$\gamma^*\gamma^* \to \pi^0$ Search

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Analysis Status

⋆ **What we did so far**:

- Analysis of a first reconstructed data sample of 500 pb^{-1} performed $\rightarrow$ no evidence of $\gamma\gamma \rightarrow \pi^0$ processes established both on DoubleArm and SingleArm analysis.
- MVA performed on the data sample of 550 pb^{-1} . No clear evidence of the tagged signal found also from the events in the signal region. The analysis is based on the info of the two clusters associated to π^0 candidates.
- Detector efficiency measured channel by channel. Runs with the scintillators at different distances used to peform the measurement. Rate comparison between different scintillators in the same position gives their relative efficiency.

In Progress

- Bhabha cross section measurement at very low angle and progress in BBBREM validation $\rightarrow$ energy acceptance of the HET
- Reconstruction of a new data sample of 500 pb^{-1} after replacement of the old discriminators. Selection criteria revised for the SA sample.
- New criteria for data reduction adopted (applied also to the first 500 pb^{-1} sample) to study more details on the candidates.
- Bckg studies: three data samples of 20 pb^{-1} each reconstructed to compare 2015-2018 backgrounds with 2005 ones before CGEM installation

Plans

⋆ **Plans for the analysis:**

- Finalize Bhabha cross section measurement
- Perform MVA again: this time the training will be done per scintillator channel group
- Perform analysis of all reconstructed data samples

- Reconstruction of about 100 $pb^{-1}$of data without requiring in the selection a particular topology of clusters in KLOE $\rightarrow$ exclude evidence of other channels that could be tagged by HET
- Acceptance studies: preparation to acquire data during Siddharta run $\rightarrow$ to derive impact of KLOE magnetic field on HET energy acceptance

New pre-selection : SA and DA

Old selection :
2TB of pre-filtered data produced

Double-Arm events (DA):

coincidence btw HET stations (± 1 bunch)

control sample of events with $2 \leq \Delta T_{ep} \leq 7$ bunches

Single-Arm events (SA):

HET ele/pos events in time with KLOE trig ($-3 \leq \Delta T_{\mathrm{tri-clu}} \leq 8$ bunches)

HET ele/pos events in time with a bunch with 2 clu in the barrel $20 < E_{clu} < 300$ MeV

$\Delta T_{\mathrm{KLOE_{clu}-HET}} \leq 4$ bunches

New selection :
almost 7 TB of prefiltered data produced

Double-Arm events (DA):

Hits in both taggers with $|\Delta T_{ep}| < 12$ns

Single-Arm events (SA):

HET ele/pos events in time with the corresponding trigger acquired by the tagger station with $|\Delta T_{\mathrm{tri-hit}}| \leq 8$ bunches

HET ele/pos events in time with a bunch in KLOE with 2 clusters in the barrel with $|T_{\mathrm{trig}} - (T_{\mathrm{clu}} - R_{\mathrm{clu}}/c)| < 30$ns ,
$20 < E_{clu} < 300$ MeV and $cos\theta_{\gamma_1\gamma_2} < 0.8$

Selection criteria improved:

Time distance between KLOE and HET hits not imposed anymore

Time distance between HET hits and trigger imposed independently for the two stations

