Luminosity measurement

Accelerator
Division

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17/03/15

Luminosity measurement method

Precise

Needs:
- Clean signals
- Precise acquisition
- Redundant determination

Allows:
- Machine performance logging
- Fast luminosity calibration
- Long term performance feedback

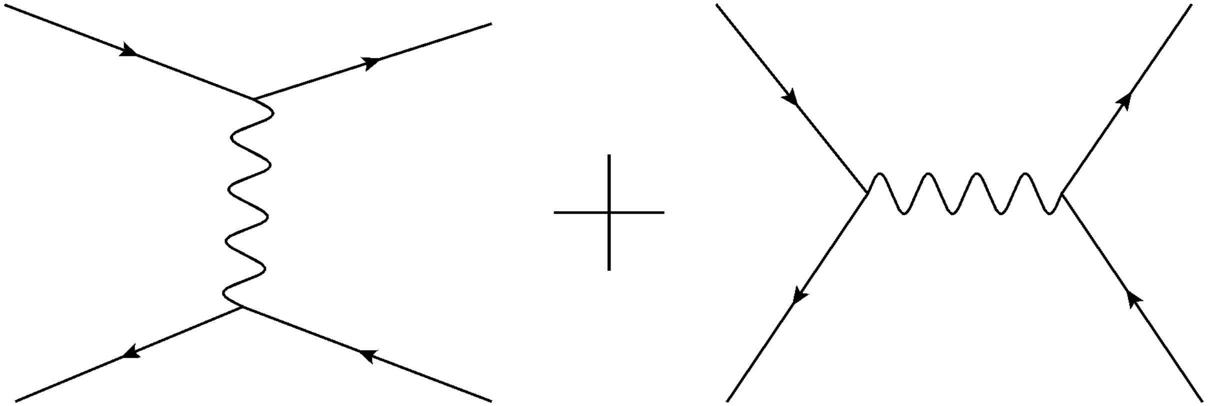
Fast

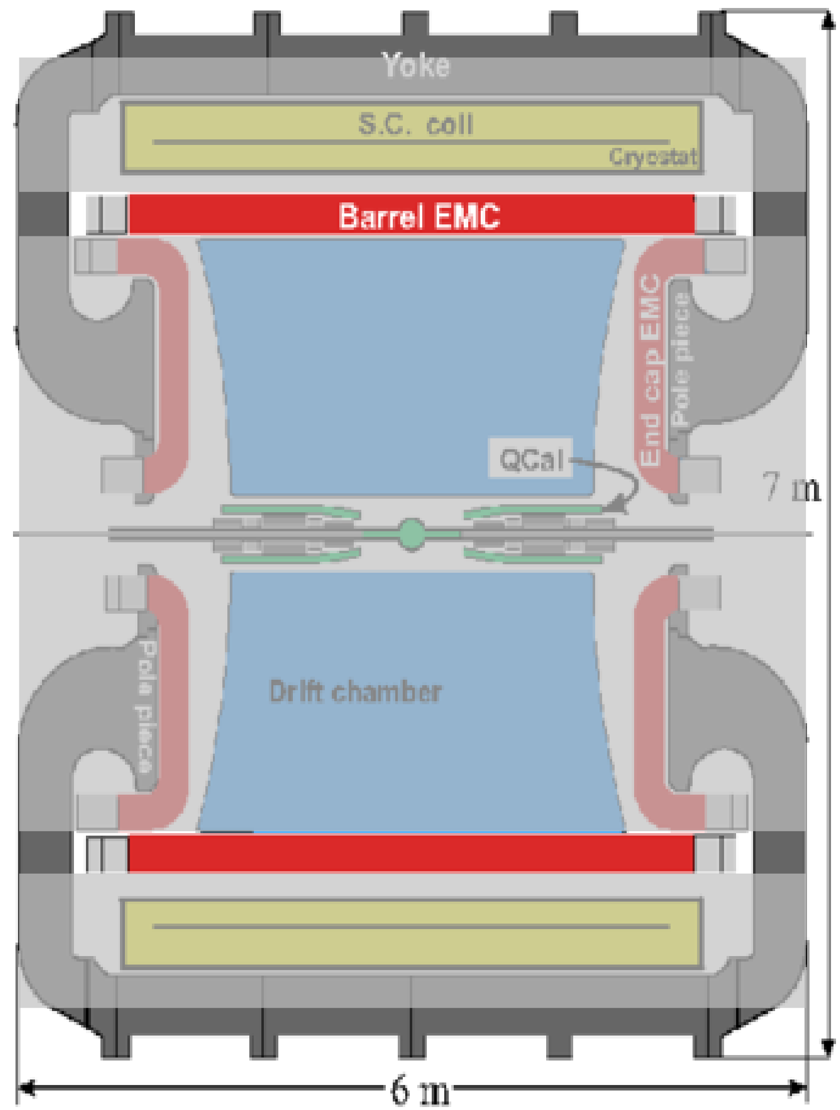
Needs:
- Fast detectors & FEE
- Real time acquisition
- Accidental rate << Signal rate

Allows:
- Collision optimization
- Machine feedback

Precise luminosity monitor: Large Angle Bhabha

$$\sigma(e^+e^- \to e^+e^-(\gamma)|\sqrt{s} \simeq m_\Phi, \theta_+ < 45°, E_\gamma < 10\ \mathrm{MeV}) = 431\ \mathrm{nb}$$





Process selected directly at the trigger level using High Energy Threshold (BBT) multiplicity in the EMC Barrel

Process monitoring the luminosity provides values every 15 seconds (KLOE-2 fast data)
The accuracy of the value depends on the value of the instantaneous luminosity itself:

$$\delta_{\mathcal{L}} \propto \frac{1}{\sqrt{\mathcal{L}}}$$

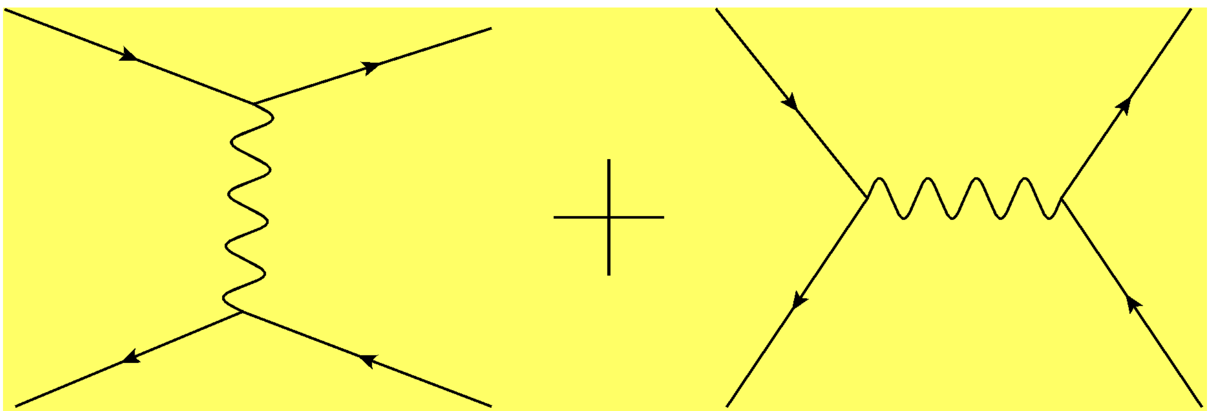
Fast luminosity monitor(2): Small Angle Bhabha

