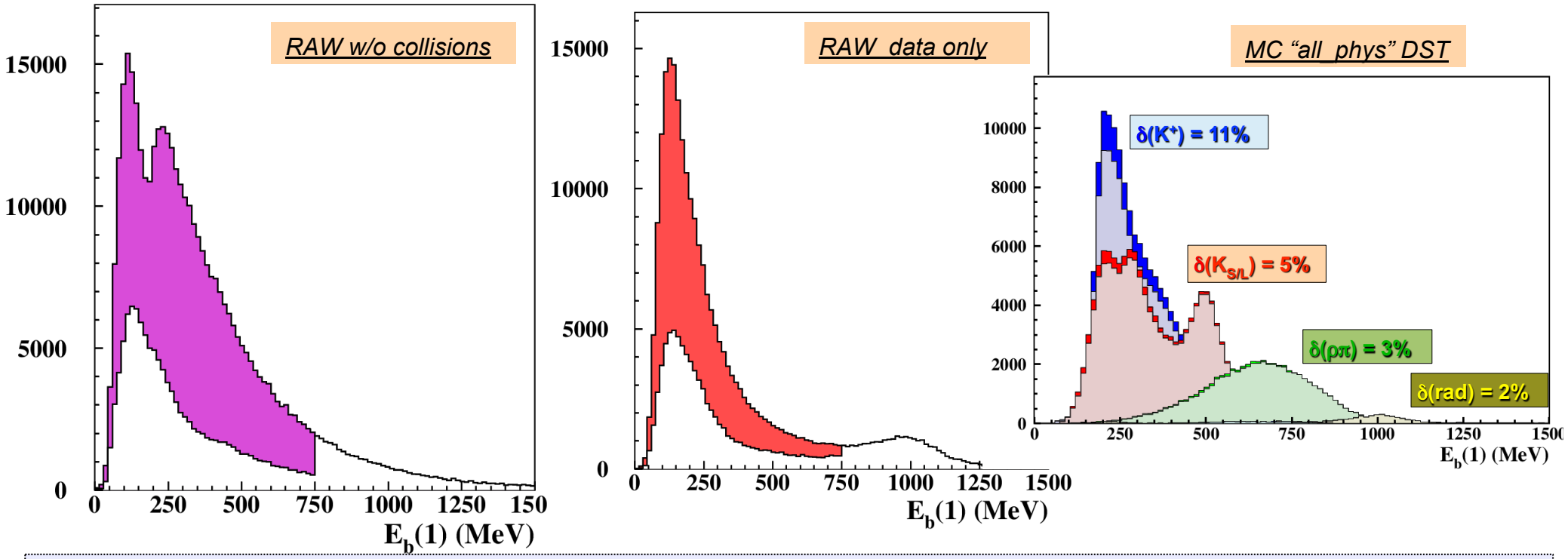
Data throughput increased by a factor 13 with respect to 2005:
Event size: 2.1 kB => ~8 kB
Trigger rate: 3 kHz => ~10 kHz
Data volume for 1 fb^{-1}: 46 TB => ~550 TB
=> with the new online/offline machines configuration and the new technology tape drives (10 TB/tape) it is possible to store 1 PB/year



Possible actions for data reduction:

- Increase the zero suppression window of the EmC
  => done from 3 to 4 σ : few % effect
- Increase the trigger thresholds, in particular in the forward region. If we trigger on barrel only we almost halve the trigger rate
  => studies on some key physics channels show a significant reduction of signal events (e.g. loss of ~40% of K_S->πeν events with barrel trigger only)
- Implement a real level 3 filter (or an offline filter) to reject by software part of the machine background evts **=> under study: reduction of >50 % possible (see next slide)**

Data reduction (II)



"Bunching" and simple topological cuts on maximal bunch energy events $E_b(1) < 750$MeV. Shaded regions represent the discarded events.