Bunch with 2 clusters search extended

New pre-selection : SA and DA

```
   Production - Summary


Lista1 - 107 run - 6345 files -    97.417 pb^-1
         hbook    1052 GB
         rootples  545 GB
         Reduced rootples 68  GB

Lista2 - 109 run - 6287 files -   102.064 pb^-1
         hbook     927 GB
         rootples  484 GB
         Reduced rootples 69.5 GB


Lista3 - 111 run - 6207 files -   102.082 pb^-1
         hbook    1070 GB
         rootples  551 GB
         Reduced rootples  85 GB

Lista4 - 111 run - 6411 files -   106.041 pb^-1
         hbook    1206 GB
         rootples  619 GB
         Reduced rootples  95 GB

Lista5 - 108 run - 5498 files -   102     pb^-1
         hbook    2295 GB
         rootples 1175 GB
         Reduced rootples 135 GB
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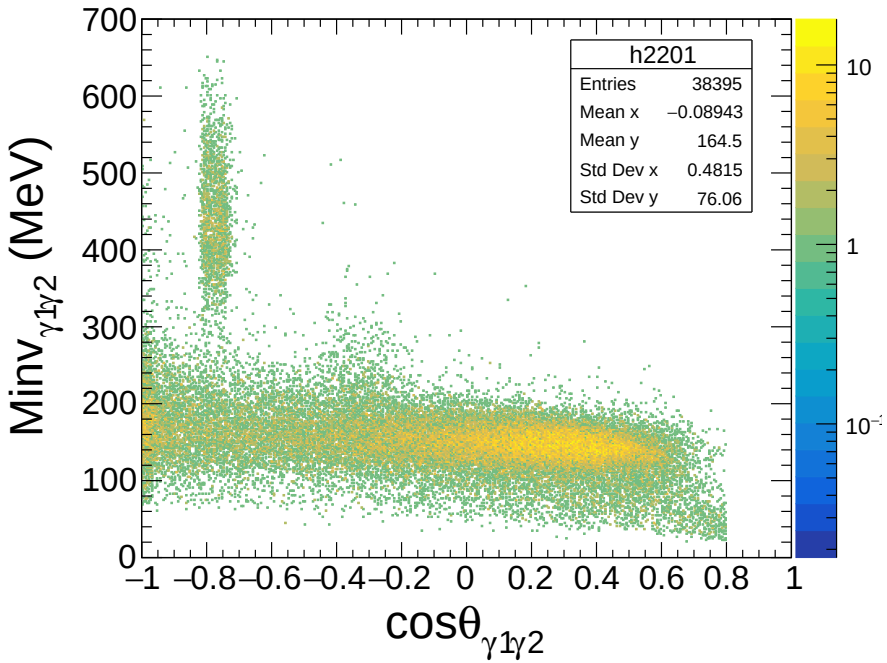
New data reduction

New data reduction creteria applied to the first and the second samples of 550 pb^{-1}



Old data reduction: we processed info from bunches with 2 clusters

→ no significant difference between analyzed and control samples

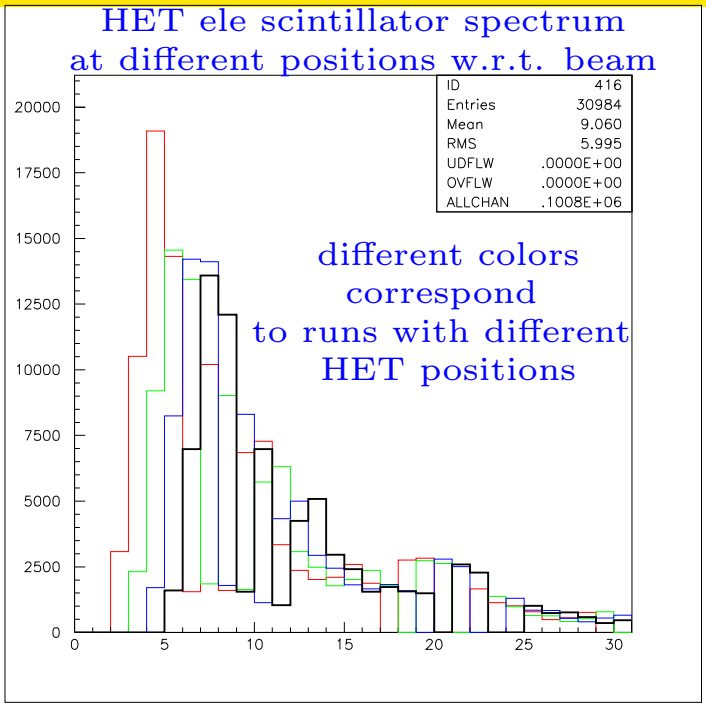
New data reduction : we processed more info on the events (time, energy, position of the other clusters, if any)

→ test new criteria for background suppression.

reduced rootple size : 452 GB

Efficiency Measurements: method

Measurements of the BhaBha flux at the same distance from the beam with different HET scintillators: runs acquired with HETs in different positions wrt beam.
The measurements give the relative efficiency of each scintillator on respect one (the reference).
Ref efficiency obtained using long scintillator which covers whole x-window of all small pls.
Dependence of the efficiency of the long scintillator on the distance from the beam, taken into account.



$$\varepsilon_i = \frac{\varepsilon_{\rm i}}{\varepsilon_{\rm ref}}\varepsilon_{\rm ref} = \alpha_i \varepsilon_{\rm ref}, \quad N_{\rm long} : \sum_{i=1}^{28} \frac{N_{\rm pl_i}}{\alpha_i \varepsilon_{\rm ref}} \varepsilon_{long(i)},$$

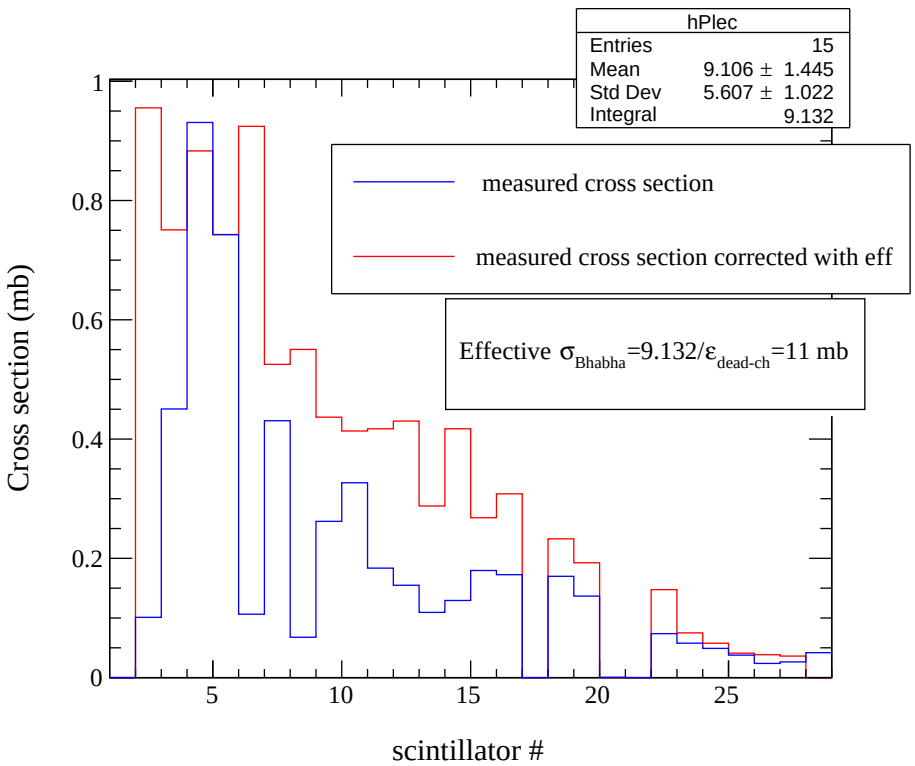
$$\varepsilon_{\rm ref} = \frac{\sum_{i=1}^{28} \frac{N_{\rm pl_i}}{\alpha_i} \varepsilon_{long(i)}}{N_{\rm long}}.$$

By correcting measured Bhabha fluxes for efficiency obtained channel by channel, and interpolating corrected fluxes for dead channels, we obtained as global efficiency for Bhabha:

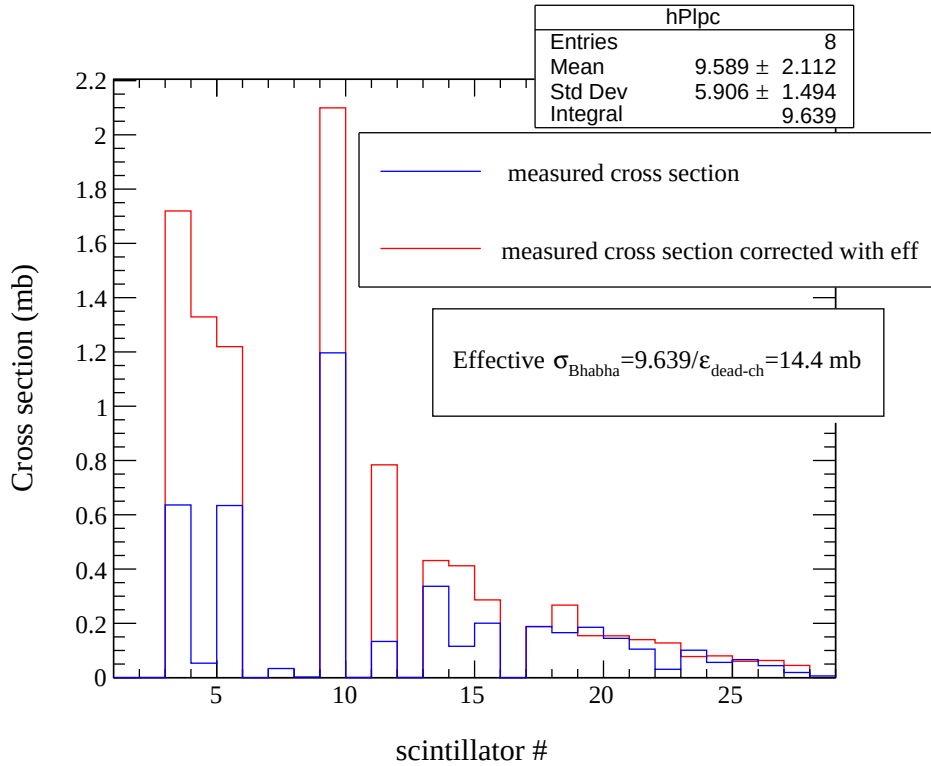
$\epsilon_{\rm HET(Bhabha)} = 0.26$ for HET ele
$\epsilon_{\rm HET(Bhabha)} = 0.30$ for HET pos

σ_{Bhabha} FORWARD ANGLES: 2016 DATA

HET ELE



HET POS



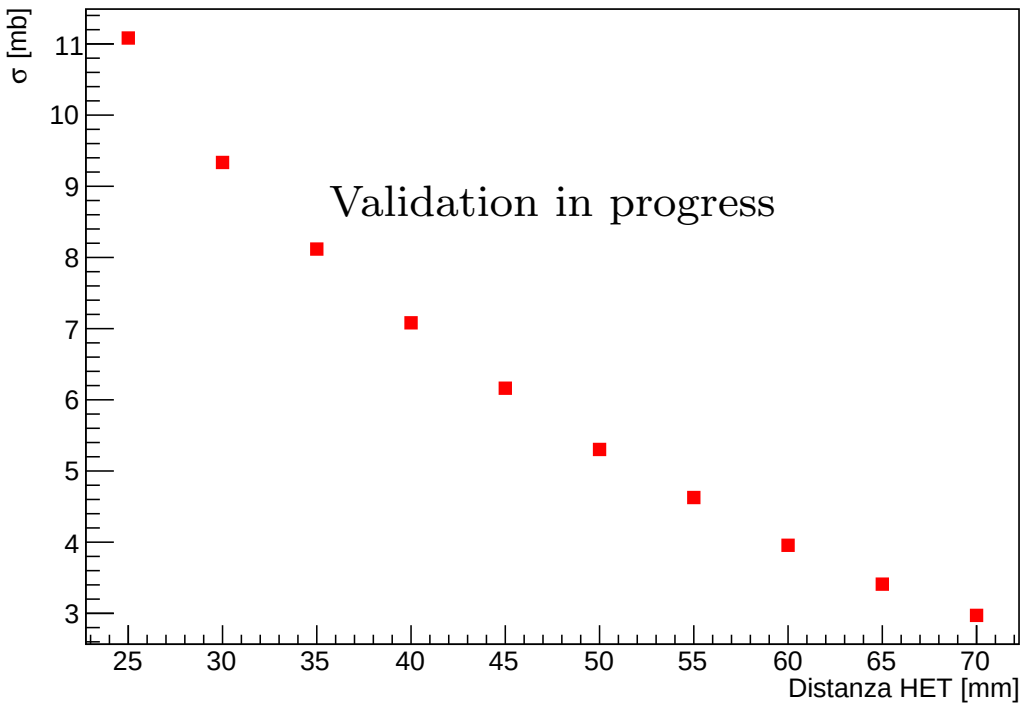
Cross section as obtained from the DAFNE luminosity measured with Bhabha at large angle by the KLOE-DAQ system

$$\sigma^{\text{ele}}_{\text{Bhabha}} = 11 \text{ mb}, \; \sigma^{\text{pos}}_{\text{Bhabha}} = 14 \text{ mb}$$

We are also studying the whole data set of runs acquired with the HET at different distance from the beam (Jan -March 2018) $\rightarrow$
new eff almost ready , some inconsistencies in the data under investigation