At small polar angle the Bhabha cross section is very high

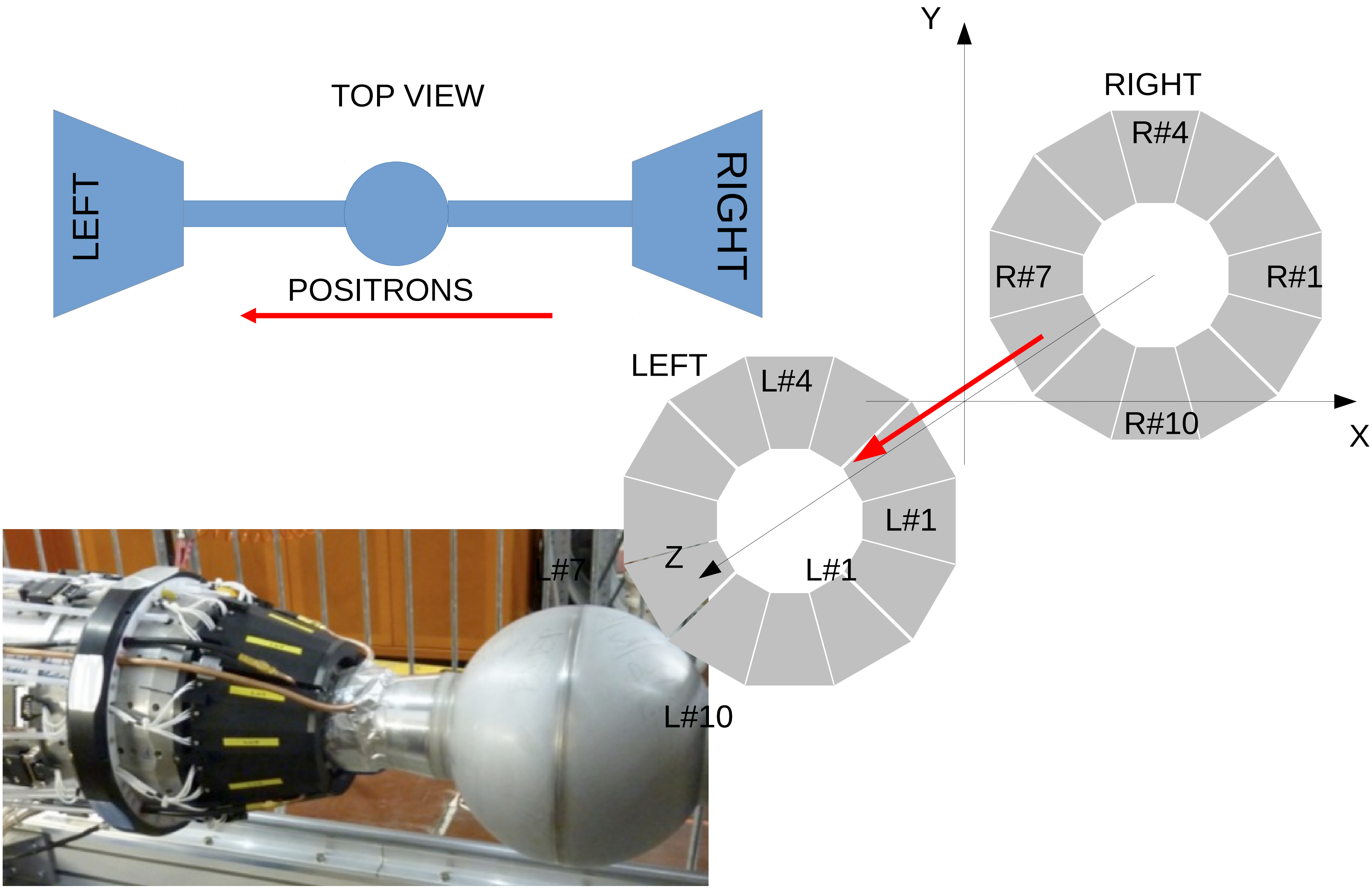
$$\frac{d\sigma}{d(\cos(\theta))} = \frac{\pi\alpha^2}{s}\left[u^2\left(\frac{1}{s}+\frac{1}{t}\right)^2 + \left(\frac{t}{s}\right)^2 + \left(\frac{s}{t}\right)^2\right]$$

The aim of the CCAL-T luminometer is to use this process to measure the instantaneous luminosity faster and with reasonable accuracy (few percent)

$$e^+e^- \rightarrow e^+e^-(\gamma(\gamma(\gamma)))$$



KLOE-2 CCAL-T geometry



Simulation

Monte-Carlo simulation

Event simulation based on **"BABAYAGA"** (*ref. Nucl. Phys. B758(2006) 227*) event generator with:

- $\theta_{p(e)} > 5°(\pi\text{-}5°)$
- Max three radiated photons stored (up to 30° of acollinearity)

DAFNE specific effects added:

- Longitudinal beam spread (1 cm width)
- Real Center of Mass momentum (P_x = -27 MeV)
- Beam energy spread 300 keV
- 0.51 T KLOE magnetic field
- CCALT geometry (simplified with annulus between min and max radii)

Simulation outcome

```
final state = ee
ecms    =      1.0200 GeV
thmin   =      5.0000 deg
thmax   =    175.0000 deg
acoll.  =     60.0000 deg
emin    =      0.0500 GeV
ord     = exp
model   = matched
nphot mode =    -1
seed    =101451135
iarun   =    0
eps     = .000500000
darkmod =    0
```

BABAYAGA OUTCOME

Total cross section: 128 µb

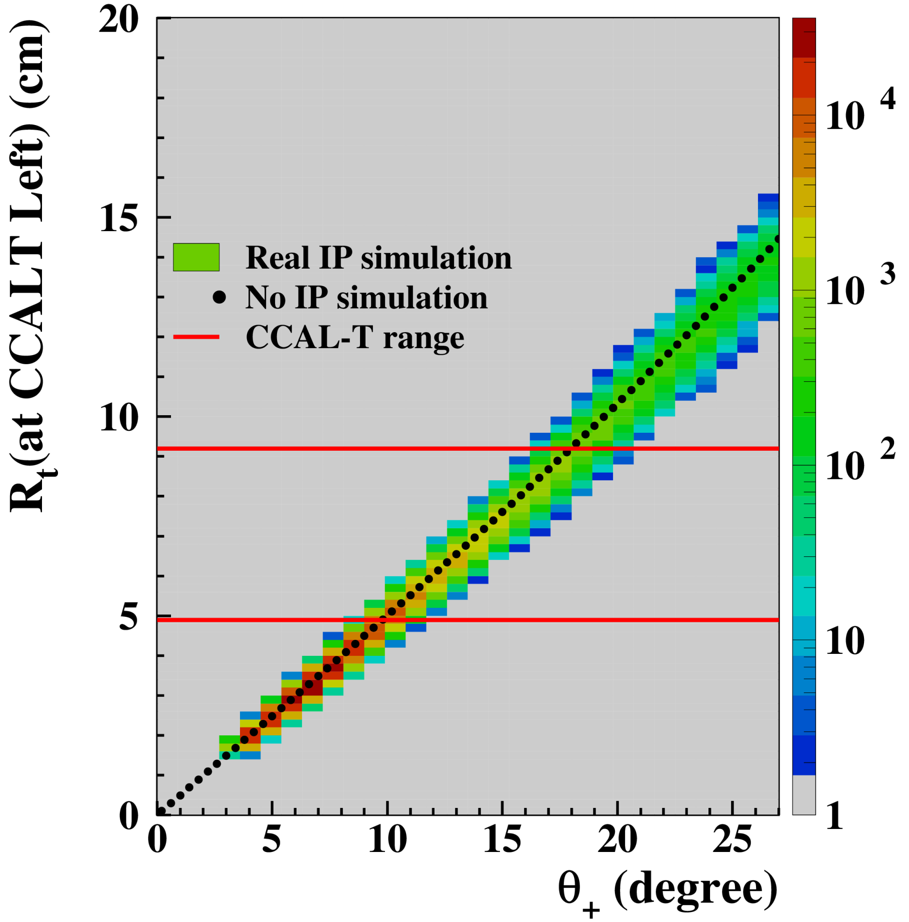
```
· Generating      500000 unweighted events ~
```