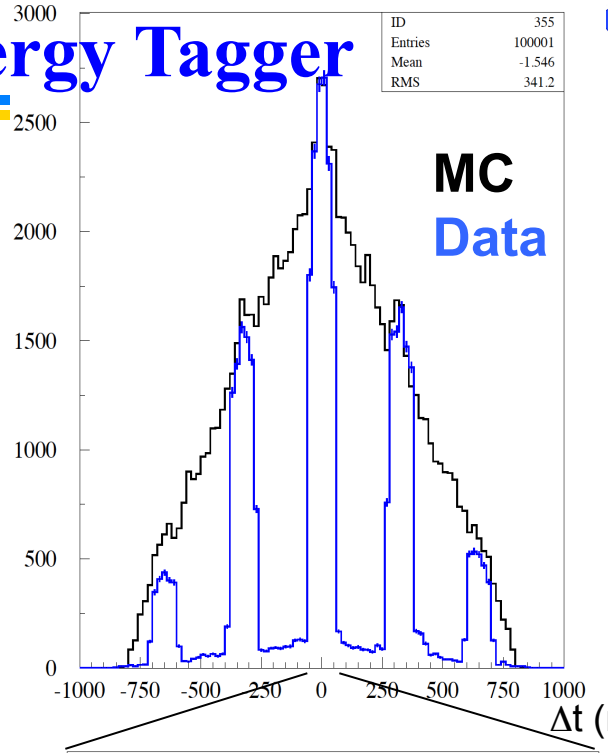
RAW event number reduction **61%** on **BKG: Run 76943 (w/o collisions Jun 2015)** and **56%** on **Run 76024 (May 2015)**

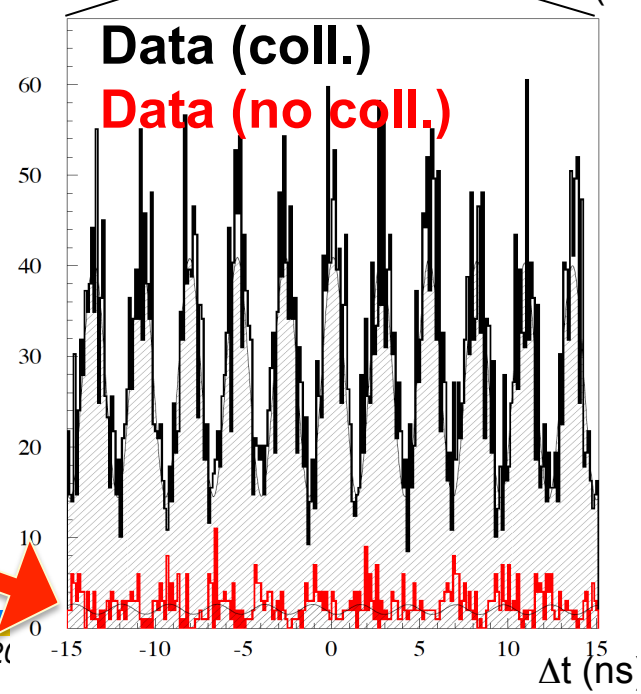
CPU mean time per event reduced by 30% using filter

Commissioning of new detectors: High Energy Tagger

- Data selection
  - For each KLOE trigger, TDC (multihit) infos from 2.5 DAFNE turns are acquired
  - For each HET station, single-plastic scintillators AND the longest finger with full acceptance, must be present with same time information (valid hit)
  - After a synchronization procedure of both HETs, events with hits in both stations are selected
  - Maximum HET-HET time delay is ~810 ns (we select a part of these for our studies)

- Hit origin
  - Most events are from Bhabha scattering, with only one e- or e+ tagged
  - The delay distribution is what we expect from 2 of these events within 810 ns
  - Most events are NOT detected by KLOE. The acquisition is determined by the presence of other interactions in the time window of interest
  - Observed rate is in agreement with MC evaluation within 30%
  - **The contribution from intra-bunch scattering is less than 10%. It has been measured with a NOT-COLLIDING (out-of-phase) BEAMS run**