BBBREM validation

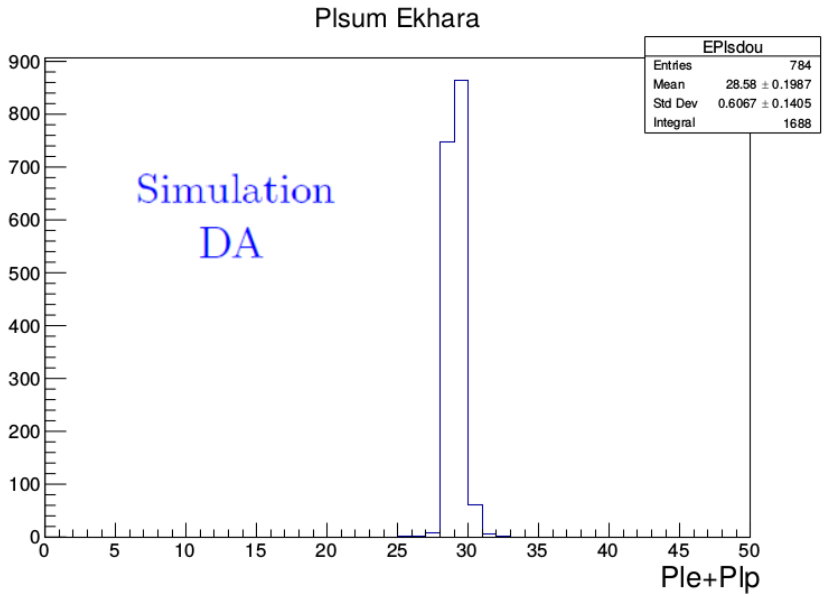
- ⋆ BBBREM generator→ able to simulate single radiative Bhabha scattering event in the very forward direction
- ⋆ Simulation performed for different distances of the HET from the beam
- ⋆ Preliminary results give an effective $\sigma^{\text{simu}}_{\text{Bhabha}} \sim 11\,\text{mb}$ for a detector at around 2.5 cm from the beam

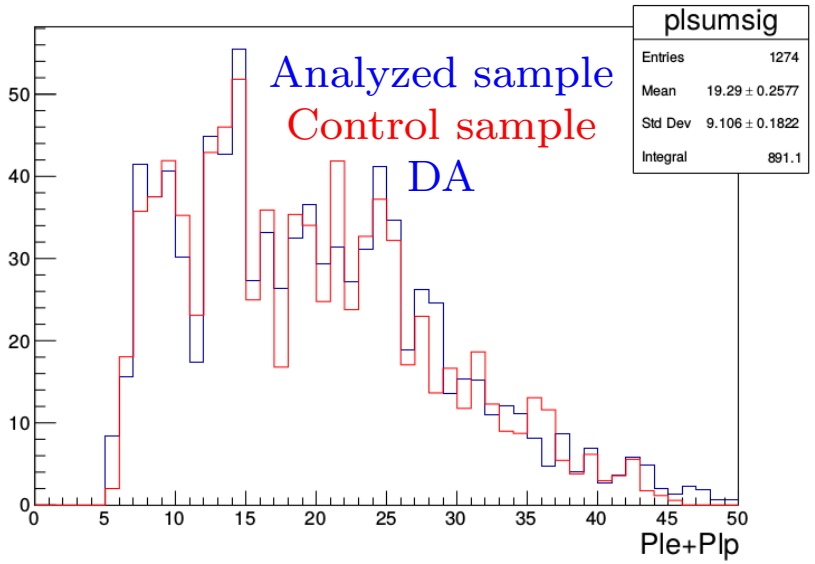


Plans: New MVA training

From simulation (Ekhara+BDSIM) → strong anti-correlation in the energy of the leptons →
very narrow distribution for leptons in the taggers expected

Data distributions are very wide →
need for a different approach for the MVA





New MVA training to be performed per scintillator channel group
→ S/(S+B) ratio expected to be different for different channels

Plans: Bckg studies

Preliminary analysis of new data → no clear criteria to suppress the bckg

KLOE05 and KLOE15-18 data samples of 20 pb^{-1} each reconstructed → same cluster selction criteria of the last reconstruction adopted

Our purpose → study bckg topologies with and without IT

Moreover, we plan the reconstruction of a new data sample of 100 pb^{-1} without any requirements on event cluster topology in KLOE → exclude other possble tagged channels

Conclusions

- ⋆ No evidence of $\gamma\gamma \to \pi^0$ processes established by the analysis of both, DA and SA events, based on a 550 pb^{-1} sample.
- ⋆ Multivariate analysis on DA and SA events on the 550 pb^{-1} sample has been completed. Again with the sample selected in the signal region we do not obtain any firm evidence for the π^0 production.
- ⋆ We completed the reconstruction of a new data sample of 500 pb^{-1} after discriminator replacement.
- ⋆ We implemented a new data reduction (also on the old data set) to evaluate other info on the candidates.
- ⋆ Efficiency of the HET stations measured channel by channel on a data set of year 2016. We are repeating the measurement on the data-set of 2017-2018, will be ready for the next SciCom meeting. Progress in BBBREM validation.
- ⋆ We reconstructed data samples of $20\,\text{pb}^{-1}$ of KLOE05 -15-18 in order to compare background before and after the installation of the IT

Conclusions

We plan:

- ⋆ to finalize Bhabha cross section measurement
- ⋆ to perform new MVA training per scintillator channel group
- ⋆ to analyze all data samples already reconstructed for π^0 search and bckg studies
- ⋆ the reconstruction of a new data sample of 100 pb^{-1} without any requirements on event cluster topology in KLOE to exclude other possible tagged channels
- ⋆ to take data with the first Siddharta run to derive the impact of KLOE magnetic field on HET energy acceptance

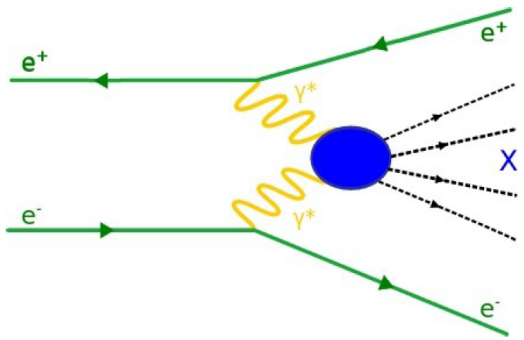
Thank You!

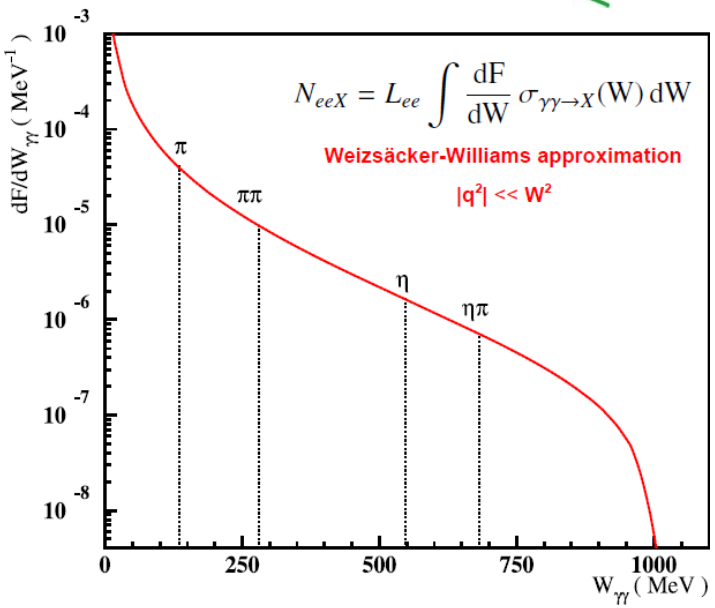
SPARES

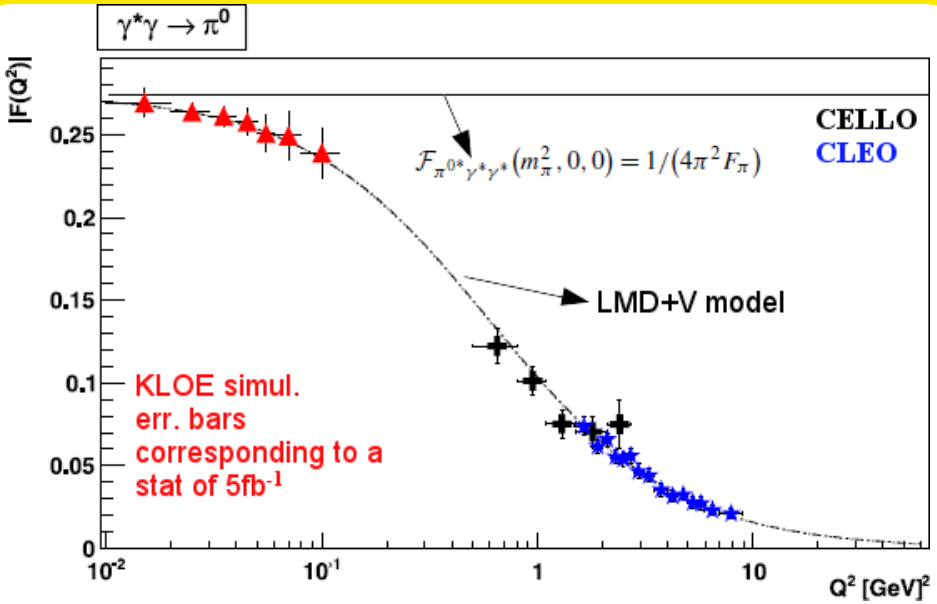
$\gamma\gamma$ Physics at KLOE-2 : Motivations

$$e^+e^- \to e^+e^-\gamma^\star\gamma^\star \to e^+e^-X$$

for quasi-real photons $J^{PC}(X) = \{0^{\pm,+}, 2^{\pm,+}\}$
$\to X = \{\pi^0, \pi\pi, \eta\}$