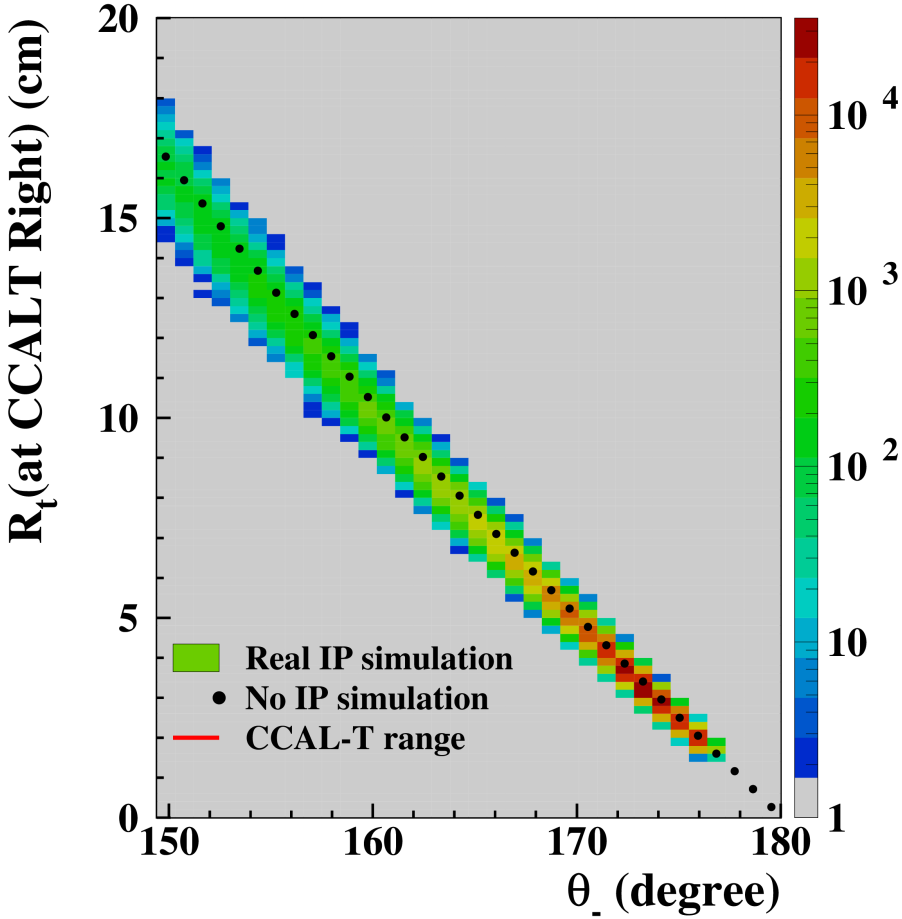
```
::::::>>>>>> weighted events <<<<<<::::::
0 photons:   73062.48011260 +-      0.77002674     ( 57.0219 %)
1 photons:   40646.06377959 +-      1.16586632     ( 31.7224 %)
2 photons:   11796.65815176 +-     64.51369488     (  9.2068 %)
3 photons:    2264.06715336 +-     13.46741818     (  1.7670 %)
4 photons:     320.87108066 +-      1.49880322     (  0.2504 %)
5 photons:      36.59816686 +-      0.58454848     (  0.0286 %)
6 photons:       3.38029847 +-      0.13989764     (  0.0026 %)
7 photons:       0.27440515 +-      0.02486465     (  0.0002 %)
8 photons:       0.06336398 +-      0.04150403     (  0.0000 %)
9 photons:       0.00045797 +-      0.00030501     (  0.0000 %)
total:    128130.45685933 +-     65.92868583 nb
```

@10^{32} cm^{-2} s^{-1}

Rate ~13 kHz

Charged particles tracking

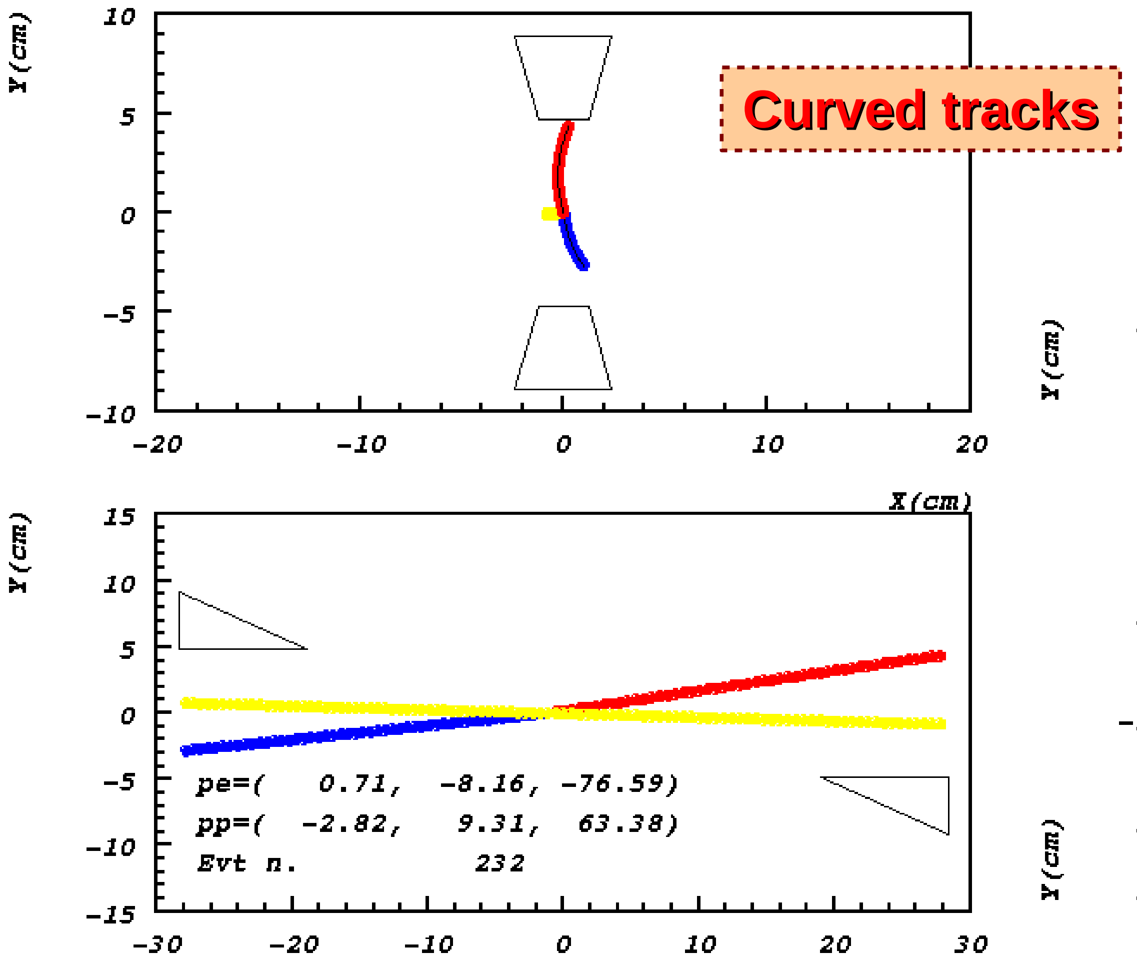


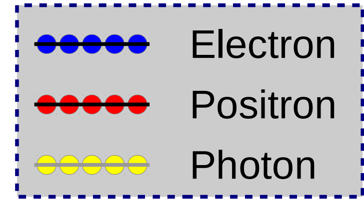


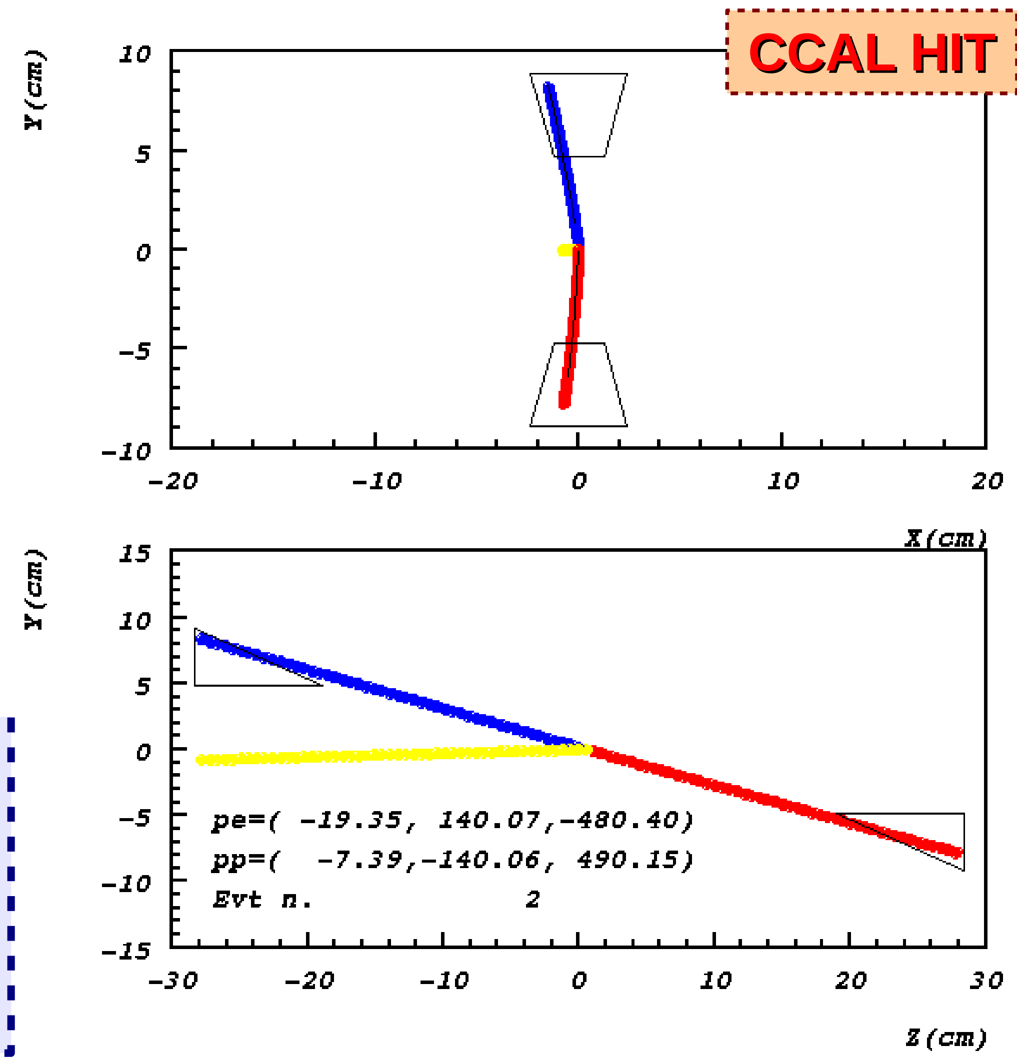
$$R_t(t_{fly})[m] = \frac{\sqrt{2}p[GeV]sin\theta}{0.3B[T]}\sqrt{1-\cos\frac{0.3B[T]\Delta z[m]}{p[GeV]\cos\theta}}$$

Expression evaluated in the approximation of no dE/dx in the Beam Pipe materials.