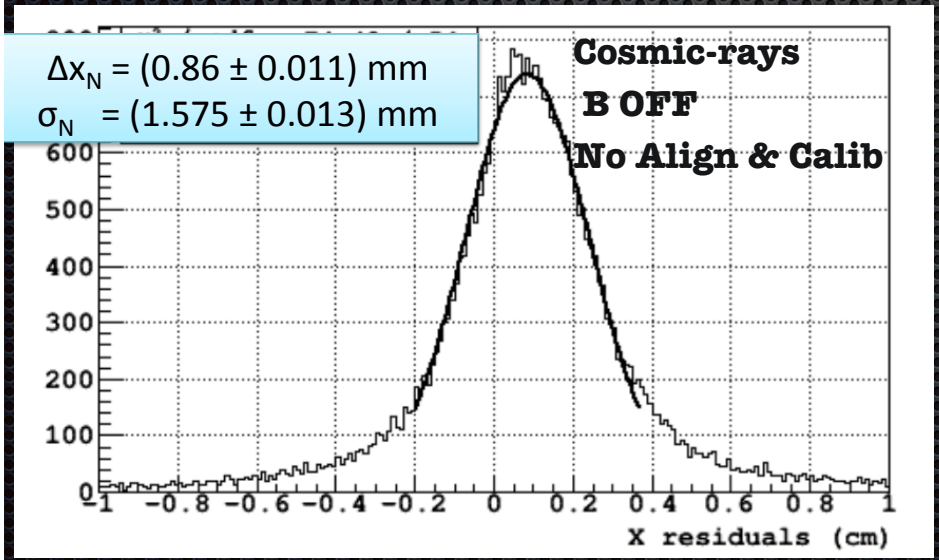
9% intra-bunch scattering contribution

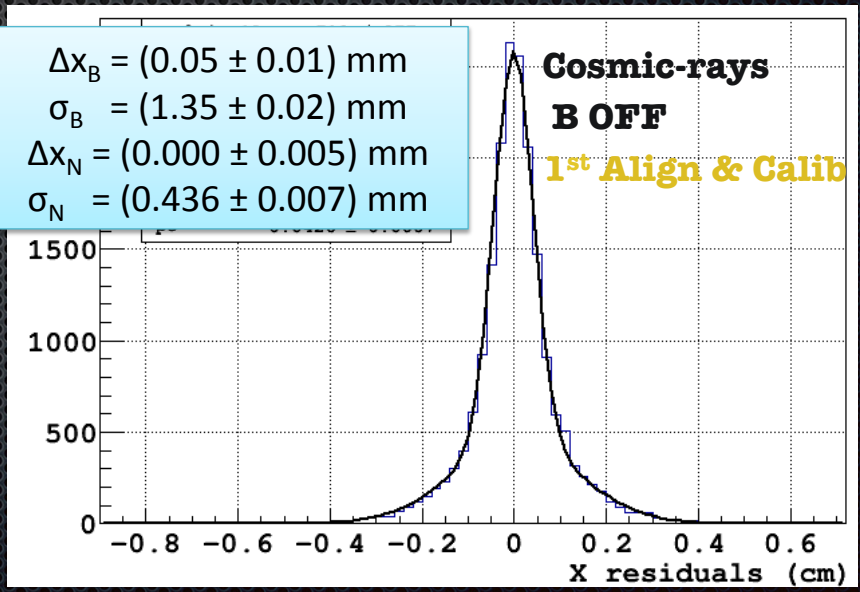
Commissioning of new detectors: Inner Tracker

- Cosmic-ray muons B OFF: 1st Align & Calib

Calibration of Non-radial track effect

- Resx = 1.5 mm => 440 μm
- Resy = 280 μm => 240 μm
- Resz = 3.6 mm => 1.1 mm
- Δx = 860 μm => 50 μm
- Δy = - 50 μm => -50 μm
- Δz = 2 mm => 5 μm
- Similar results obtained for all layers





Convolution of DC + IT resolution

Commissioning of new detectors: Inner Tracker

◎ Cosmic-ray muons B OFF: 1st Align & Calib

Calibration of Non-radial track effect

- Resx = 1.5 mm => 440 μm
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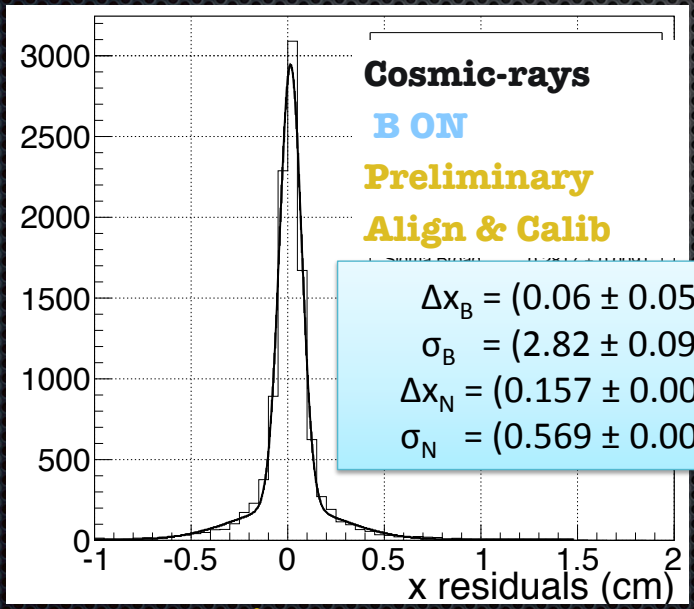