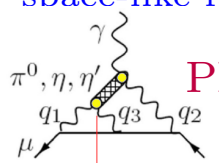






Physics goal:

- Precision measurement (1%) of the $\Gamma_{\pi^0\to\gamma\gamma}$
  $\Gamma^{Th.}_{\pi^0\to\gamma\gamma} = 8.09 \pm 0.11$eV (1.4% precision)
  $\Gamma^{Exp}_{\pi^0\to\gamma\gamma} = 7.82 \pm 0.22$ (2,8% precsion, most precise meas); $\Gamma^{PDG}_{\pi^0\to\gamma\gamma} = 7.63 \pm 0.16$eV (2% precision)
- First measurements of the $F_{\pi^0\gamma^\star\gamma}(q^2, 0)$ in the space-like region for $q^2 < 0.1\,\mathrm{GeV}^2$

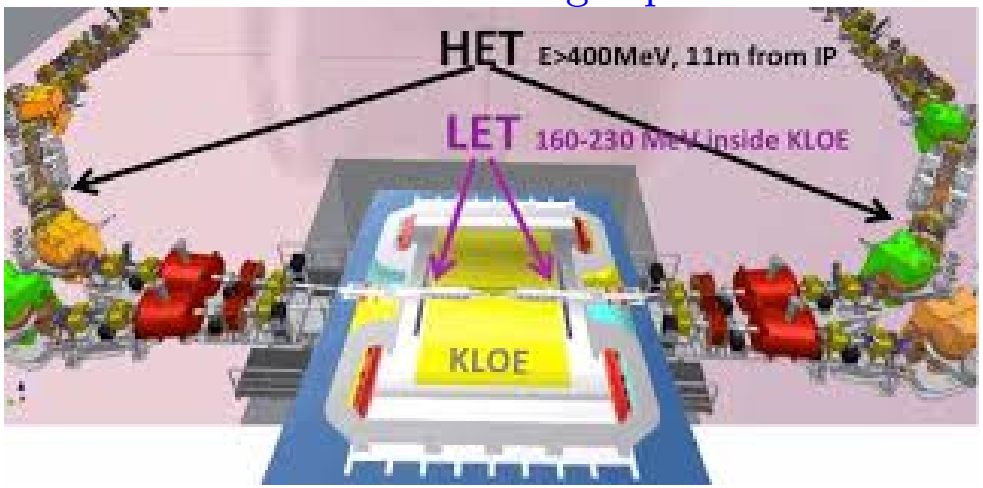


$F_{PS^*\gamma^*\gamma^*}$
Phenomenological Estimation

Physics motivation:
impact on the value and precision of the $a_\mu^{\mathrm{LbyL};\pi^0}$

The HET Detector

The HET stations are located 11m away the IP after the bending dipoles

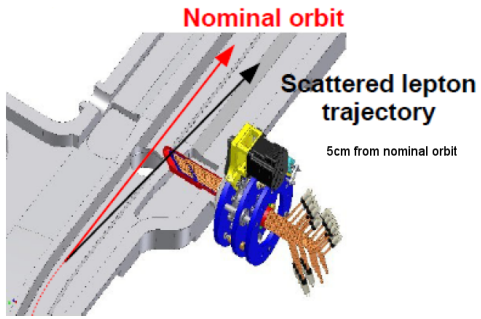


$\sigma_\theta \sim 2,5\text{mrad}, \sigma_r \sim 5\text{mm}$

$e^+ e^- \to e^+ e^- \gamma^* \gamma^* \to e^+ e^- X$

to taggers

in KLOE

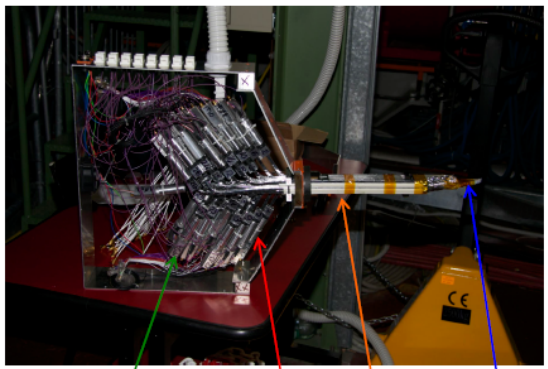


The EJ-228 plastic scintillators are inserted in roman pots: 28 of 5x6x3 mm^3

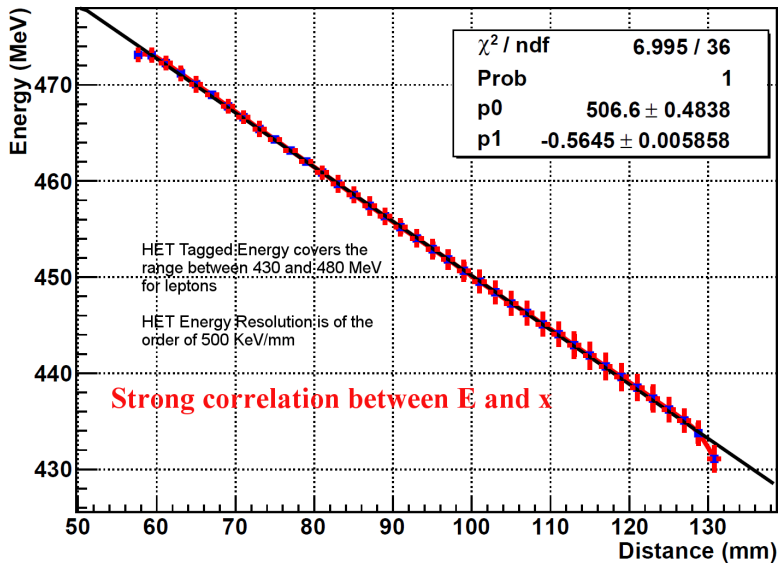
1 Long Plastic for coincidence

HAMATSU PMT R9880U-110 SEL

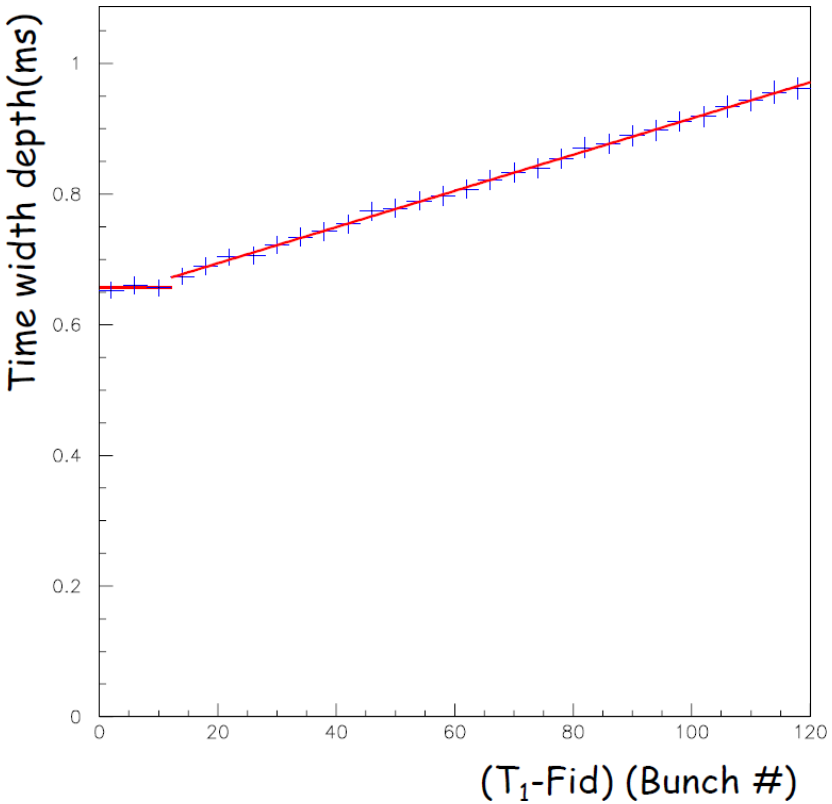
Quantum efficiency $\sim 35\%$

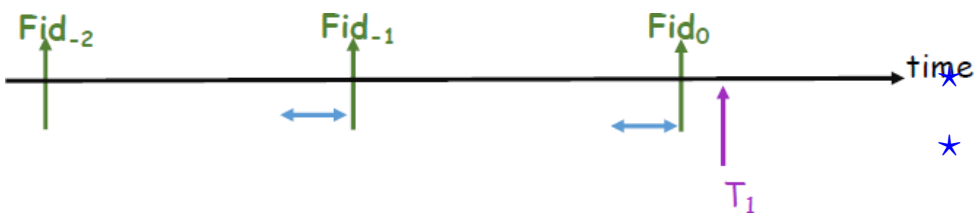


Energy of leptons vs Distance from the nominal orbit



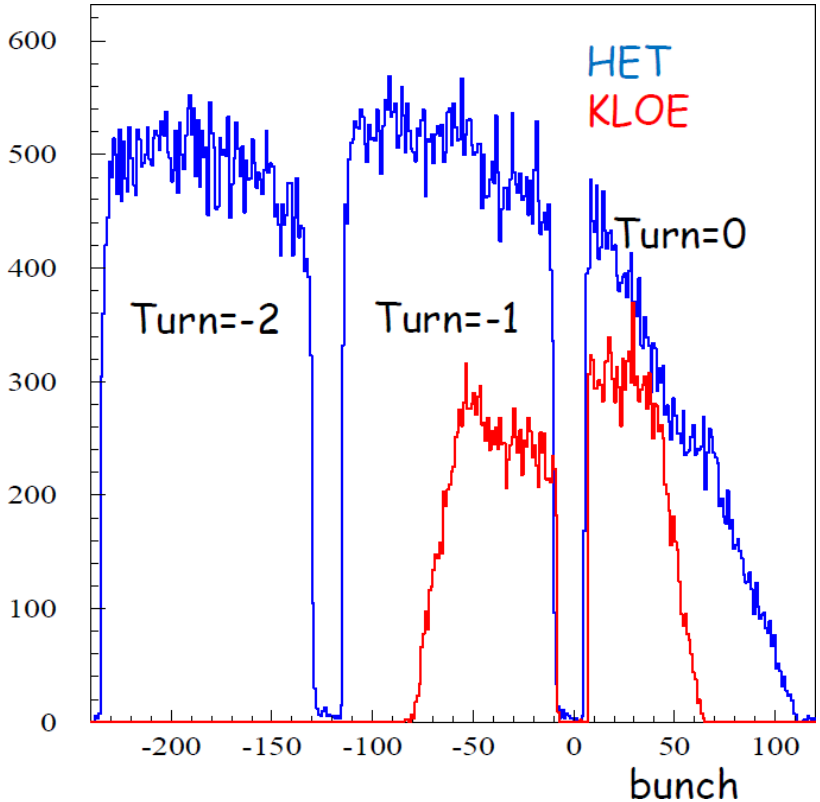
The HET DAQ





- ⋆ HET discriminators provide an output signal with a width of ∼2 ns → possibility to discriminate 2 consecutive bunches in DAΦNE ($\Delta T_{\text{bunch}} = 2.7$ ns)
- ⋆ TDCV5 uses custom logic in order to manage signals from HET, DAΦNE and KLOE
- ⋆ HET data acquisition system has been designed to register hits from two complete machine turns plus the part of a third turn preceding the trigger signal (T_1) from KLOE
- ⋆ The time-depth for the HET data recording has been measured as a function of the delay between KLOE trigger and the Fiducial (DAΦNE radio-frequency signal) and ranges from 660 to 970 ns
- ⋆ The HET do not provide trigger to KLOE
- ⋆ We read the history of the HET in turns of DAΦNE only when a valid KLOE trigger is asserted

The HET DAQ



- ⋆ KLOE and HET acquisition systems are asynchronous: we use the Fiducial provided by DAΦNE which is in phase with respect to the first bunch circulating in DAΦNE
- ⋆ A global delay is used for each TDCV5 in order to shift the Fiducial signal used as common start
- ⋆ We acquire also the KLOE trigger in both HETs for cross-checks and monitoring purposes.
- ⋆ The long plastic scintillator from HETs is also acquired by the TDC of KLOE trigger

- ⋆ KLOE and HET asynchronous Data Acquisition overlapping region.

$\gamma\gamma \to \pi^0$ signal is expected in the red region , events outside the overlapping region are used as control sample

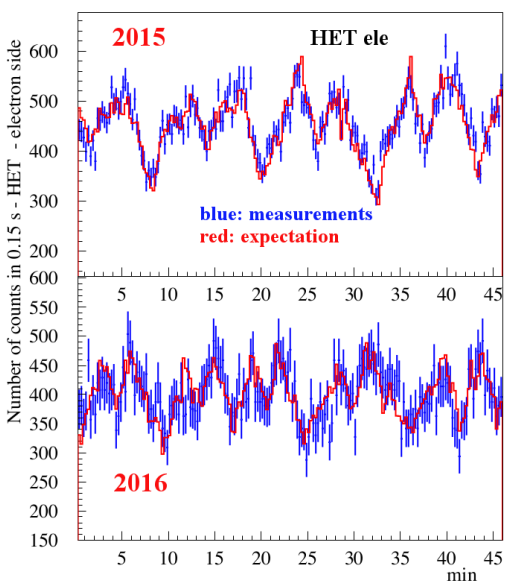
Performance of the HET detector

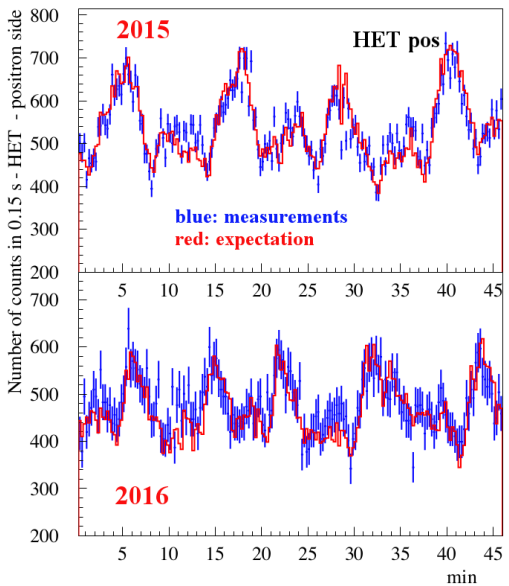
HET Rates are dominated by single-arm Bhabha's as observed in normal and dedicated runs

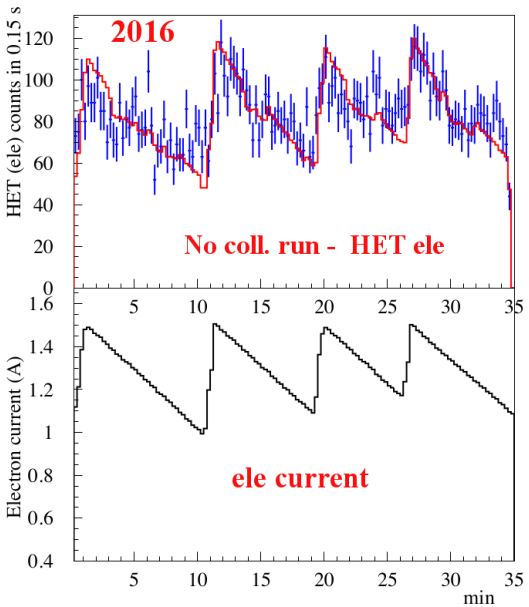