Particle tracking

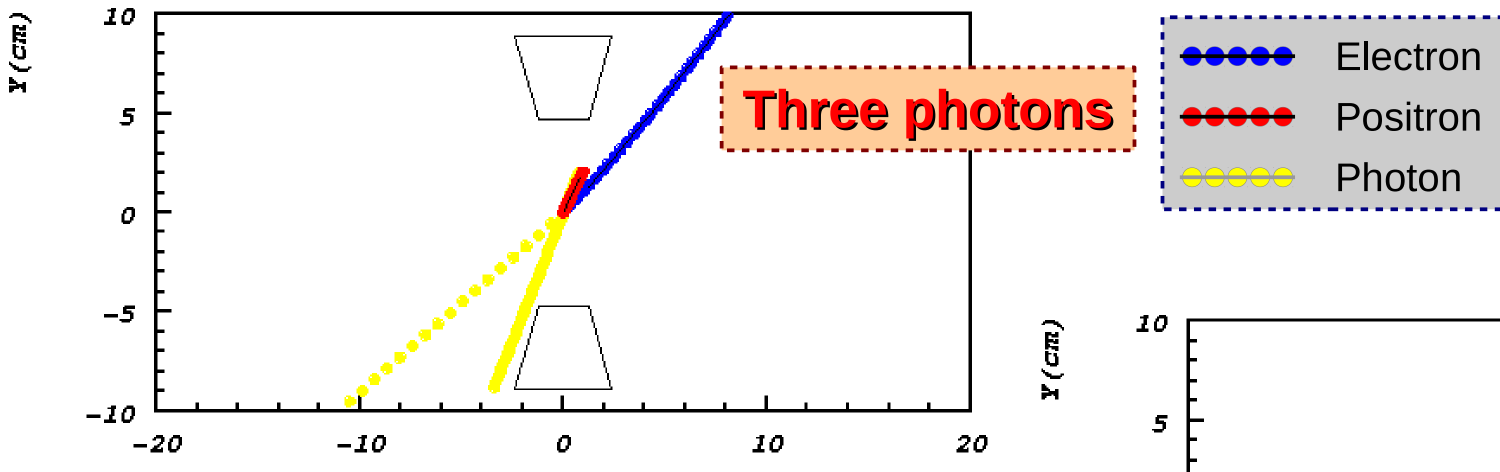


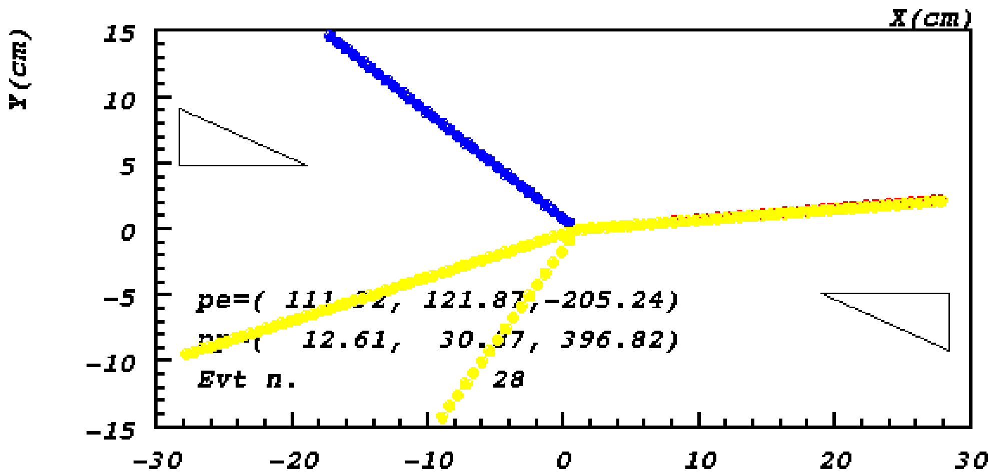


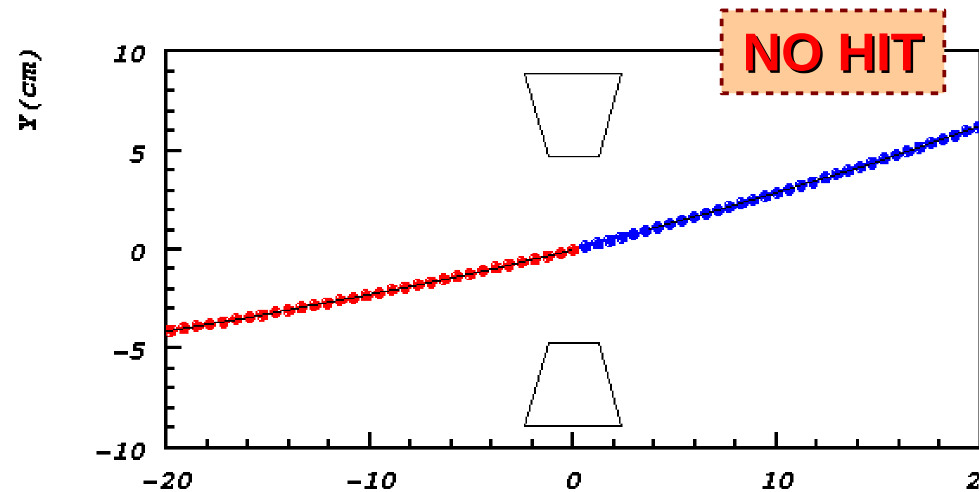


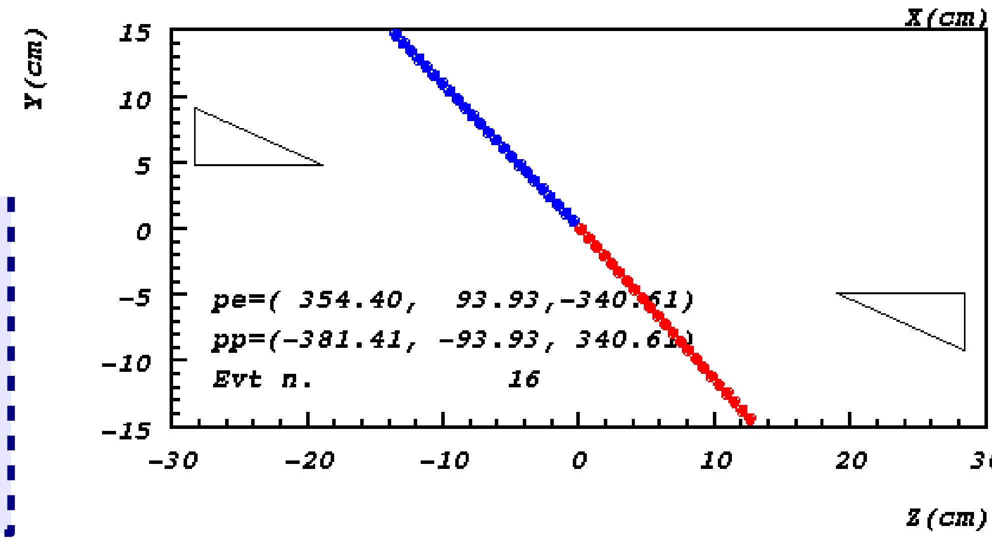
- Example of simulated events
- CCAL-T silhouette is shown
- Charged particle “arcs” drawn