Convolution of DC + IT resolution

◎ Cosmic-ray muons B ON

Calibration of Non-radial & B-field effect

Preliminary result with B OFF align & calib and average B-field correction

- Resx = 570 μm
- Resy = 300 μm
- Resz = 2 mm

Commissioning of new detectors: Inner Tracker

- Cosmic-ray muons B OFF: 1st Align & Calib

Calibration of Non-radial track effect

- Resx = 1.5 mm => 440 μm
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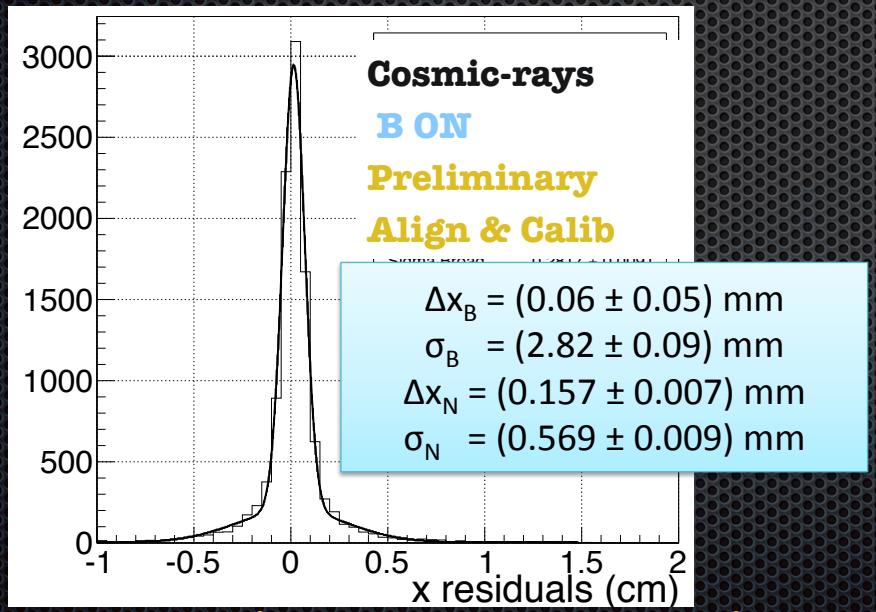