$$R_{\mathrm{HET}} = \frac{R_{\mathrm{trig}}}{\mathrm{kHz}} \left(\alpha_{\mathrm{L_{e,p}}} \frac{\mathrm{Lumi}}{0.2\mathrm{nb}^{-1}\mathrm{s}^{-1}} + \beta_{\mathrm{e,p}} \frac{I^2_{\mathrm{e,p}}}{A^2} \right)$$

Normal run: the rate timeline strictly follows the luminosity timeline as measured by the KLOE central detector

No-collision run : the HET rate $\propto I^2_{\mathrm{e,p}}$ (Touschek bckg is $\sim 45\%(15\%)$ for $e^-(e^+)$)



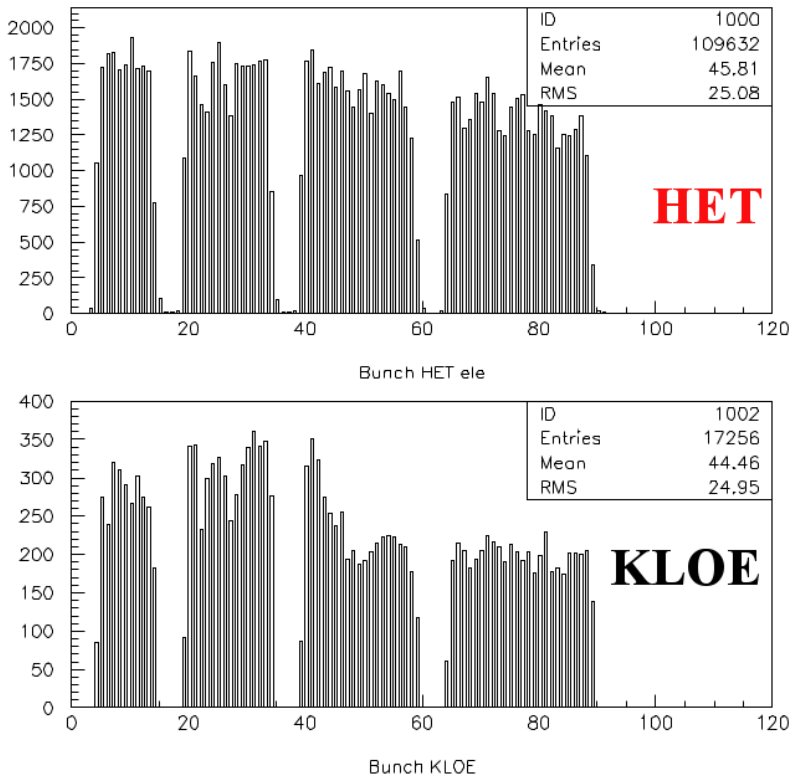




Luminometer detector: fast and reliable feedbacks on the machine operation

Performance of the HET detector

DAΦNE Bunch structure as measured by the HET with low angle Bhabha and KLOE central detector with large angle BhaBha



Run with special DAΦNE bunch pattern, both beams circulating in the machine at the same time. Holes correspond to 5 empty bunches between the filled ones.

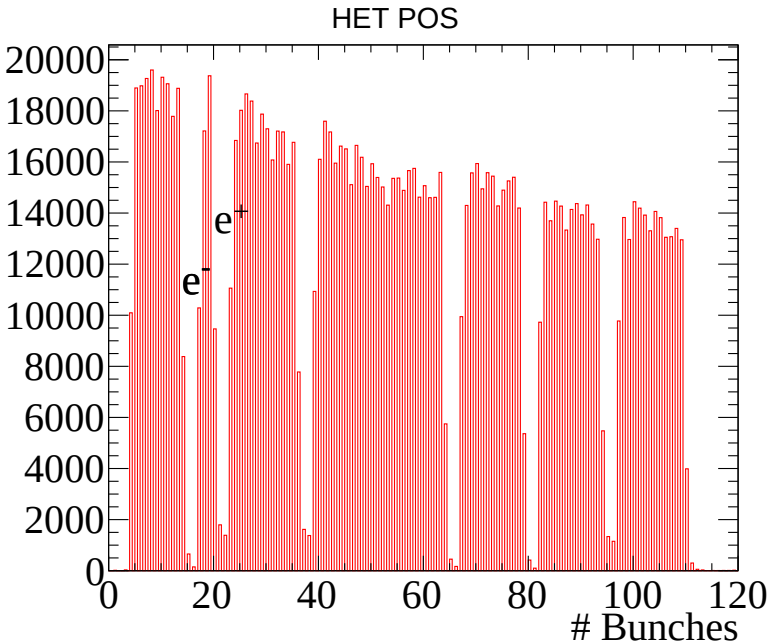
The HET hit time structure closely reproduce DAΦNE bunch structure

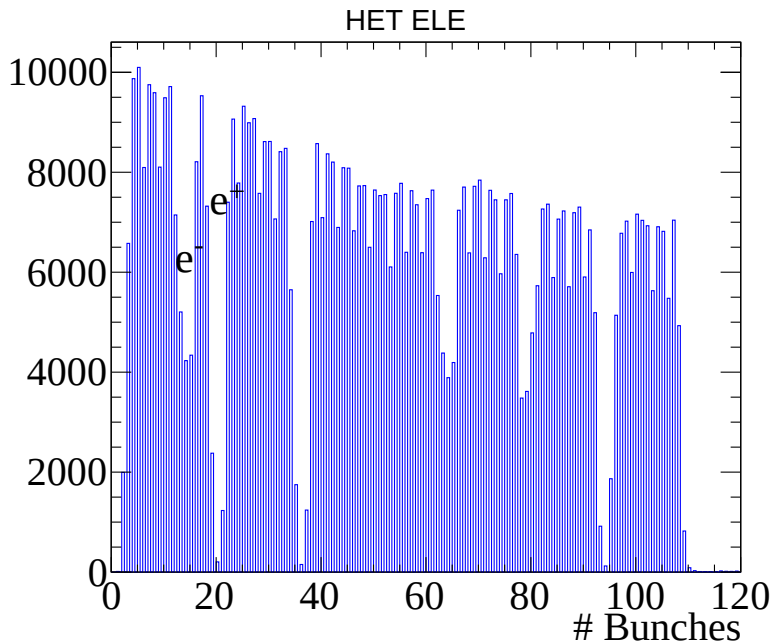
The HET detector is noiseless → hit rate with no circulating beams is negligible

The matching of the DAΦNE bunch structure seen by KLOE and HET allow us also to synchronize the two detectors

Performance of the HET detector

Special run with some DAΦNE bunches not filled, alternatively on the electron and the positron machine.

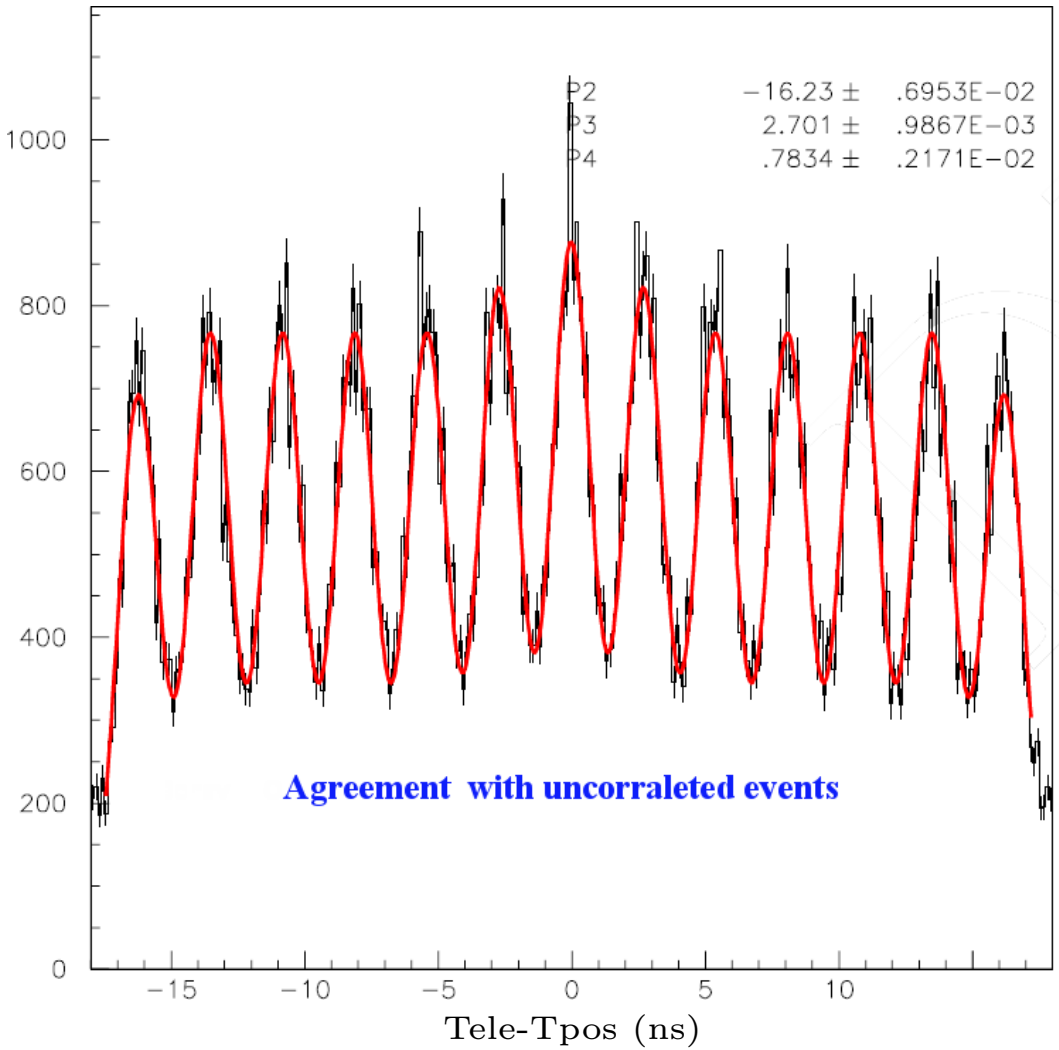




Rate variation on the two stations in the different cases shows also the higher Touschek level on the electron beam.

Time resolution of the HET detector

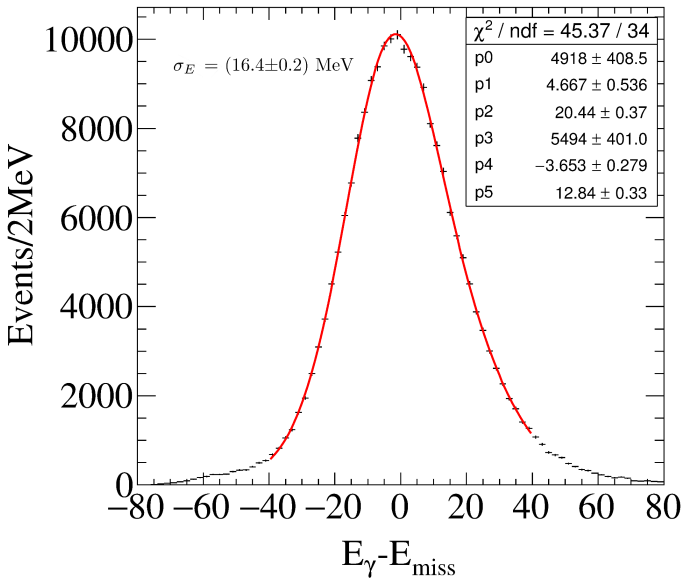
Hit delay distribution between HET ele-pos
Fit performed with 13 Gaussian of same σ

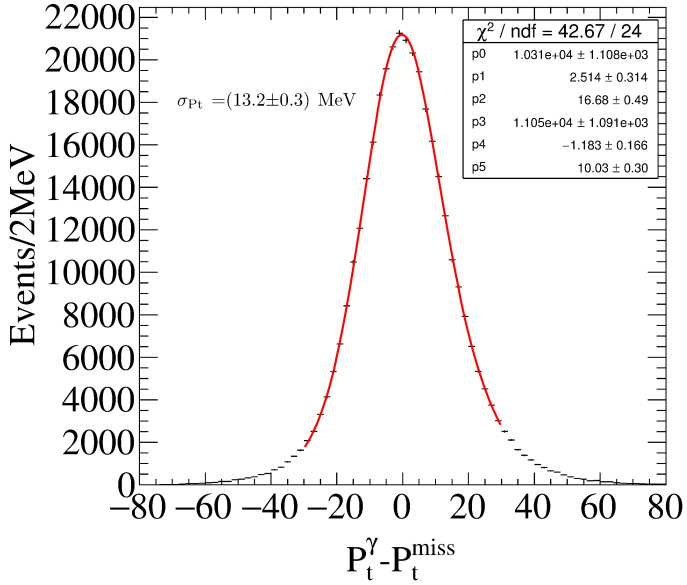


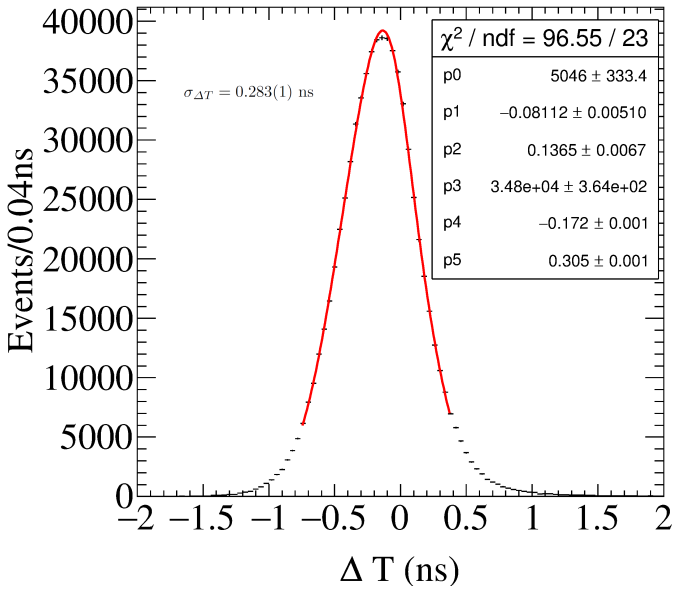
Time resolution is σ_t=550(1)ps
Time offset between stations of 24±10 ps

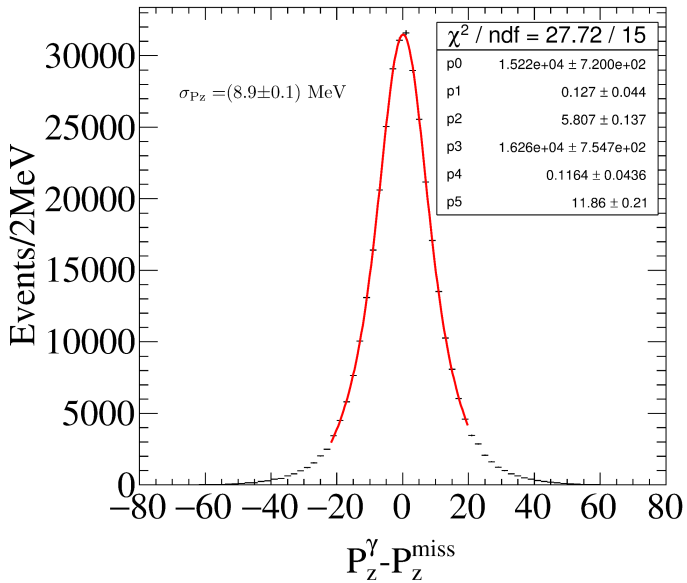
Resolution studies

Energy, momenta and time resolutions on 70 MeV energy photons. The study was performed by means of a control sample of radiative Bhabhas



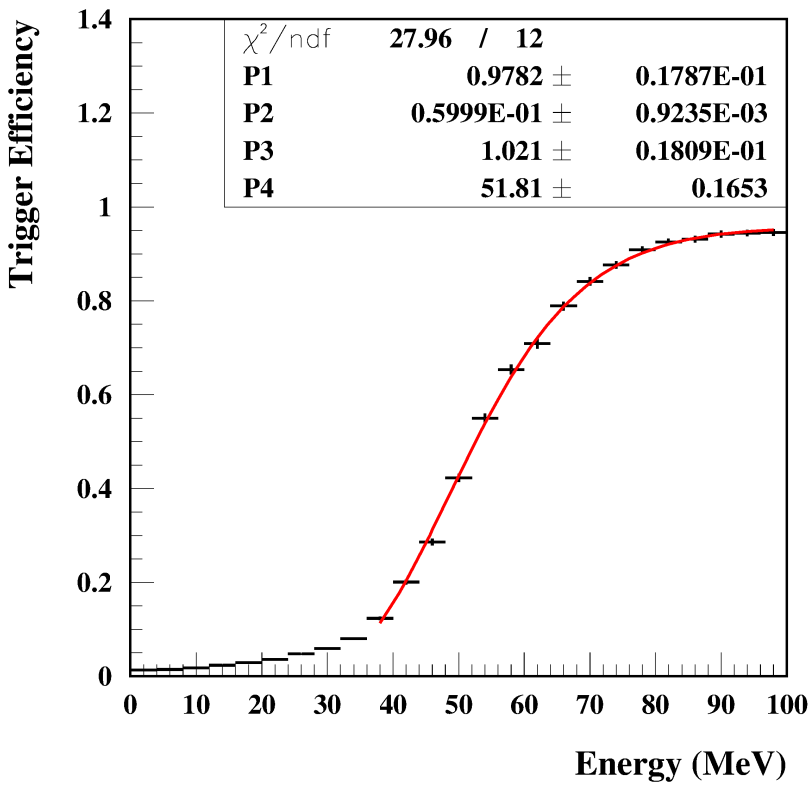


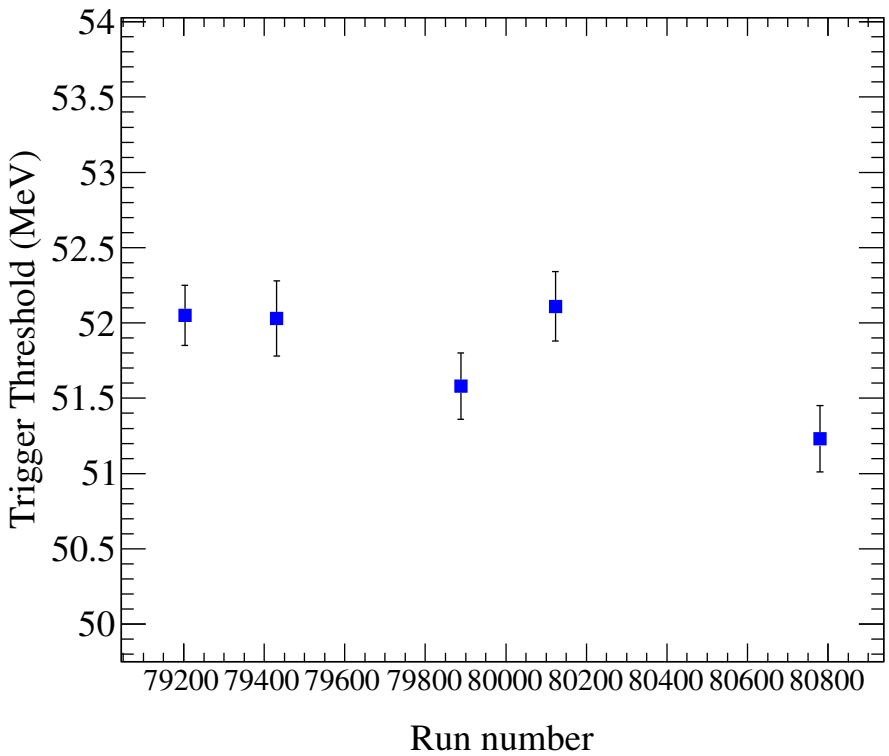




Trigger efficiency

Study based on a control sample of radiative Bhabhas



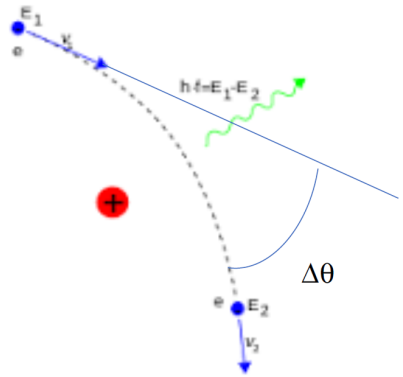


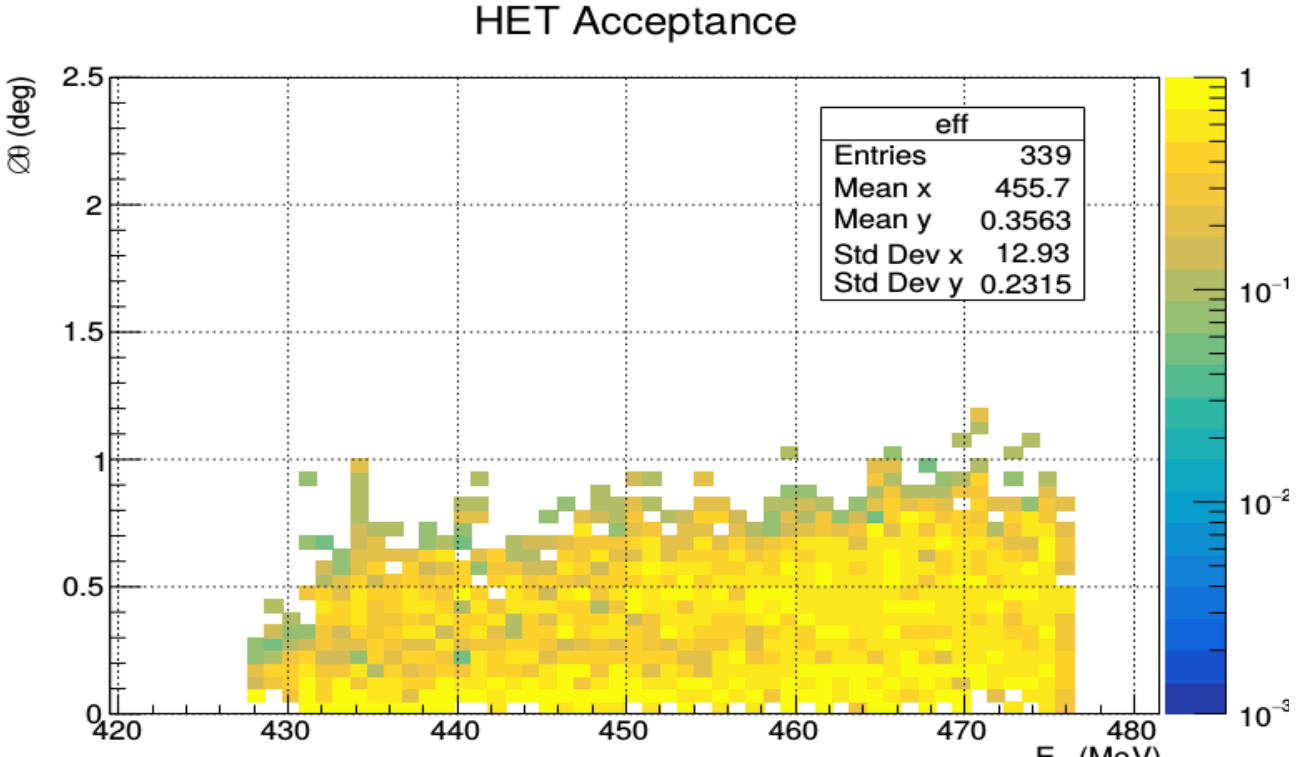
Trigger eff on 70 MeV energy photons is of about 80%

Stability of the trigger threshold over the running period November 2015–January 2016

HET Design Acceptance

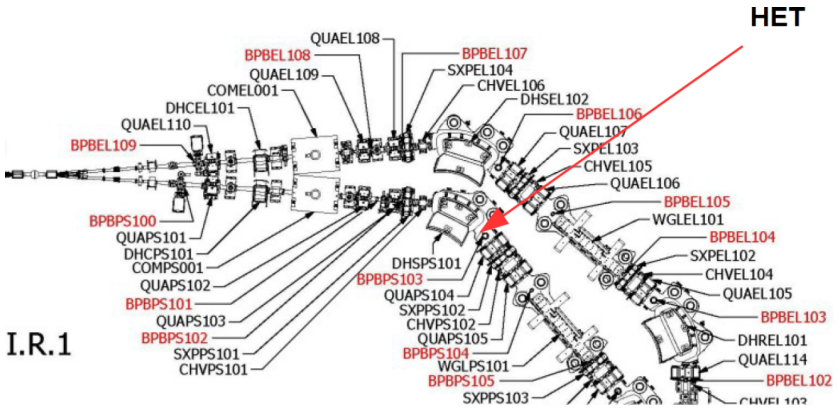
- ⋆ HET acceptance is between 425 and 475 MeV in energy and between 0 and 1.5 degree in angle
- ⋆ All the work is essentially made by the dipole before HET
- ⋆ All the previous magnets work as angular filters
- ⋆ If these regions (E, θ) move for a different DAΦNE setup we always have single arm acceptance





Bdsim Tracking

- Bdsim is GEANT4 toolkit used to simulates the particle trajectory from the IP to the HET in the DAFNE magnetic fields
- All magnets are simulated : Electron and Positron Rings are not exactly the same