Particle tracking







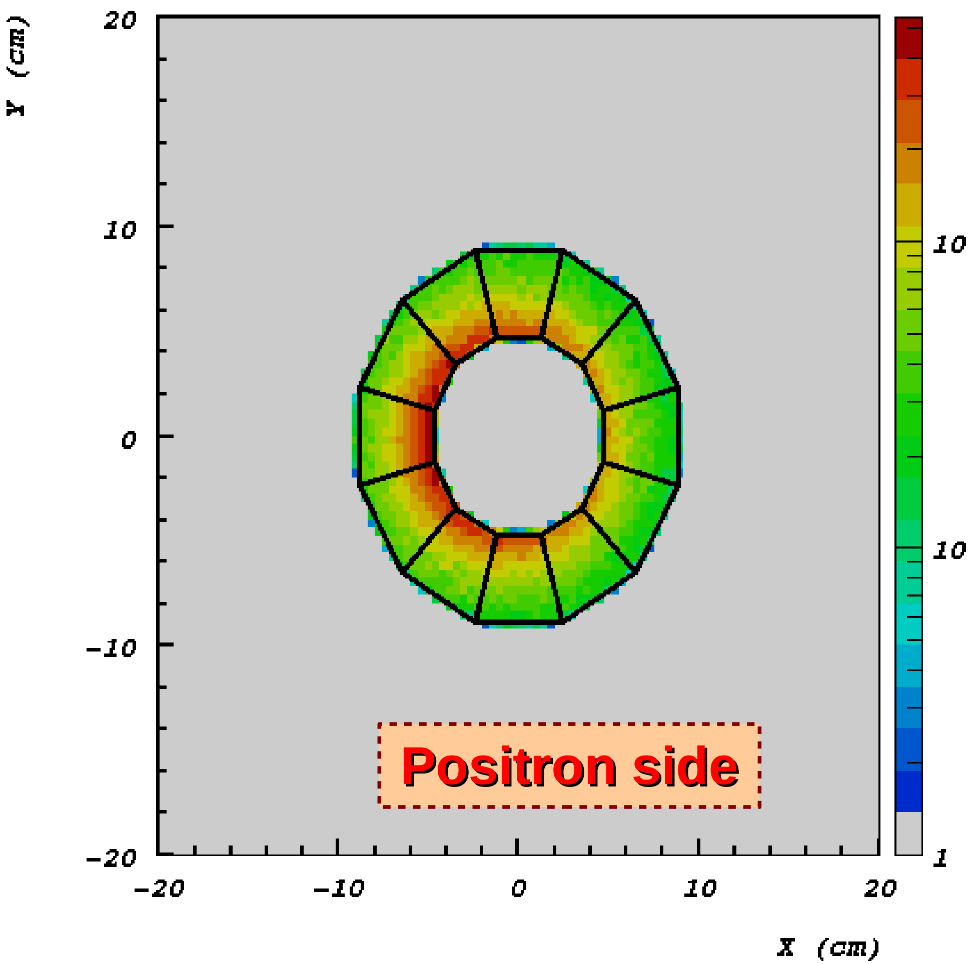


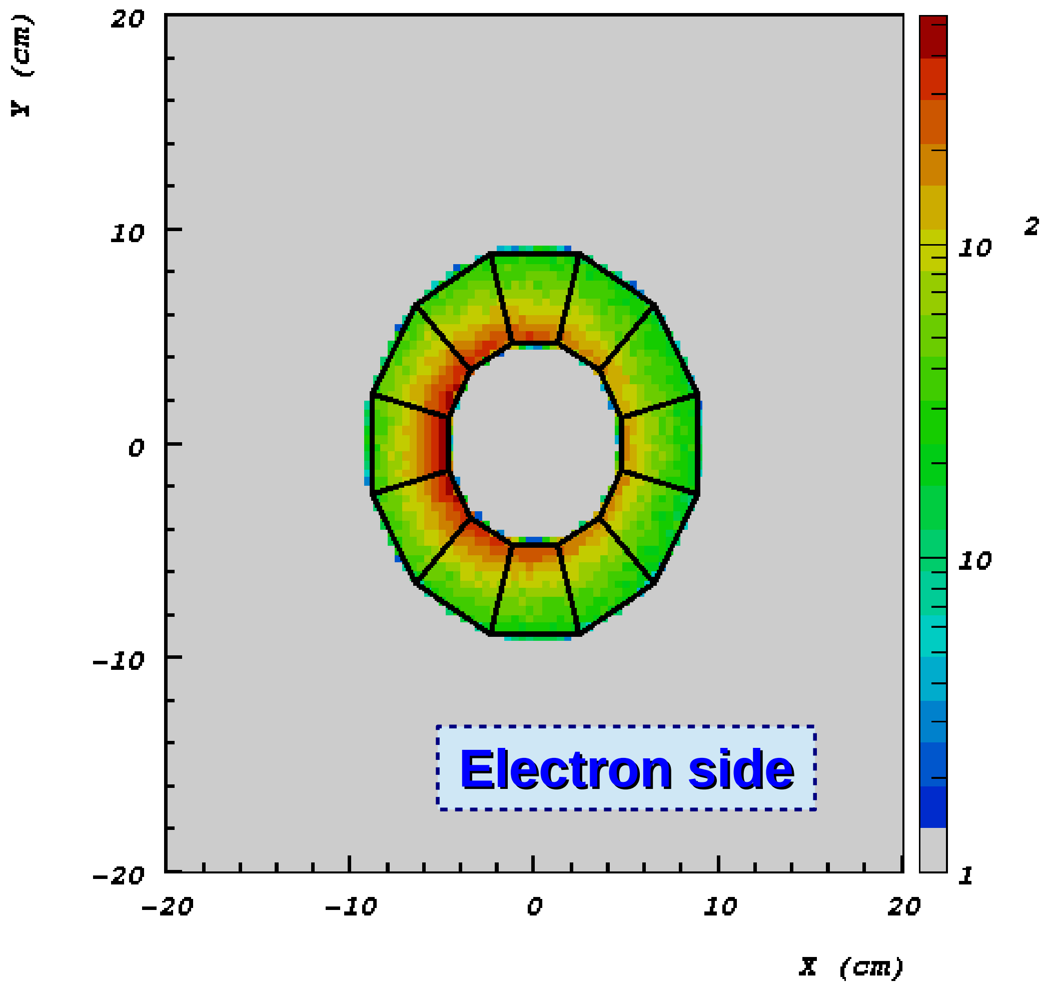
Example of simulated events

CCAL-T silhouette is shown

Charged particle “arcs” drawn

Hit distribution





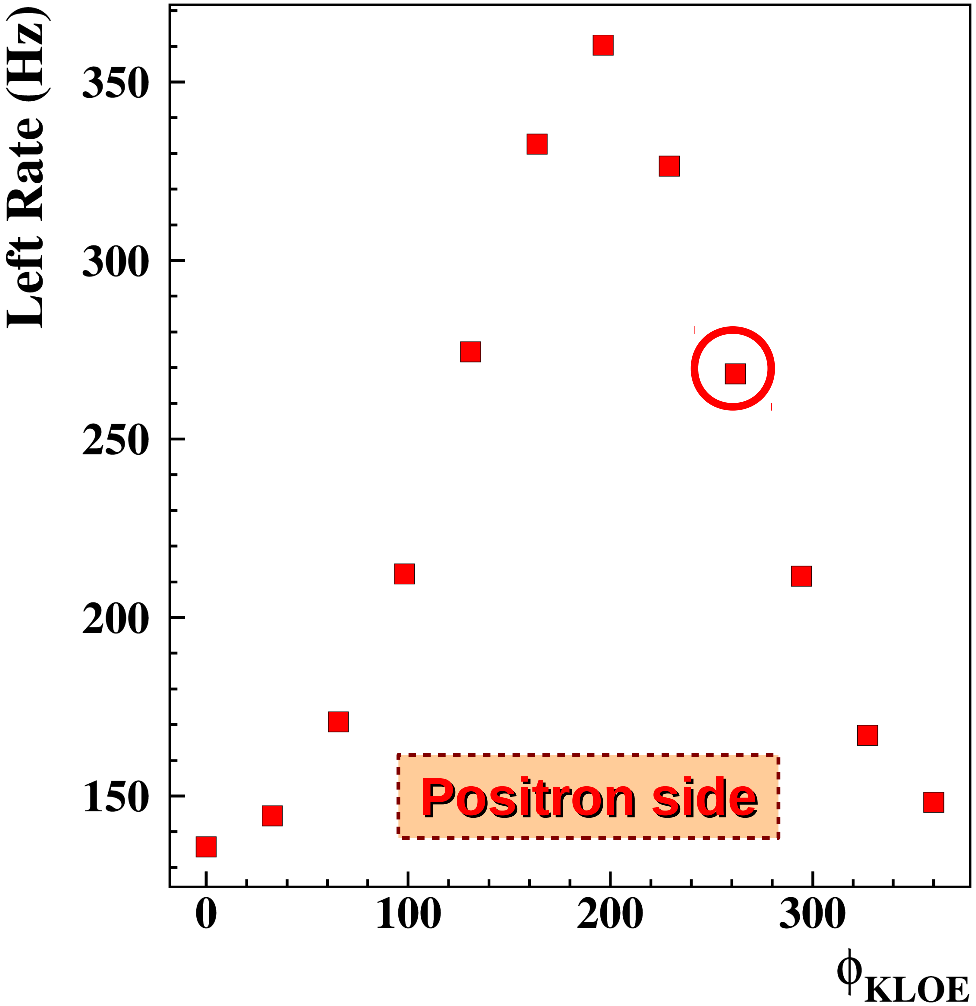
Distribution of hits on the CCAL-T end plate.