Convolution of DC + IT resolution

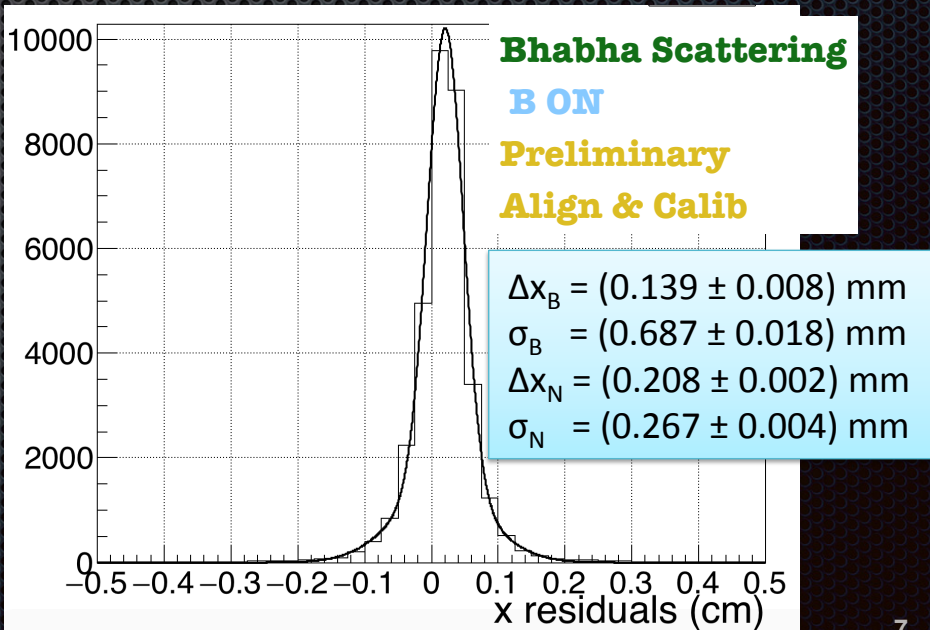
- Cosmic-ray muons B ON

Calibration of Non-radial & B-field effect

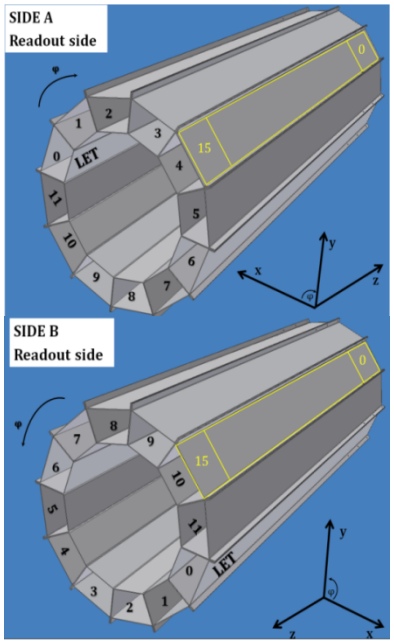
Preliminary result with B OFF align & calib and average B-field correction

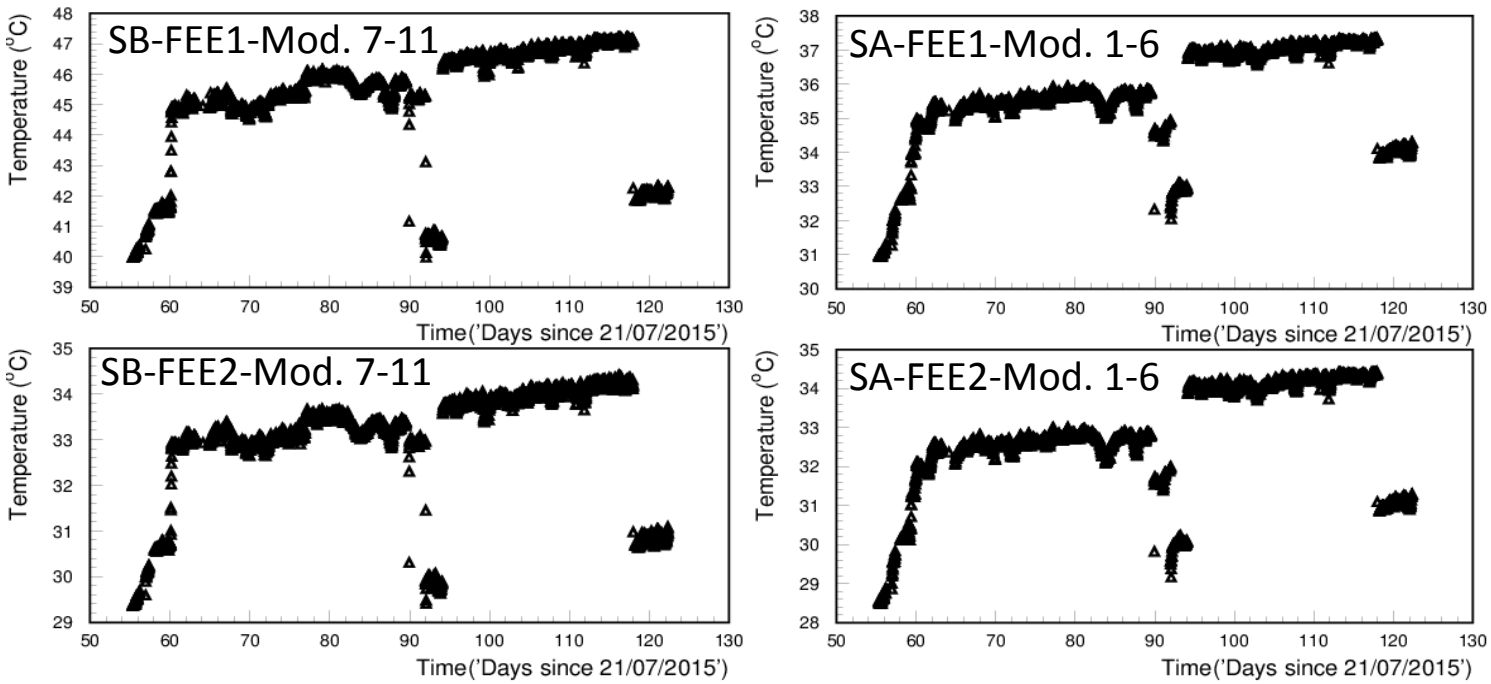
- Resx = 570 μm
- Resy = 300 μm
- Resz = 2 mm