- Tiny adjustments of the DAFNE magnetic fields needed for the machine operation (background minimization vs luminosity maximization) can change particle orbits differently in the electron and positron beam
- HET vertical dimension is the critical point for the tagger acceptance
- We have compared the simulated orbits with the Beam-Position-Monitors placed in DAFNE and slightly modified the magnetic setup in order to fit at best such positions.
- We obtained good agreement with the BPM placed before the corrector DHCPS101 and only marginal agreement with the BPM placed near the HET

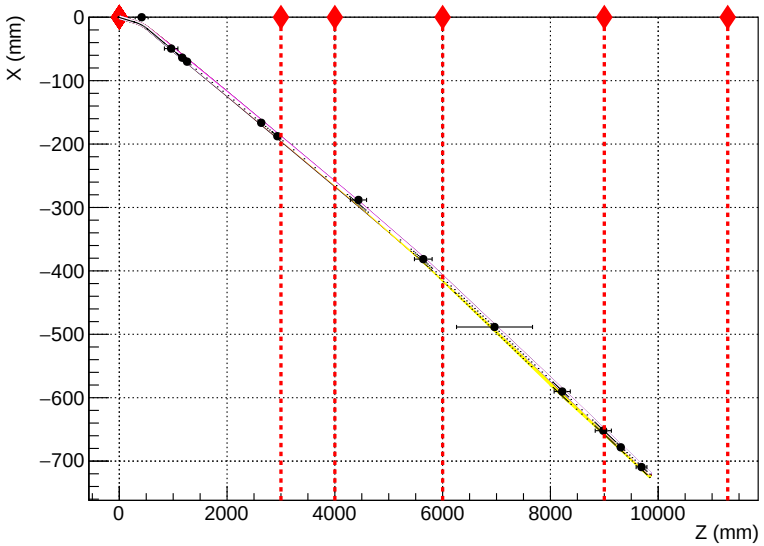


- In conclusion we expect to operate with an energy-dependent acceptance mostly due to the vertical dimension of the taggers
- Such an effect is expected much more critical for the double-arm coincidences than for the single-arm ones
- For this reason the analysis of single-arm events takes great importance

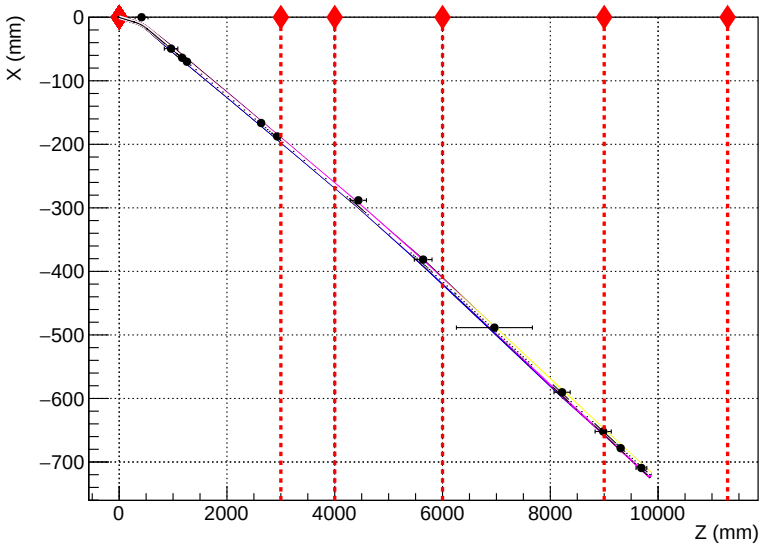
Bdsim Tracking

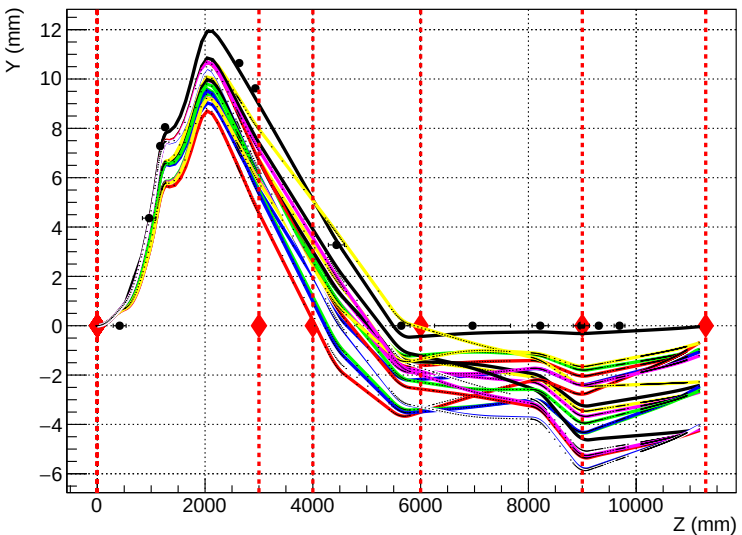
3×10^5 magnetic setup simulated, the trajectory with the best agreement with BPM is chosen

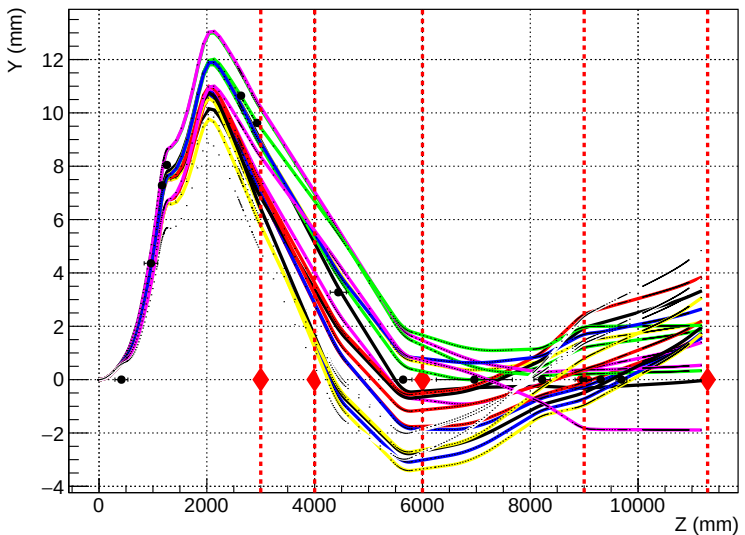
electron traject



positron traject.







DA Analysis

Signal selection:

Coincidence btw taggers hits : $|\Delta T_{ep}| < 2$ bunches

Events in time with the KLOE trig ($-3 < \Delta T_{trig-clus} < 8$ bunches)

2 KLOE clu associated in the barrel with the same bunch with $20 < E_\gamma < 350$ MeV

HET events in time with KLOE DAQ

Kine cuts:

$30 < E_\gamma < 135$ MeV

$P_{\pi 0} < 90$ MeV

$\cos\alpha_{\gamma\gamma} < -0.8$

$80 < M_{\gamma\gamma} < 230$ MeV

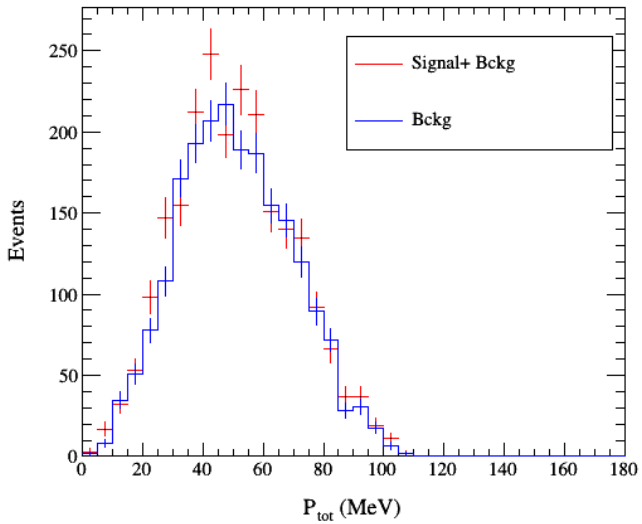
$|\Delta T_{\gamma\gamma} - \Delta R_{\gamma\gamma}/c| < 1.1$ ns

Background evaluation :

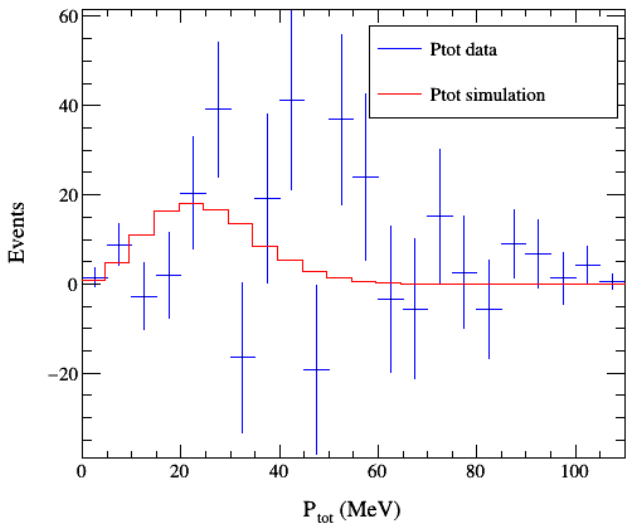
We can use as control samples:

1) Events which don't match the bunch
2) Events matching the bunch but out of time with KLOE DAQ

- Bckg normalization done using the data to bckg ratio in the signal free region suggested by simulation ($1.1 < |\Delta T_{\gamma\gamma} - R_{\gamma\gamma}/c| < 2.2$ ns)



Ptot diff compared with expectation (100 ev)



SA Analysis (HET ele)

Signal selection (ele/pos):

HET ele events in time with KLOE trig
$(-3 < \Delta T_{\mathrm{trig-clus}} < 8$ bunches)

2 KLOE clu associated in the barrel with the same bunch with $\Delta T_{\mathrm{KLOE_{clu}-HET}} \leq 4$ bunches

$20 < E_\gamma < 350$ MeV

HET ele events in time with KLOE DAQ

"isolation cut meant to increase S/B ratio"
$E^{\mathrm{tot}} - (E_{\gamma_1} + E_{\gamma_2}) < 290$MeV

Kine cuts:

$30 < E_\gamma < 180$ MeV

$\cos\alpha_{\gamma\gamma} < -0.3$

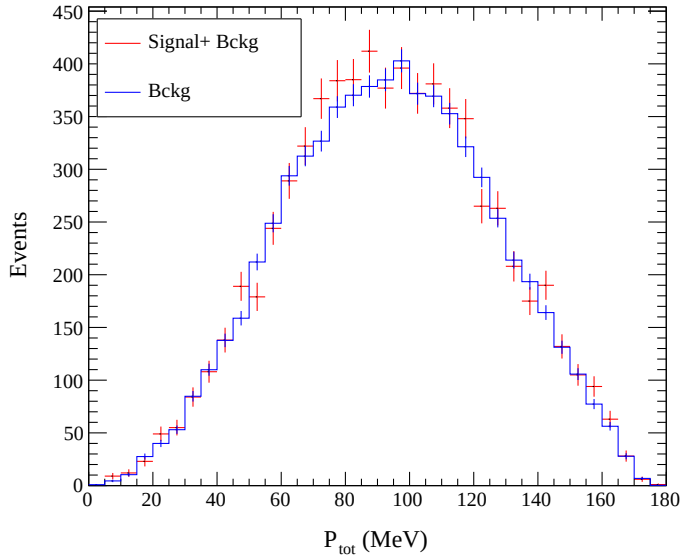
$80 < M_{\gamma\gamma} < 230$ MeV;
$|\Delta T_{\gamma\gamma} - \Delta R_{\gamma\gamma}/c| < 1.1$ ns

$\mathrm{P_{tot}} < 150$ MeV

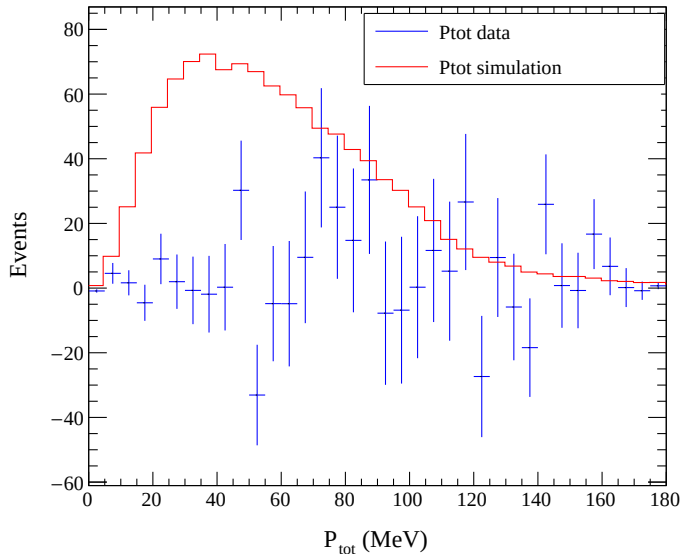
Background evaluation :

We use as control sample events out of time with KLOE DAQ

- Bckg normalization done using the data to bckg ratio in the signal free region suggested by simulation ($1.1 < |\Delta T_{\gamma\gamma} - R_{\gamma\gamma}/c| < 2.2$ ns)