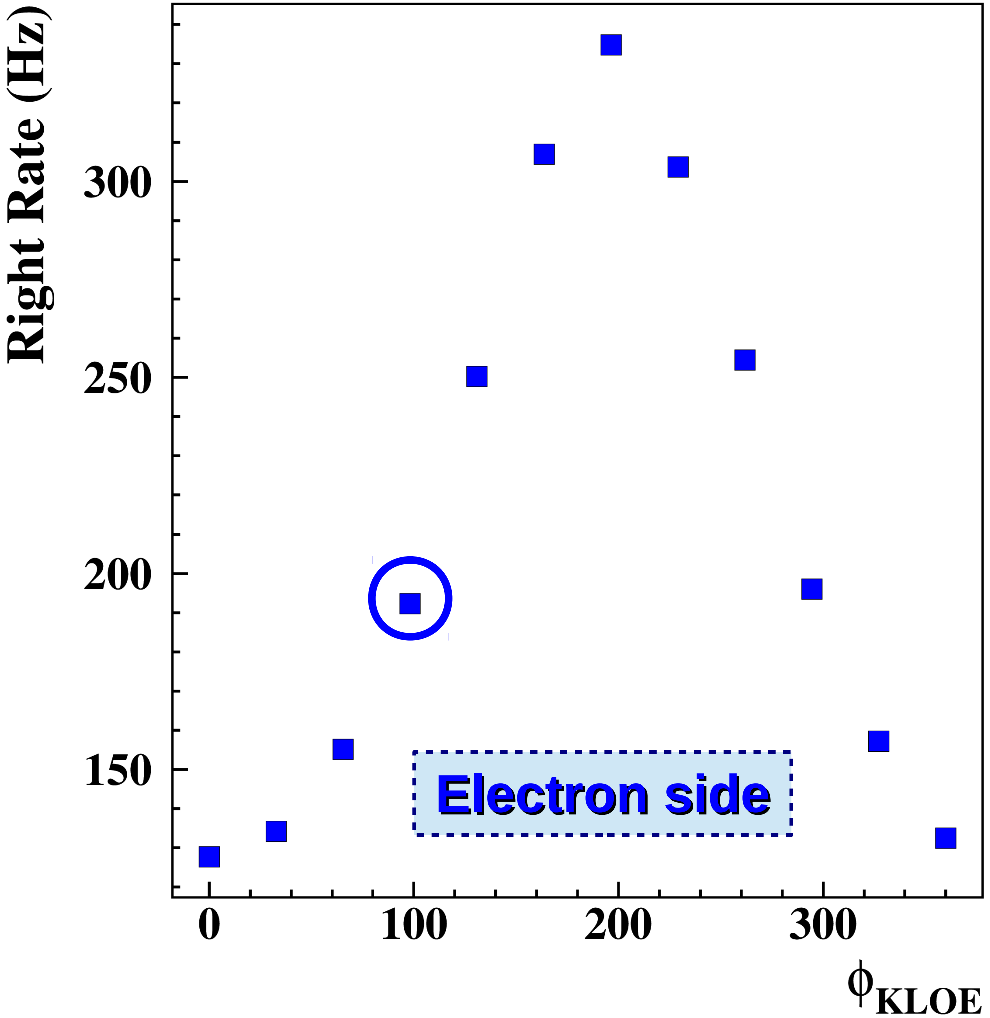
CoM momentum effect is clearly visible.

MC expectation: single rate

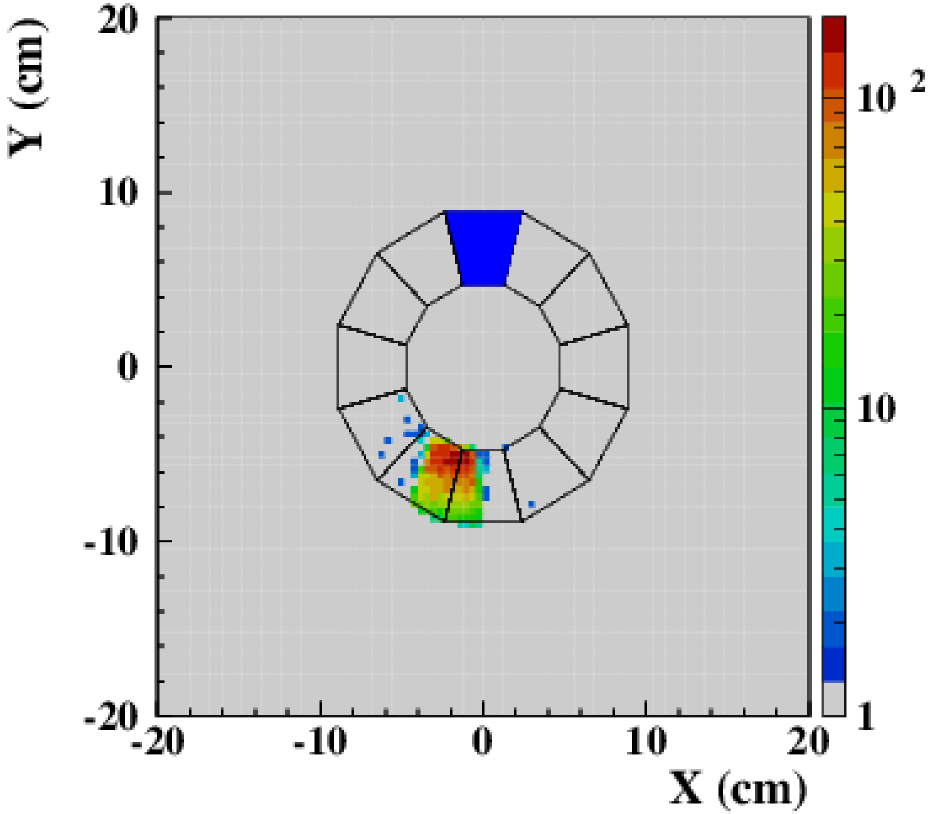
A small asymmetry is observed in the simulation. Further checks on the tracking has to be done in order to be sure about this point.

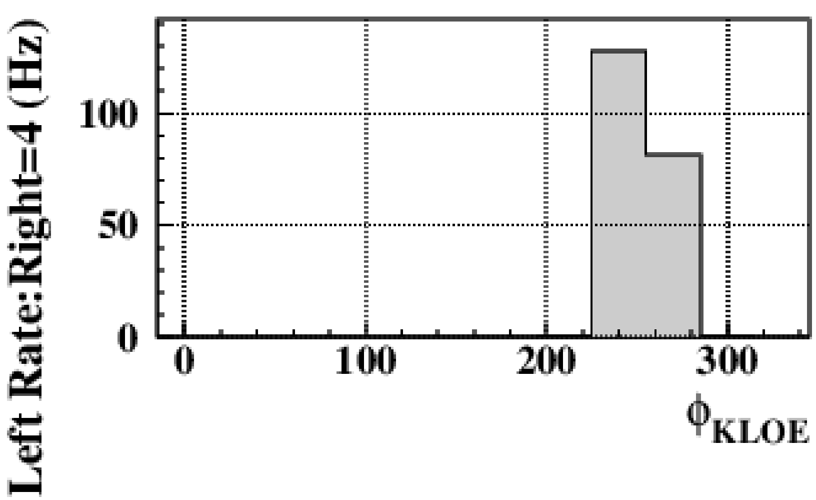
The rate on single arm for Bhabha event is few hundreds of Hertz at maximum.