- First look at Bhabha scattering
  - Resx = Resy ≈ 400 μm
  - Resz = 2 mm



Commissioning of new detectors: QCALT calorimeters





- Hardware:
  - Temperatures are under control, further decrease possible with air aspiration system
  - Monitoring of the air flux and temperature ready (installation during christmas stop)
- Software:
  - Monitoring: ready
  - Offline: element and hit information ready and in the libraries
  - Time calibration with cosmics, equalization routines: almost ready

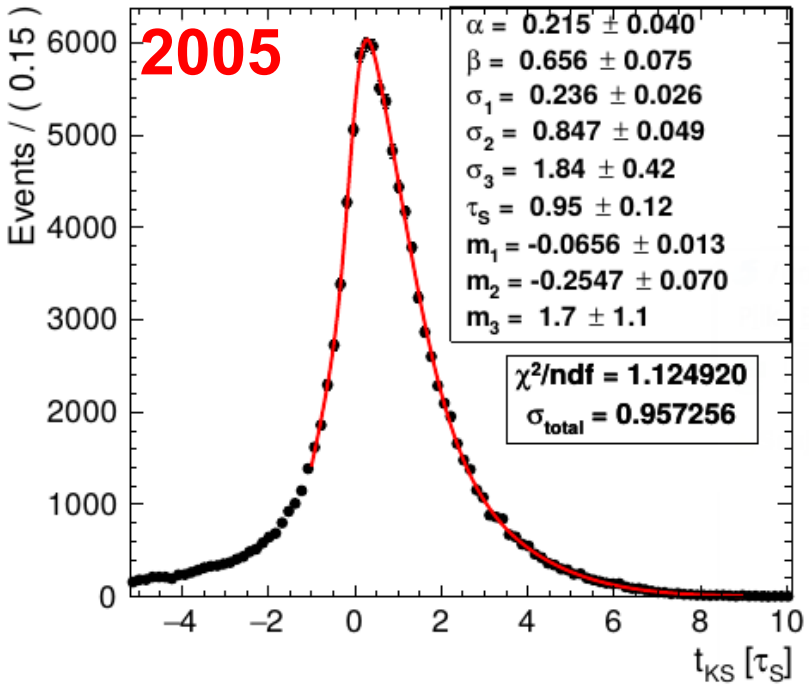
Conclusions

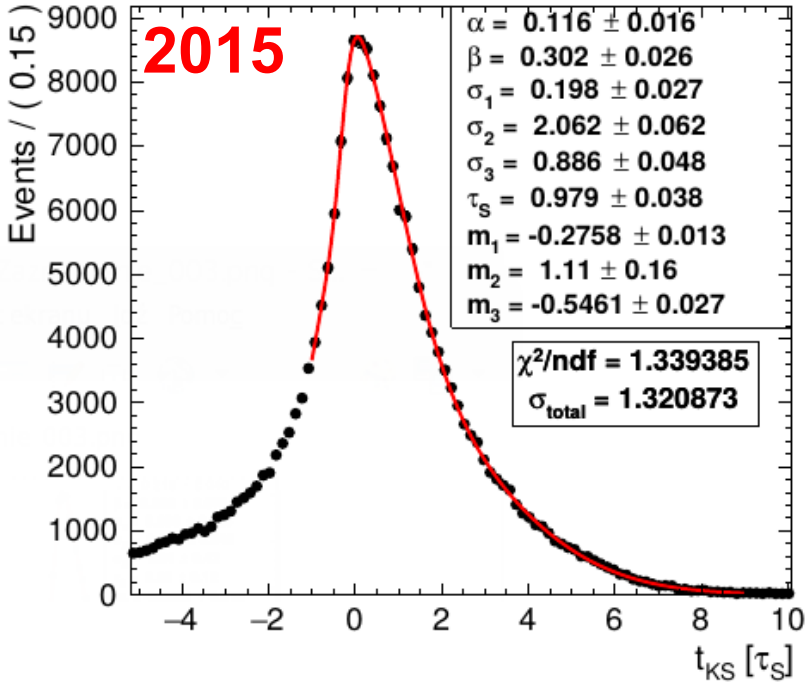
- Data taking (RUN-II) started with KLOE-2 detector fully operational: L delivered up to now ~ 400 pb^{-1}.
- A new milestone has been set after discussion with DAFNE, LNF director and CSN1 president and referees to meet the minimal KLOE-2 requirements of $L > 5\ fb^{-1}$ in a reasonable amount of time.
- First data quality studies indicate the good quality of the collected data and the possibility to “make good Physics” with them.
- The inner tracker operates now in a safer mode; alignment and calibration studies are progressing as scheduled.
- HET, QCLAT, and other detectors commissioning is going on.
- Data reduction studies are going on; reduction of ~ 50% with a simple filter possible
- The KLOE-2 **manpower issue remains critical**, but prospects for the near future are positive thanks to the help of INFN management.
- In the meanwhile:
  - a new group from Novosibirsk joined the collaboration.
  - all institutions participating to KLOE-2 officially confirmed their commitment to the KLOE-2 project both in terms of active participation to the data taking, and of strong interest in data analysis after data taking completion.