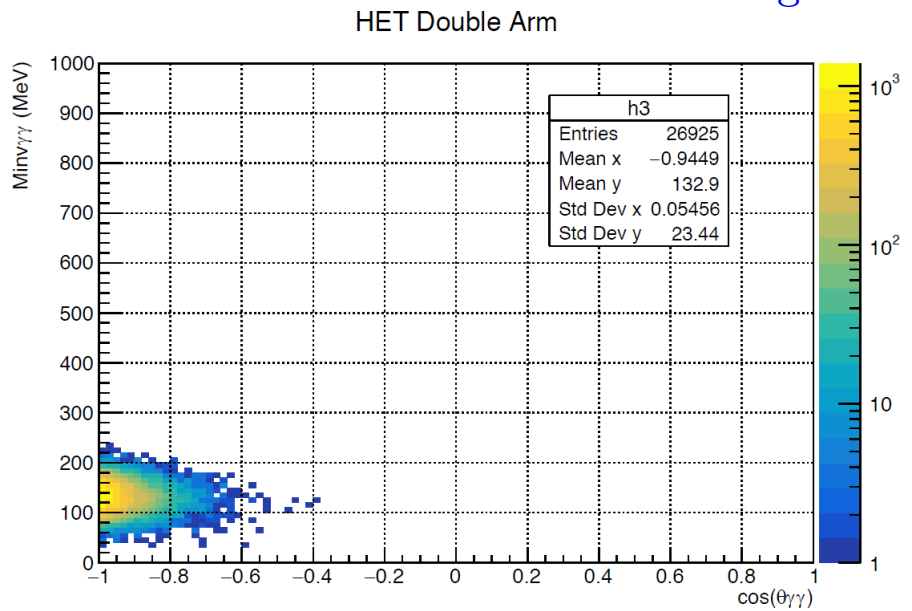


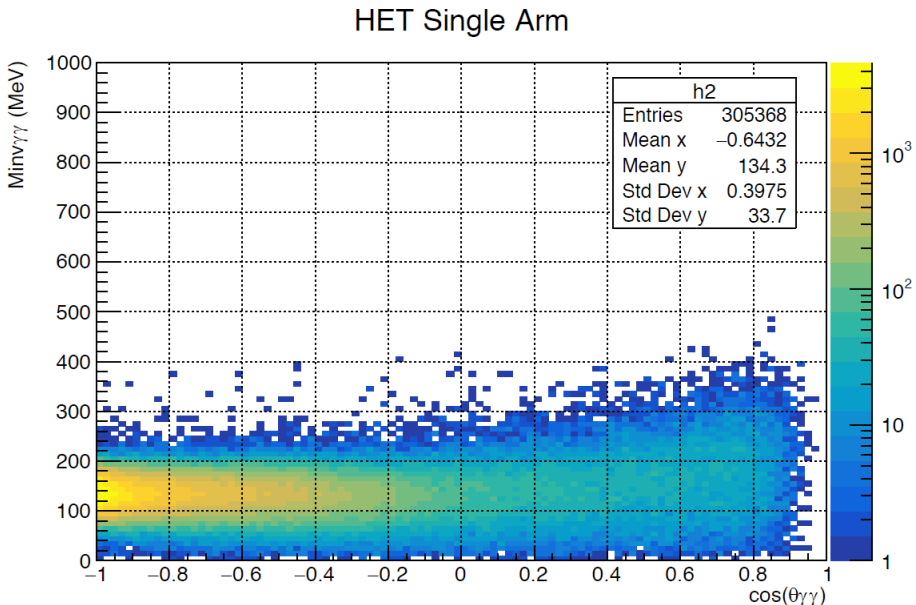
Ptot diff compared with expectation (1100 ev)



Simulation: $e^+e^- \to e^+e^-\pi^0$ process

Simulated Invariant mass Vs $\cos\theta_{\gamma\gamma}$ distributions for Double-Arm (DA) and Single-Arm (SA) events





Full Simulation:

Ekhara* for the signal :
$e^+e^- \to e^+e^-\pi^0$
+ Bdsim for beam transport along the machine lattice
+ Kloe resolution on 70 MeV energy photons
+ trigger efficiency on 70 MeV energy photon ($\sim 80\%$)

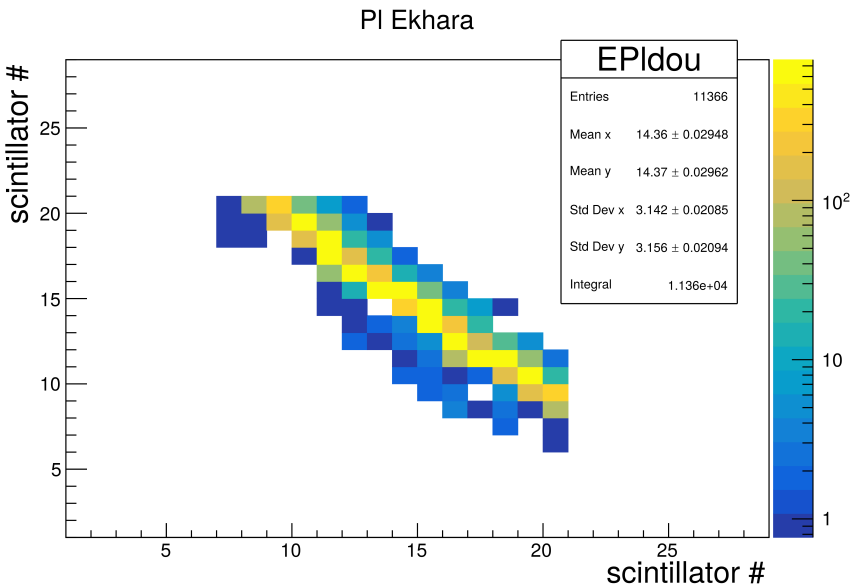
Effective cross sections:

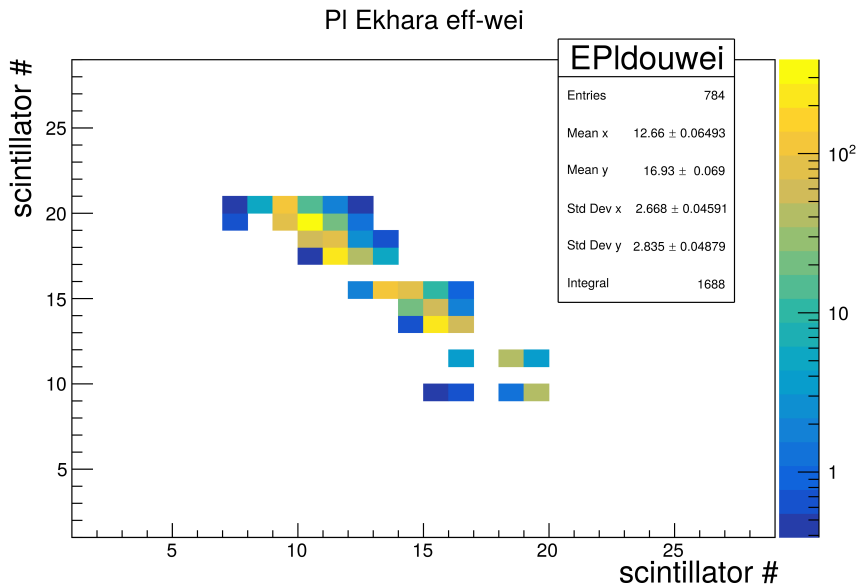
$\sigma_{\rm tot} = 283.7$ pb $\sigma_{\rm KLOE} = 41$ pb $\sigma_{\rm SA} = 7$ pb
$\sigma_{\rm DA} = 2$ pb

* Computer Physics Comunications 182 (2011) 1338-1349

Simulation: $e^+e^- \to e^+e^-\pi^0$ process DA

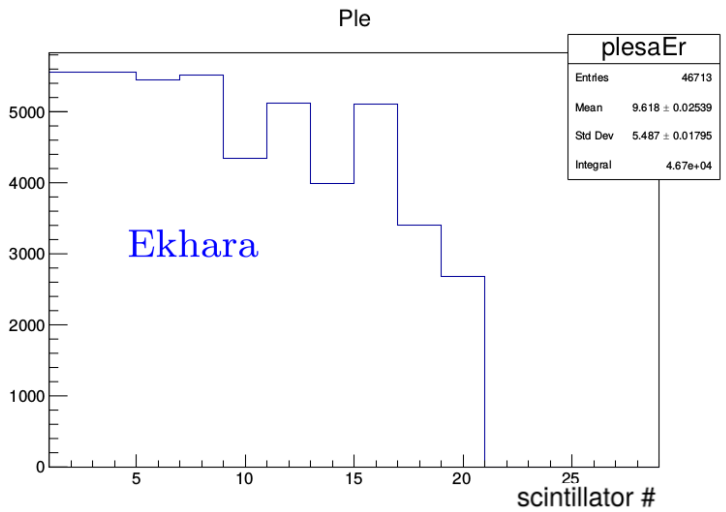
DA scintillator spectra from Ekhara

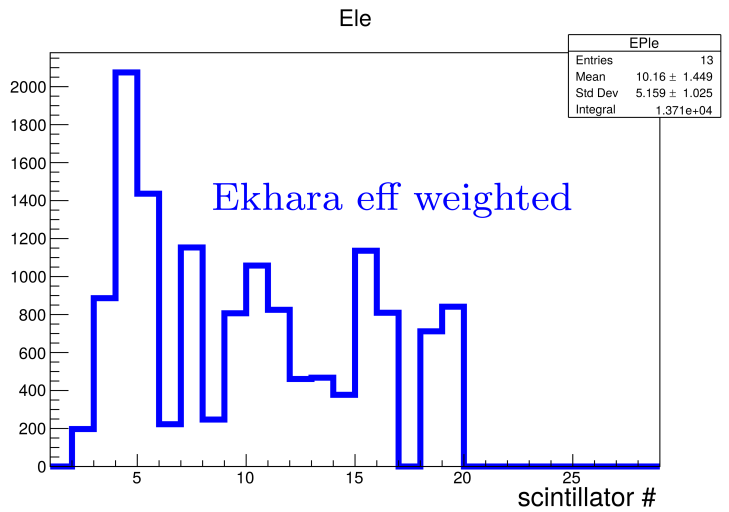




Applying the efficiency correction channel by channel at the Ekhara-simulated events we expect about 100 tagged events in the DA analyzed sample of 550 pb^{-1}.

SA Ekhara ele scintillator spectra

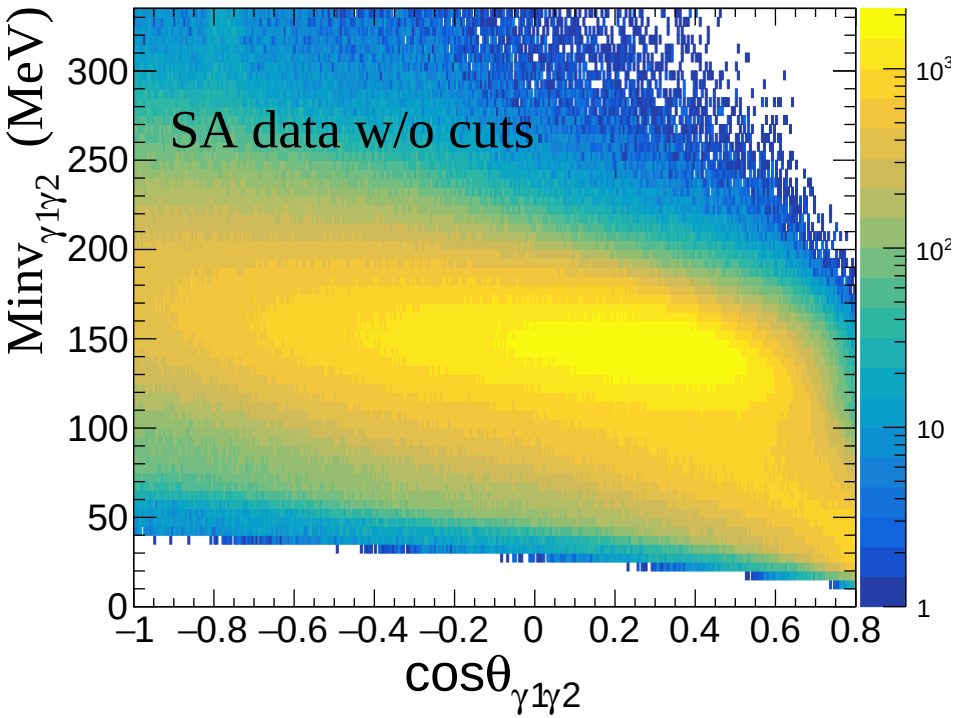


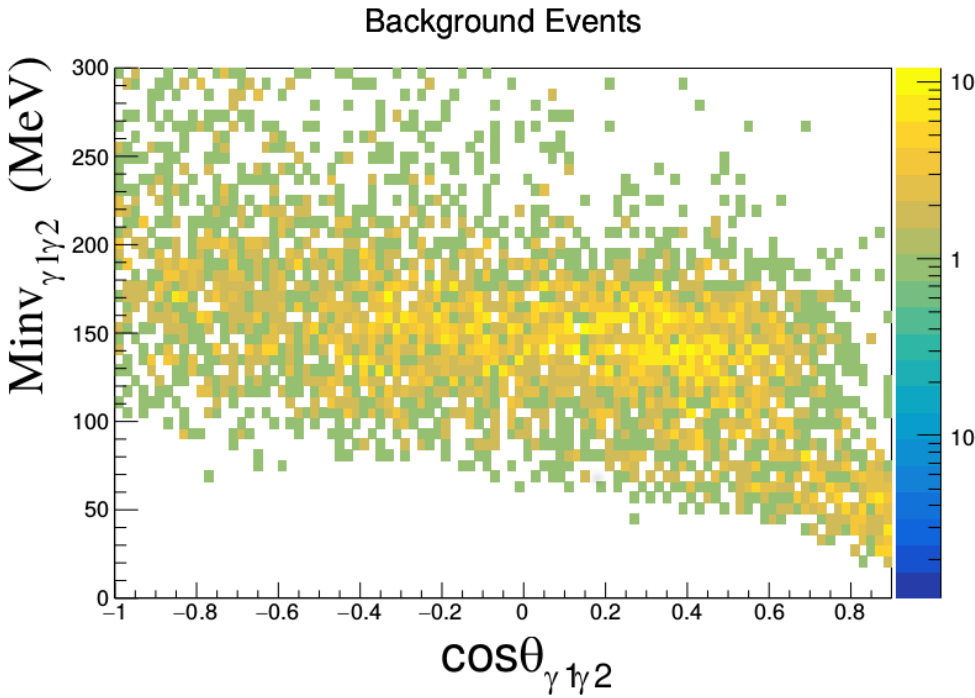


Applying the efficiency correction channel by channel at the Ekhara-simulated events we expect about 1100 tagged events in the SA analyzed sample of 550 pb^{-1}.

Investigation of low mass events

We investigated the origin of the background and simulated the distribution of Touschek-pairs starting from real distributions recorded by the experiment.
We have used the distribution of pairs reconstructed far from the trigger (not-triggering pairs).
Then, we have applied the trigger conditions to such pairs to reproduce those we have in our data as bckg





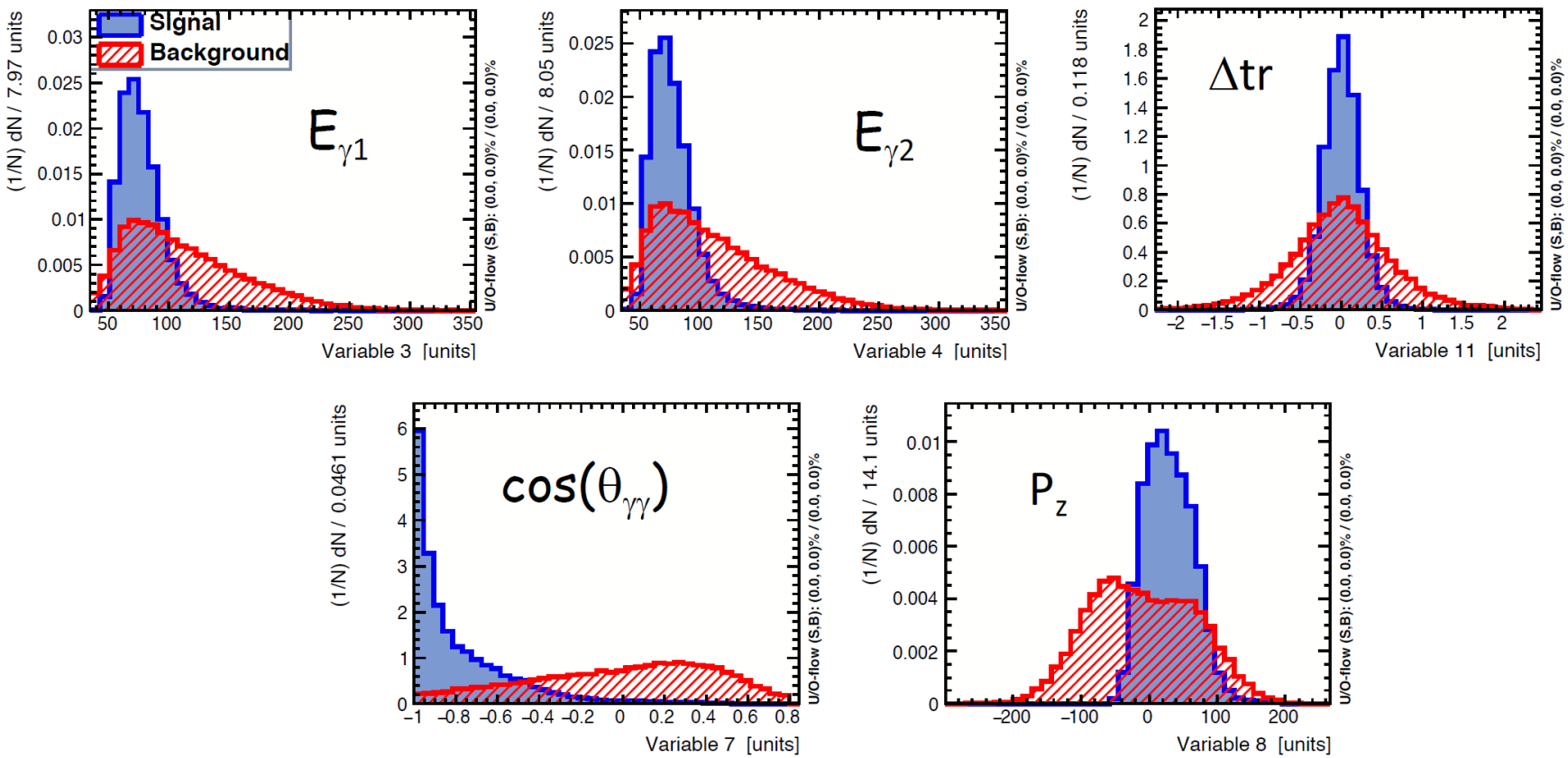
The sample used (dominated by Touschek background) is able to cover the entire kinematic range found for the background at low invariant masses

MVA

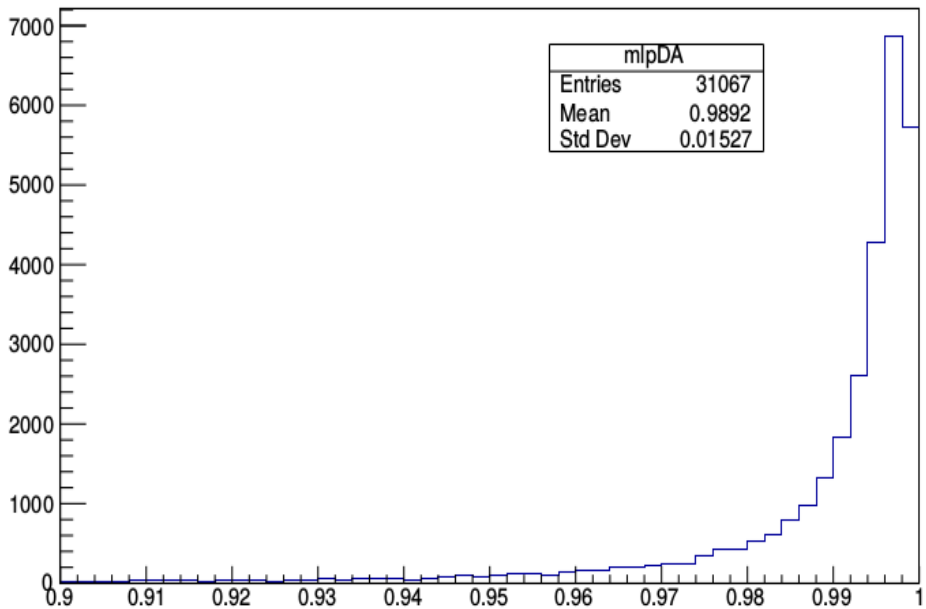
- ⋆ In order to use all the possible information in our data and correlation we performed a Multivariate Analysis (based on the root package TMVA)
- ⋆ We used as signal sample data from simulation : ekhara + bdsim (BigMatrix) + Kloe resolution and trigger efficiency
- ⋆ We use as "background" data events out of the overlapping window between KLOE and HET and also data events in which we don't have the maching of the bunch between KLOE and HETs
- ⋆ We studied both single and double arm samples (550 pb^{-1})
- ⋆ We trained the MVA by using:
  - ⋆ the angle between selected clusters
  - ⋆ the cluster energies
  - ⋆ the π^0 Pz
  - ⋆ the time resolution taken from the two clusters $(\Delta T_{\gamma\gamma} - \Delta R_{\gamma\gamma}/30)$

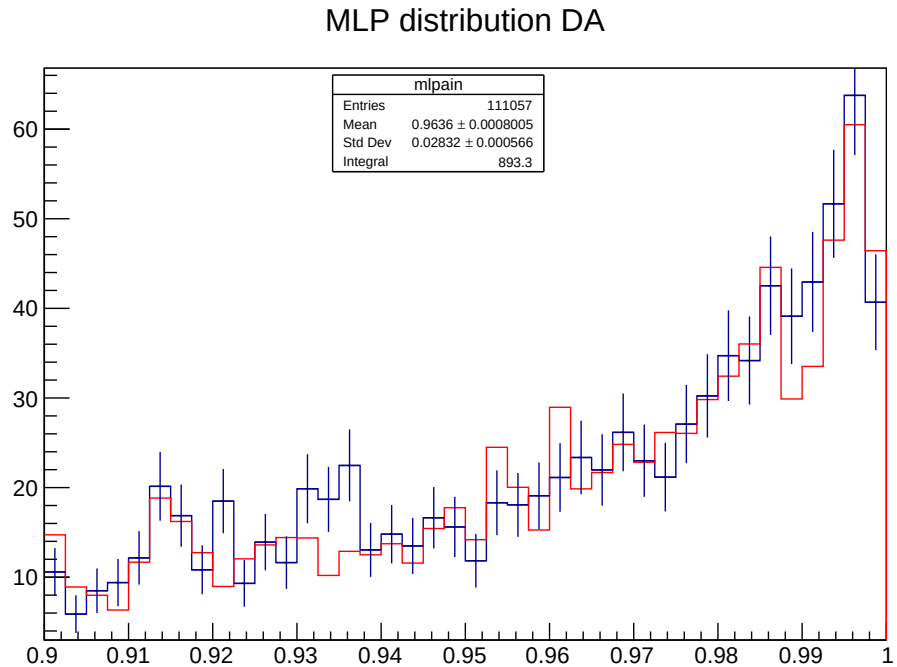
MVA: TMVA from ROOT

TMVA Inputs: signal and bckg distributions.



MVA: MLP distribution DA



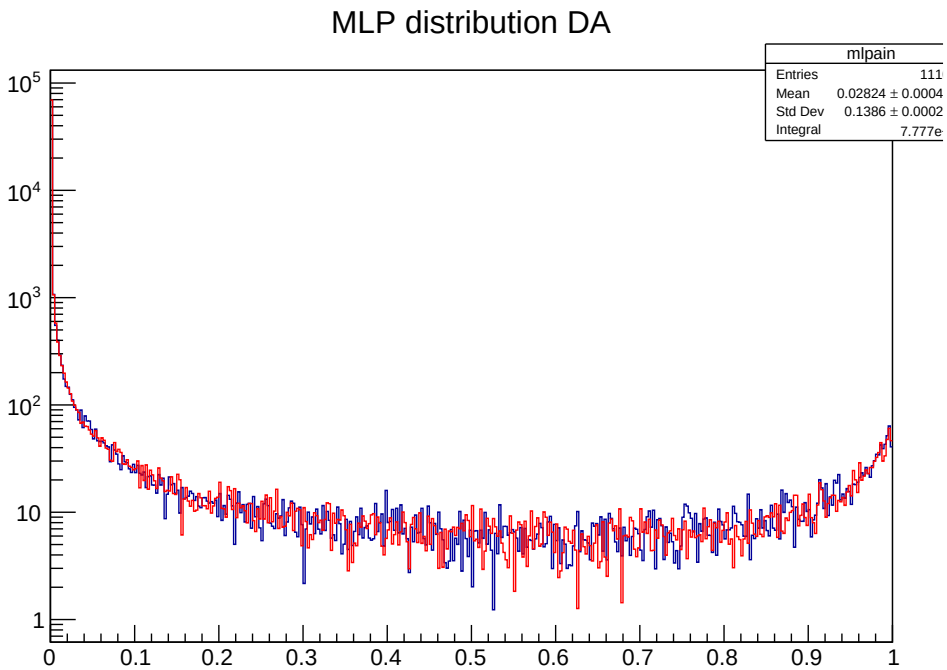


MLP distribution expected from Ekhara in the signal region

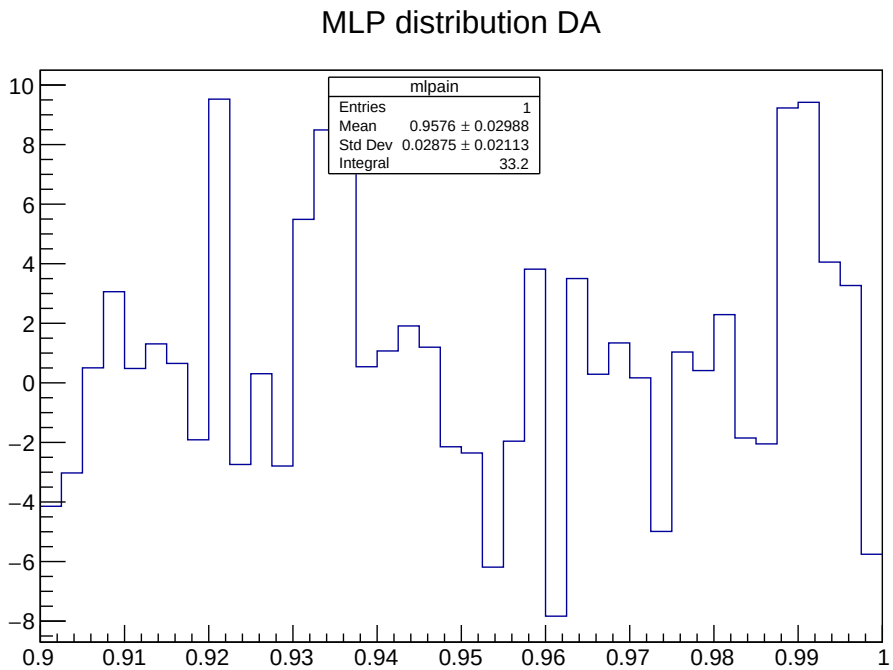