MC expectation: coincidence





HITS on CCALT-L

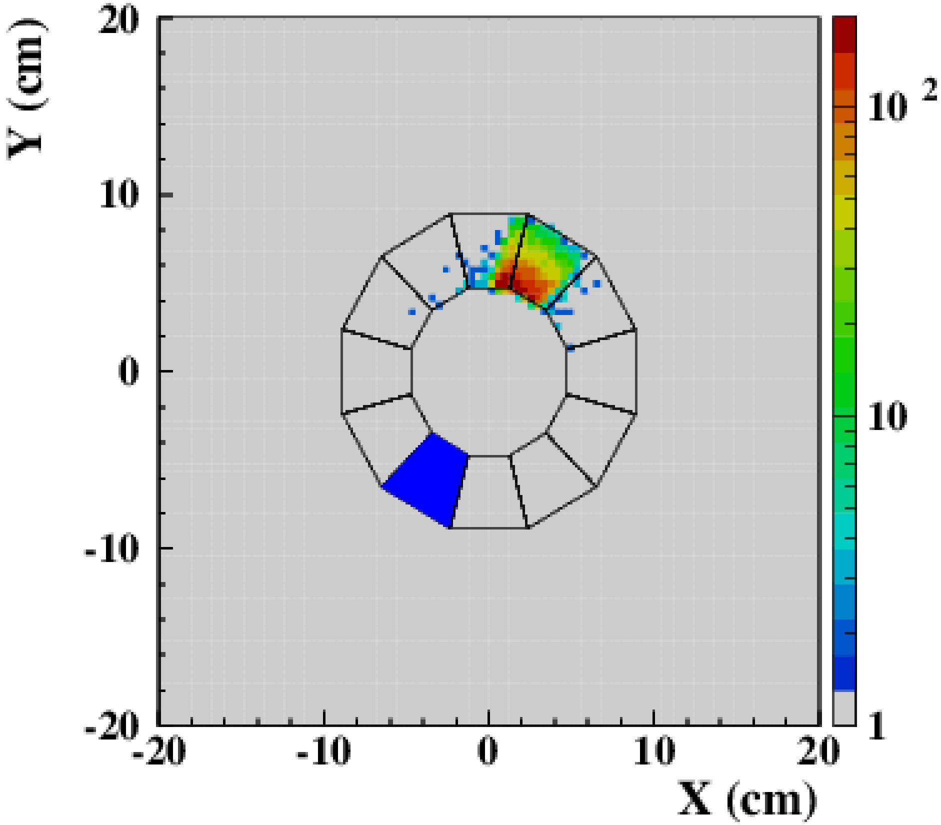
Coincidence with CCAL-R#4

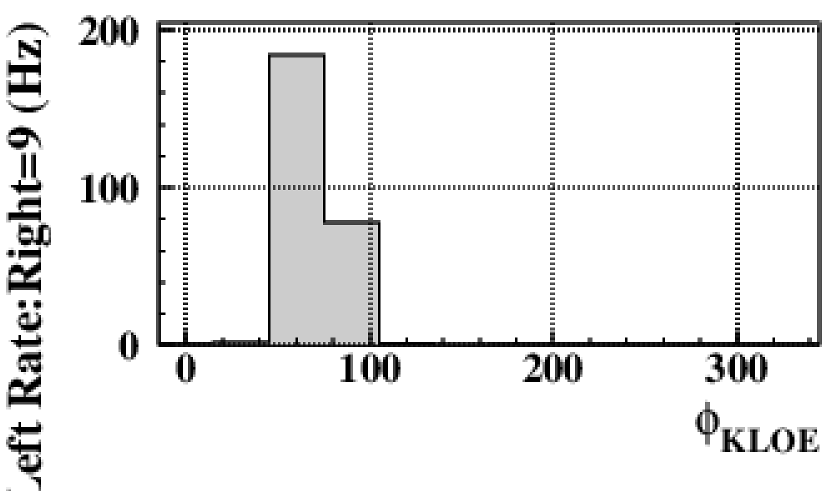
Expected rate:
- **80 Hz on L#10 (bottom) sector**
- 130 Hz on L#9 (bottom-left)

Assumed 100% efficiency and simplified geometry.

L#10 is currently acquired together with R#4

MC expectation: best coincidence rate





HITS on CCALT-L

Coincidence with CCAL-R#9

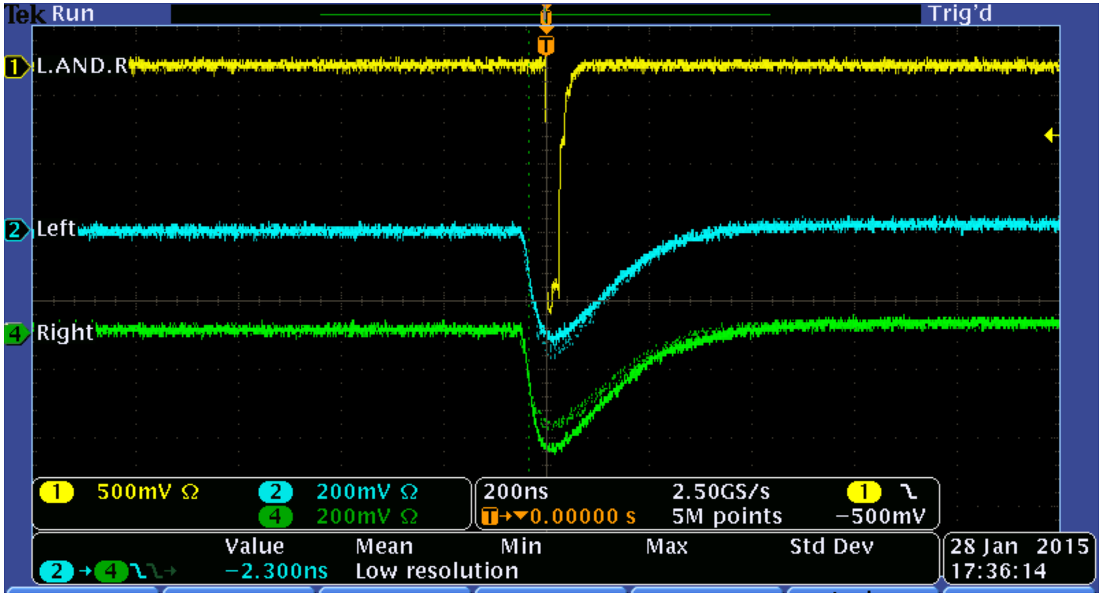
Expected rate:

- **180 Hz on L#3 (top-right) sector**

Assumed 100% efficiency and simplified geometry.

Data acquisition

Signal pulses from CCAL-T



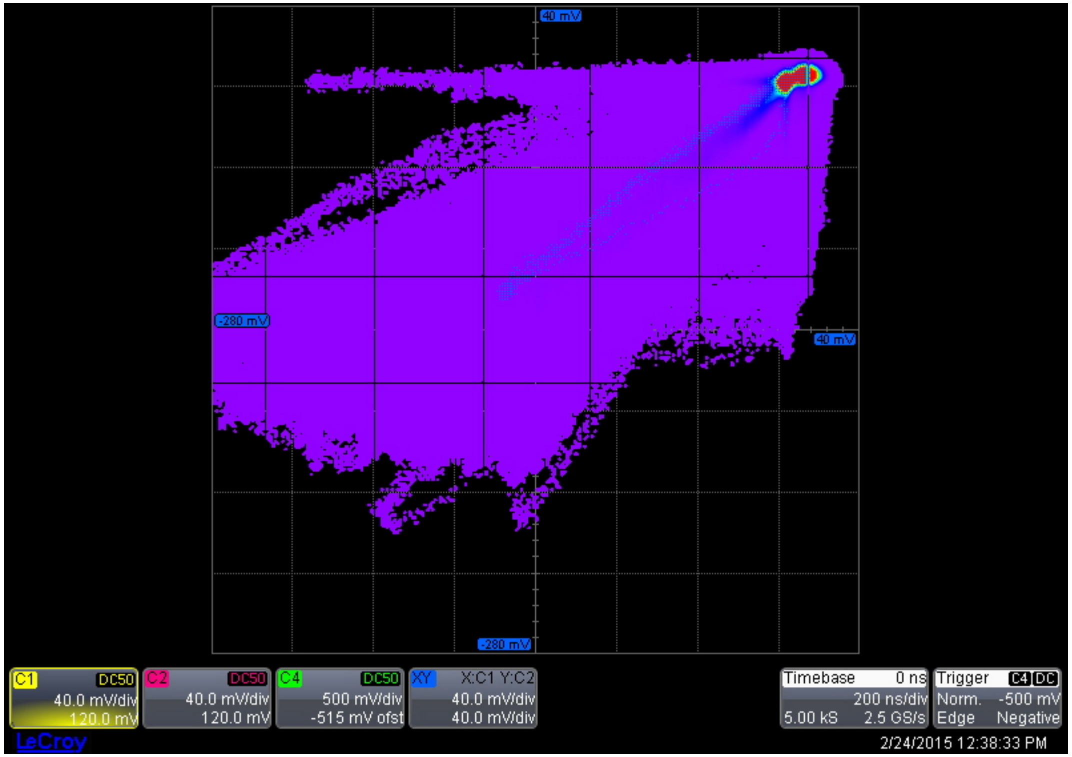
Pulses from CCAL-T sectors seen at the scope with beam operations.