SPARE SLIDES

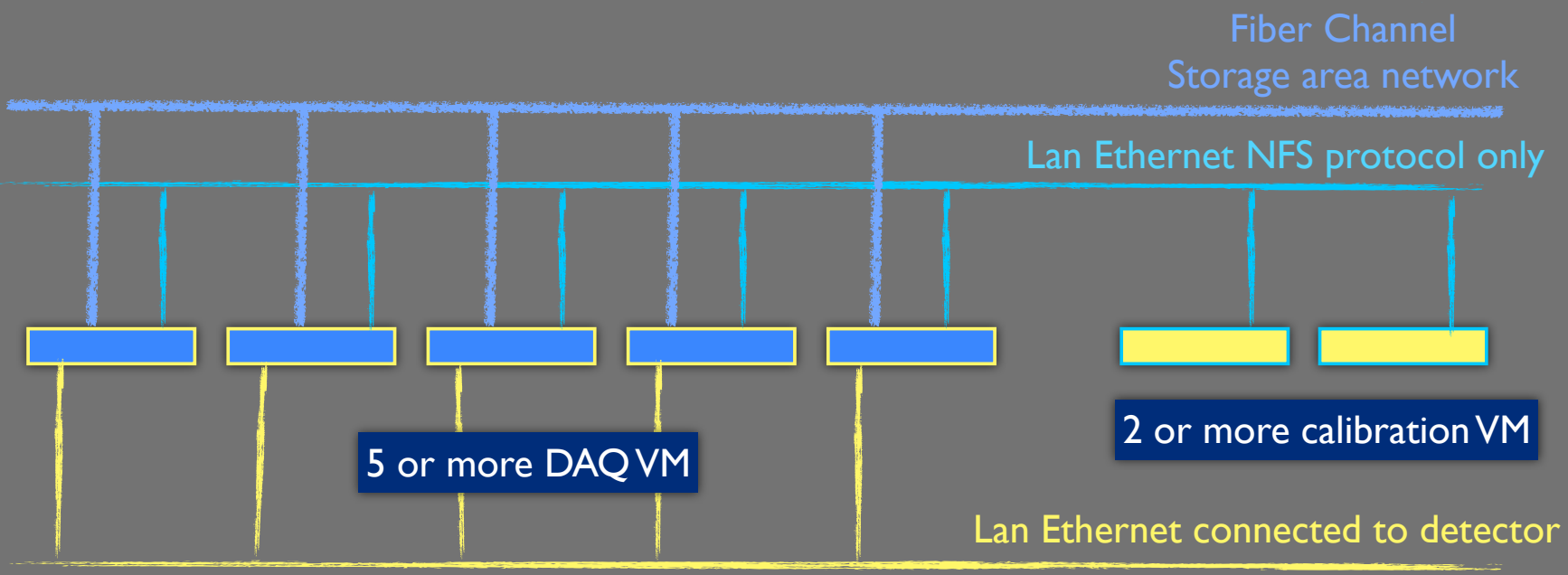
Data quality benchmark (3): K_S lifetime with $K_S \to \pi^+\pi^-$