MLP distribution comparison for events in the overlapping window of the HET and KLOE DAQs (blue) and out of the overlapping region (red).
The distributions have been normalized at the same number of events in the background region.

No significant excess is found

MVA: MLP distribution DA

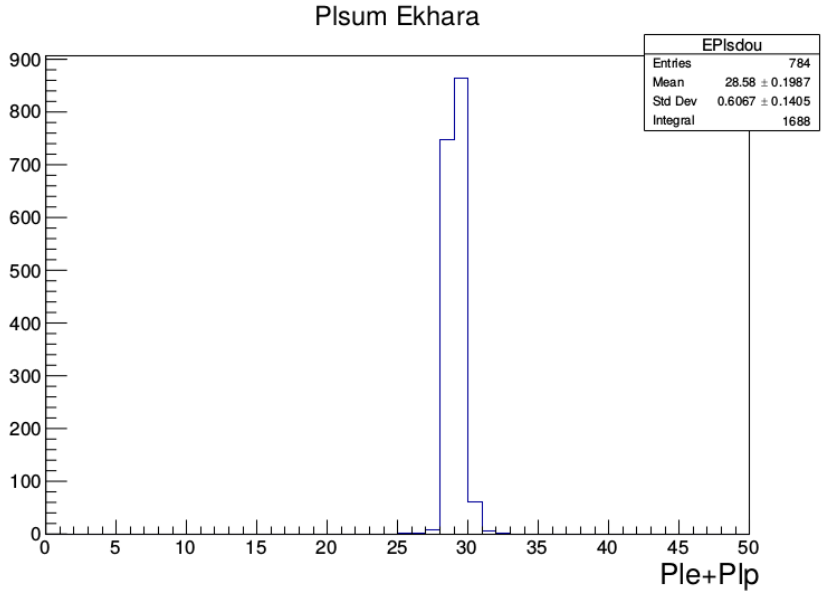


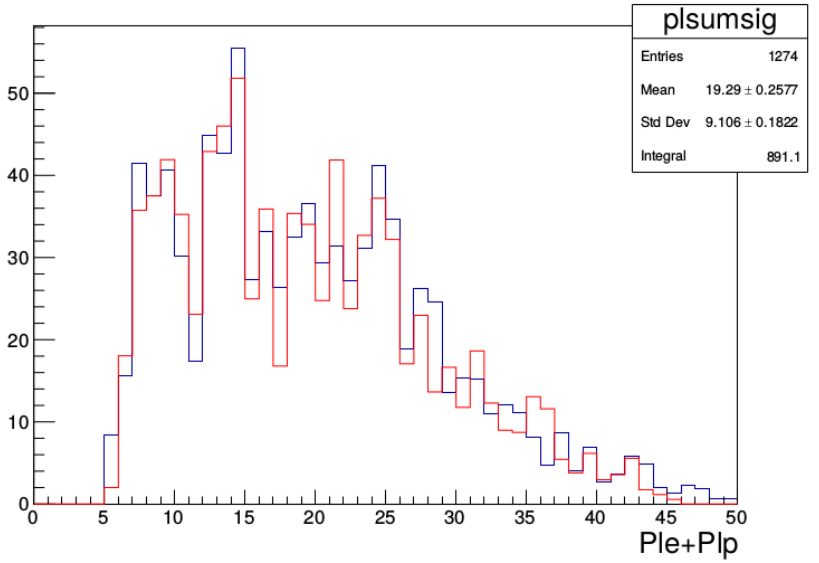
MLP distribution comparison for events in the overlapping window of the HET and KLOE DAQs (blue) and out of the overlapping region (red) in the whole MLP range



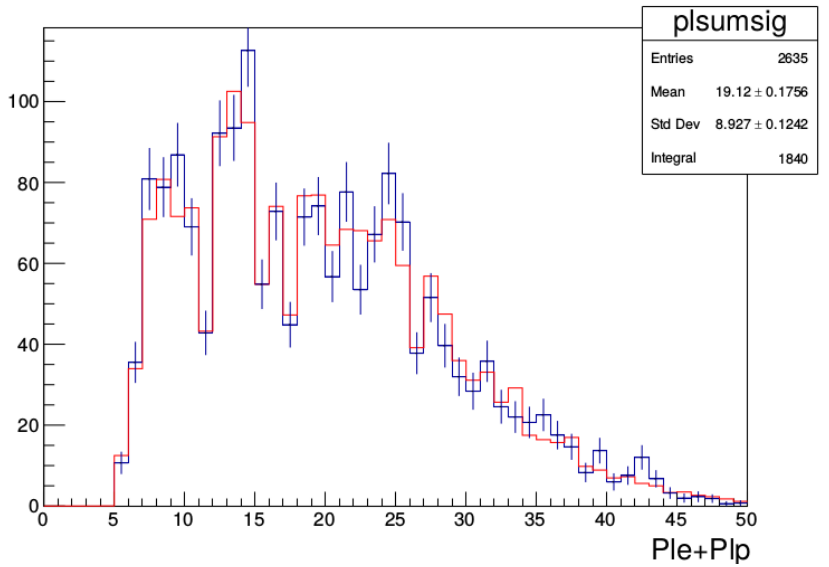
MLP distribution difference in the signal region

MVA: Pl distribution DA

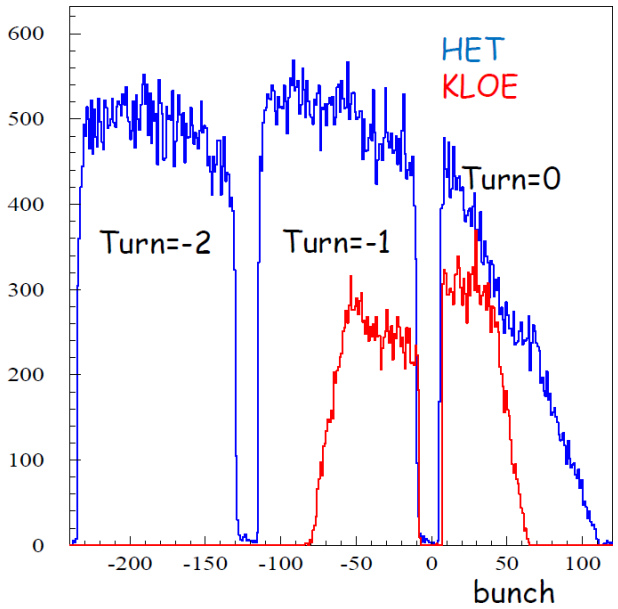




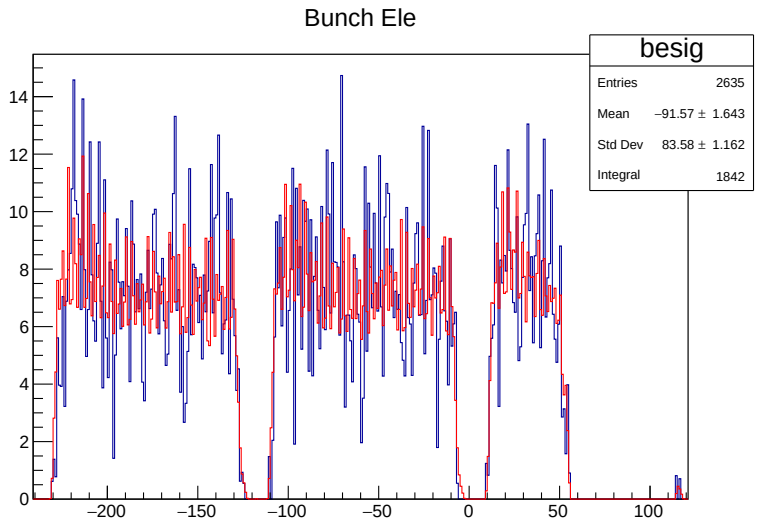
- One of the control variables studied is the sum of the plastic numbers. From simulation (Ekhara+BDSIM) we expect strong anti-correlation in the energy of the leptons.
- on the top right the comparison of the ple+plp distribution for events inside the two DAQs overlap window (blue) and out the window (red)
- on the bottom right the same comparison for events in the signal (blue) region and bckg (red) region according to the MLP distribution.



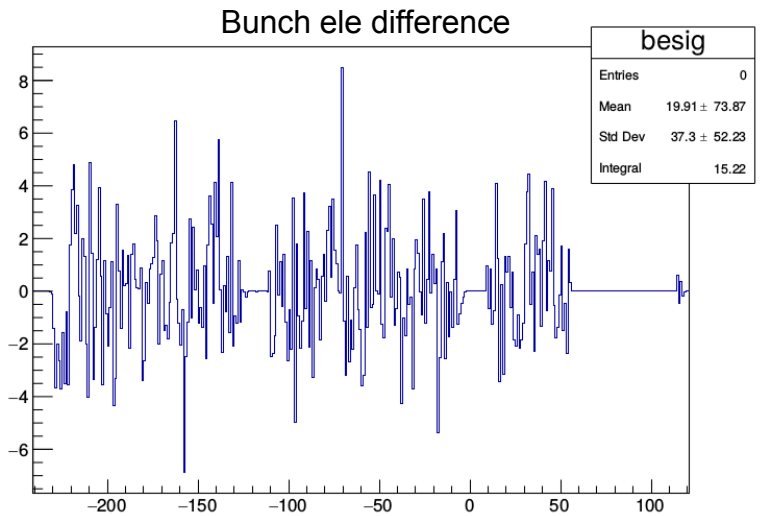
MVA: TDC distribution DA



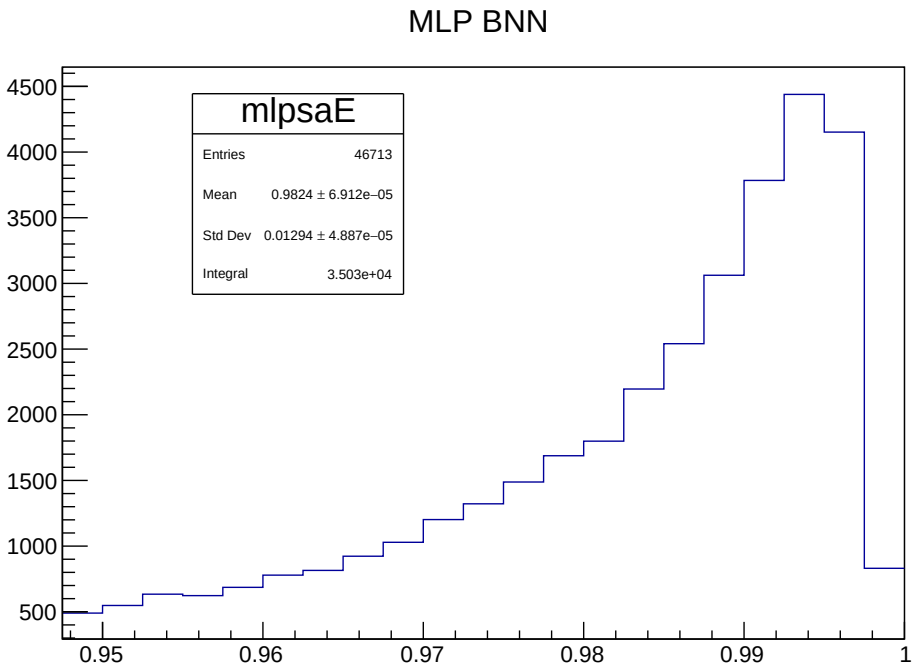
Red : events in the bckg region
Blue: events in the sig region



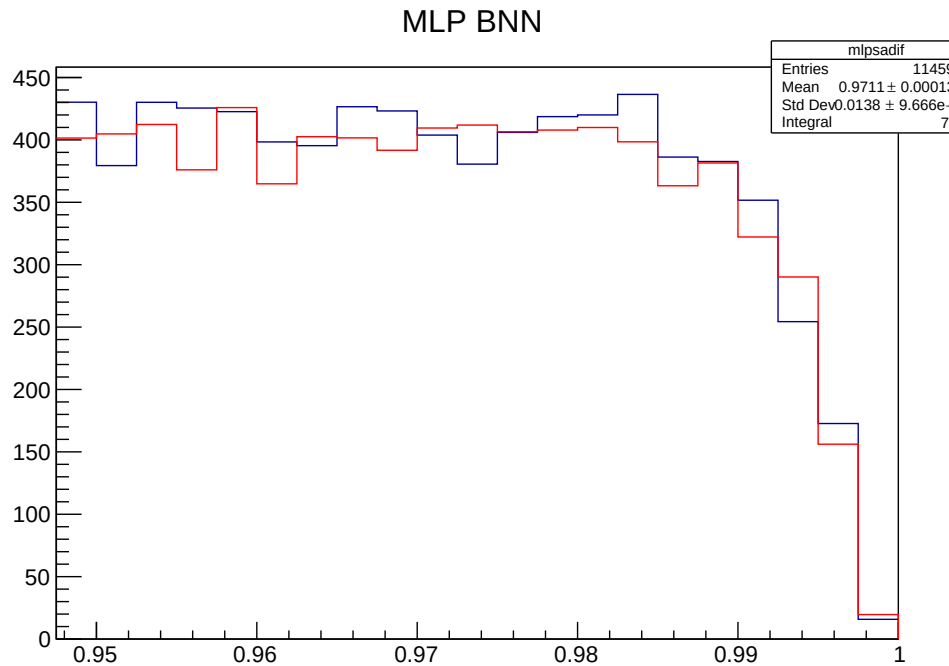
- ⋆ KLOE and HET asynchronous Data Acquisition overlap in the red region.
- ⋆ Another control distribution studied is the bunch distribution, as recorded within the ∼2.5 DAΦNE turns from the HET acquisition.
- ⋆ We compare the distributions for triggers on the signal side (mva variable) with those in the bckg region normalizing with an equal number of events in the region where KLOE-HET acquisition DO NOT overlap.
- ⋆ in case of π^0 signal from $\gamma\gamma$ scattering we expect to see an increasing of events in the overlapping region w.r.t. the others turns.



MVA: MLP distribution SA



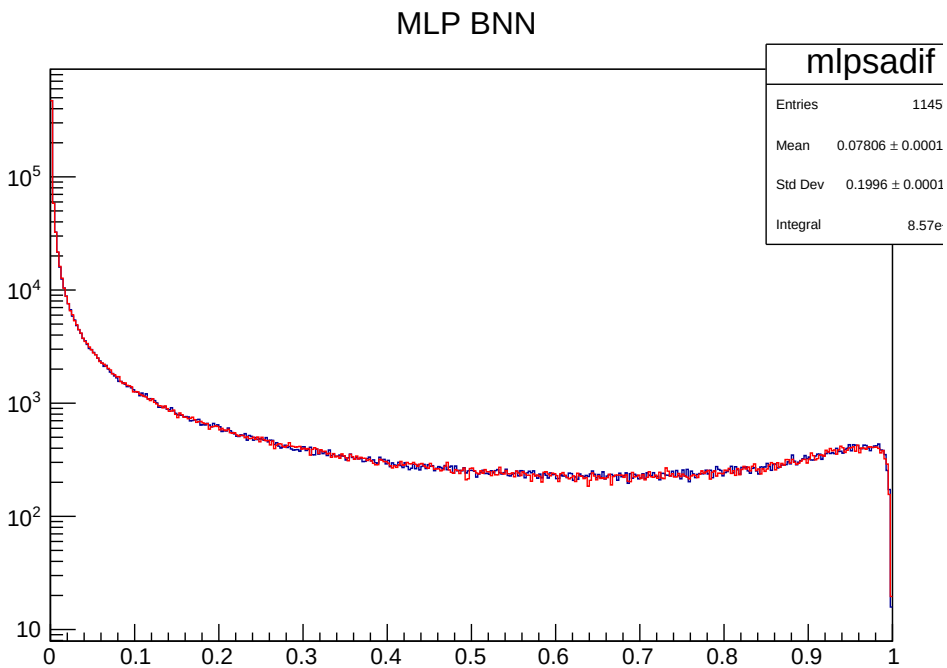
MLP distribution expected from Ekhara in the signal region



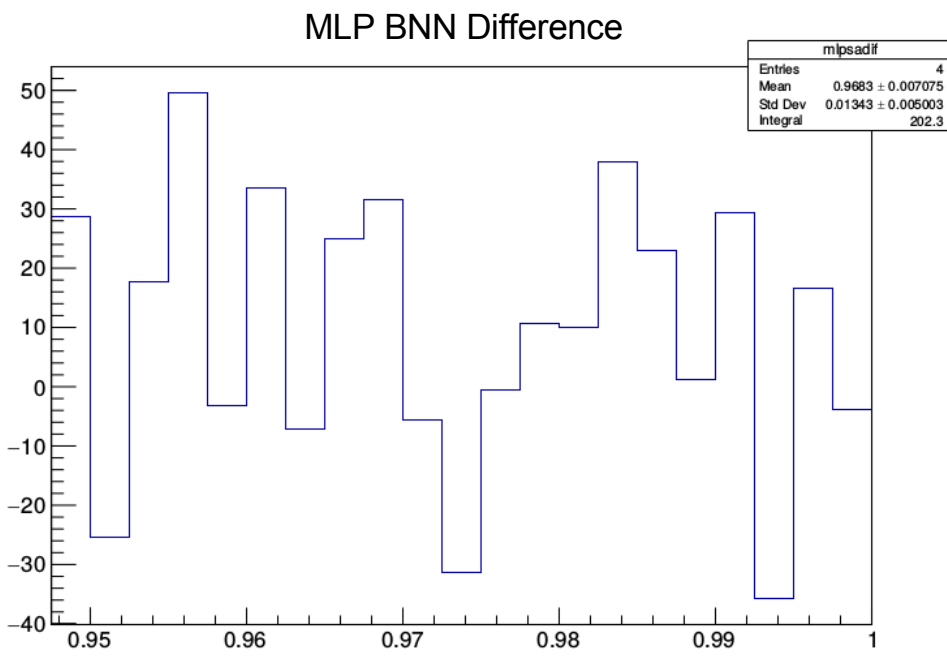
MLP distribution comparison for events in the overlapping window of the HET and KLOE DAQs (blue) and out of the overlapping region (red)

Also in this case no significant excess is found

MVA: MLP distribution SA

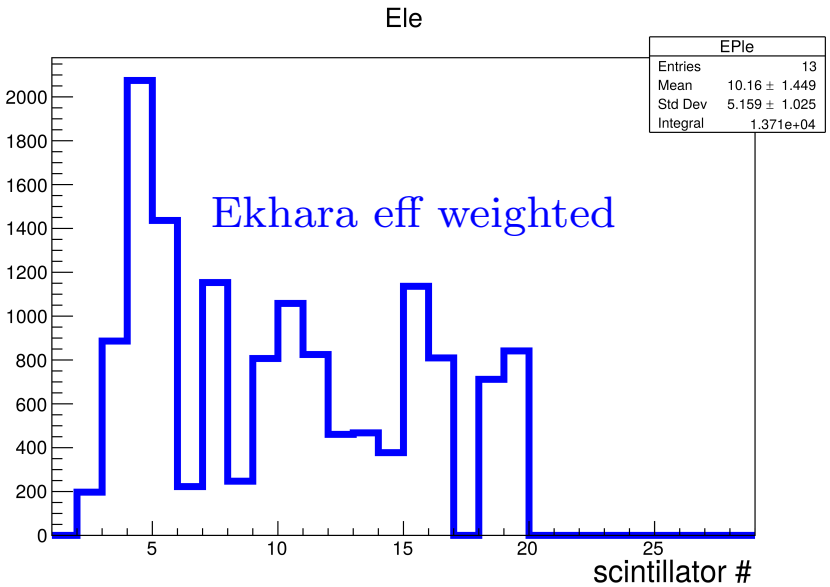


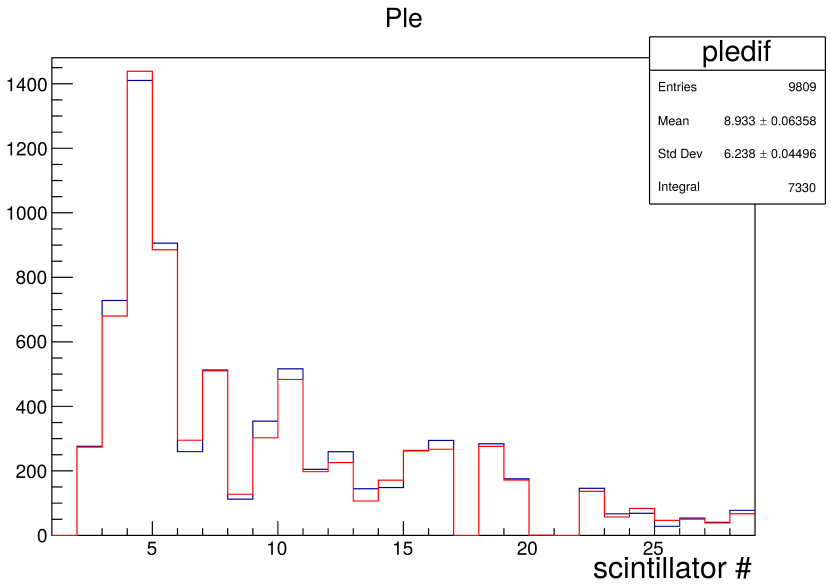
MLP BNN Distributions



Difference between the MLP distributions in the signal region

MVA: Pl distribution SA Ele



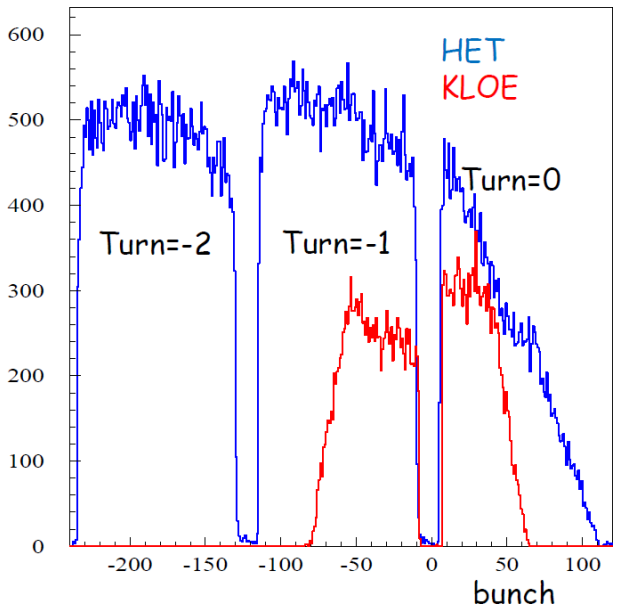


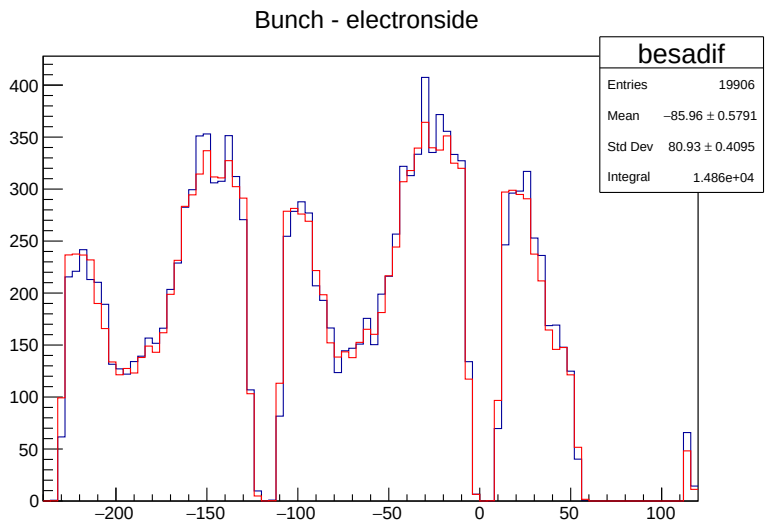
⋆ Plastic distribution eff weighted expected from Ekhara for SA ele

⋆ Comparison of the ele pl distribution for events inside the overlap window (blue) and out (red)

MVA: TDC distribution SA

Red : events in the bckg region
Blue: events in the signal region.





- ⋆ On the top right the same comparison done for DA events is shown for SA events
- ⋆ On the to left the difference of the two distributions is shown