	2005	2015
χ^2/ndf	1.12	1.34
σ_{TOT} (τ_S)	0.96 ± 0.16	1.32 ± 0.05
K_S lifetime (τ_S)	0.95 ± 0.12	0.979 ± 0.038





KLOE-2 new DAQ (I)

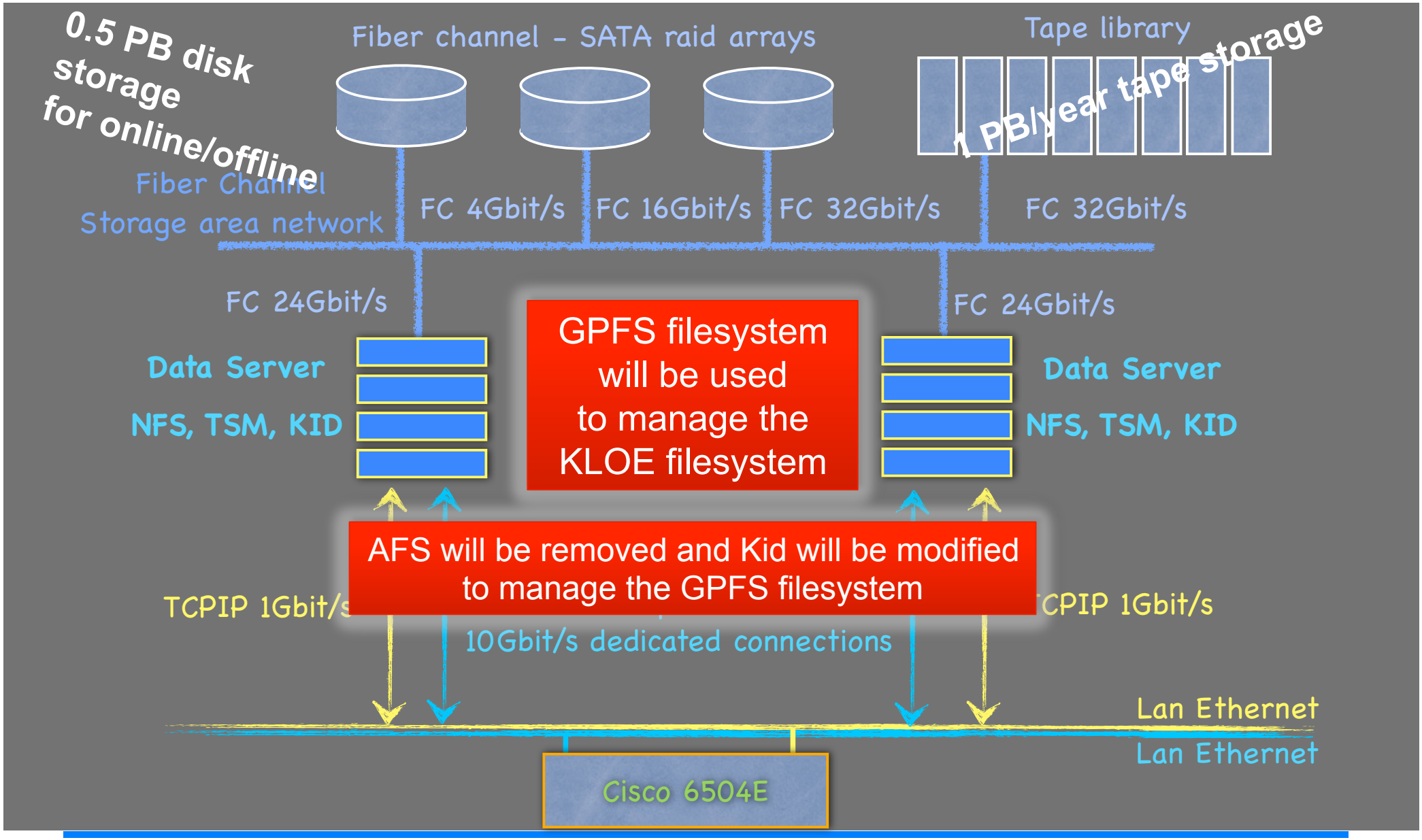


New configuration with 2 offline Power 7 servers

Offline SAS disk has been moved to online machines

The new online daq area is about 24TB - 8 times more than before
Increased overall system flexibility with Offline/Online integration

KLOE-2 new DAQ (II)



Commissioning of new detectors: High Energy Tagger

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)