Signal from beam particles are between -50 mV and -400 mV.

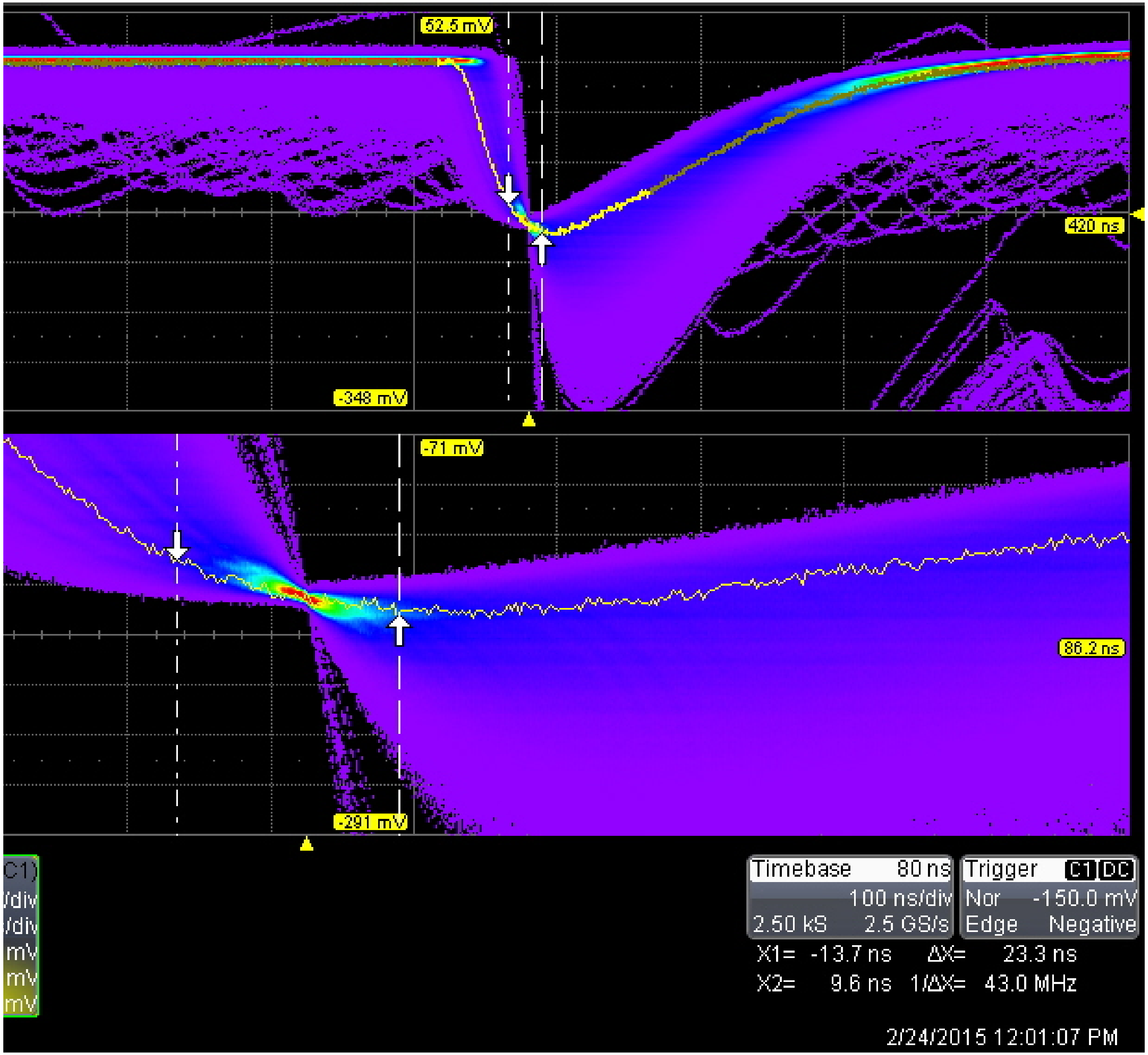
(Scope: Tecktronix DPO 3054 Courtesy of S. Miscetti)

Using coincidence as trigger it is possible to observe the relative phase between signals and also measures the effectiveness of the thresholds used to for NIM logic signals for the coincidence itself.

(Scope: LeCroy 104xS-A courtesy of S. Gallo)



Trigger time jittering



Using the persistency of the scope it is possible to observe the width of the time jitter when a threshold is set.

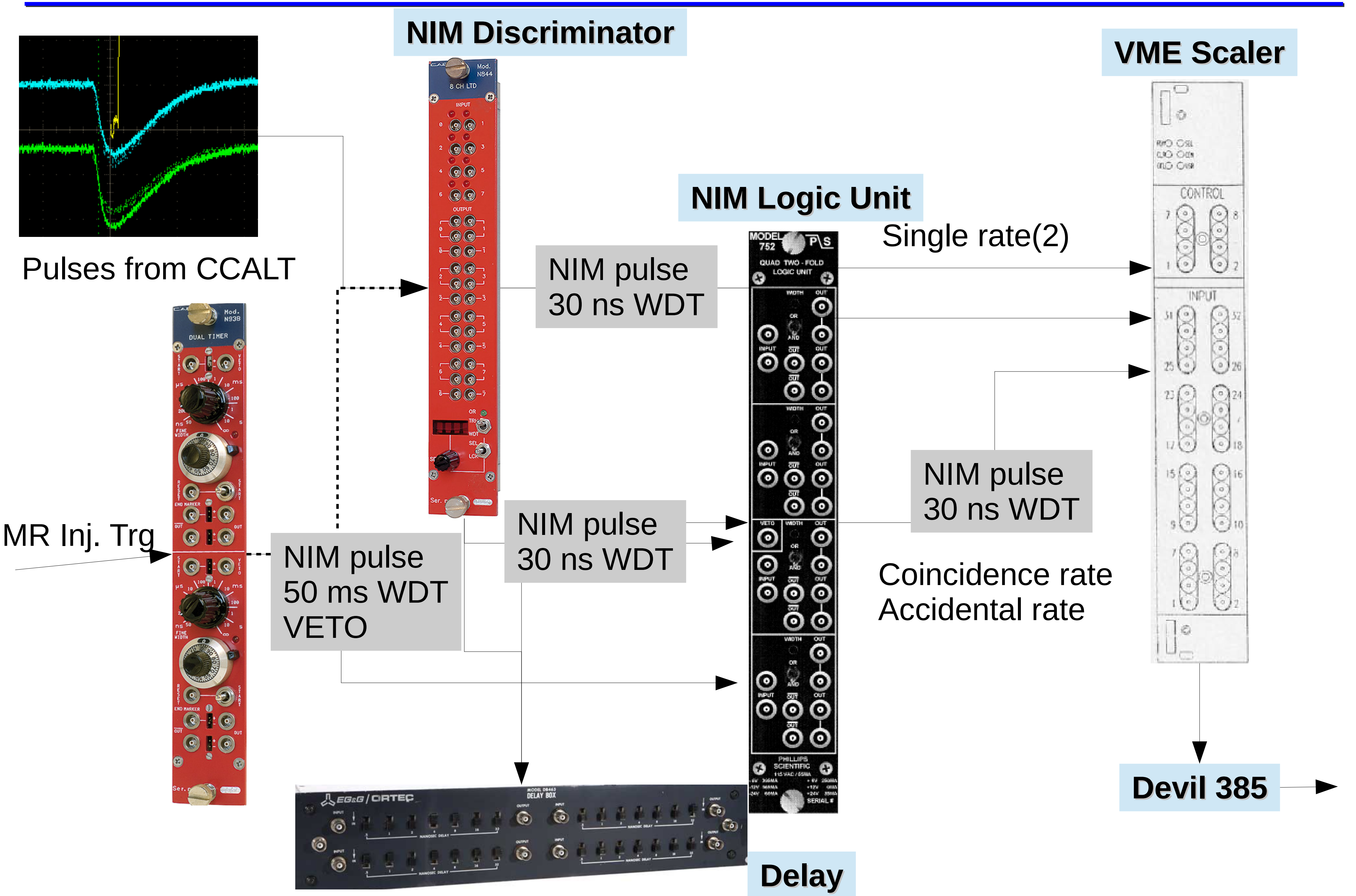
In this picture the threshold was set at -150 mV on the negative edge of the signal coming from one of the two CCAL-T sectors.

The width is well represented by the two cursors line: 23 ns

This will set automatically the width of the NIM pulses used for coincidence: 30 ns.

(Scope: LeCroy 104xS-A courtesy of S. Gallo)

Acquisition chain



Luminosity measurement application (v1.1)

KLOE Luminosity

Electron side Rate

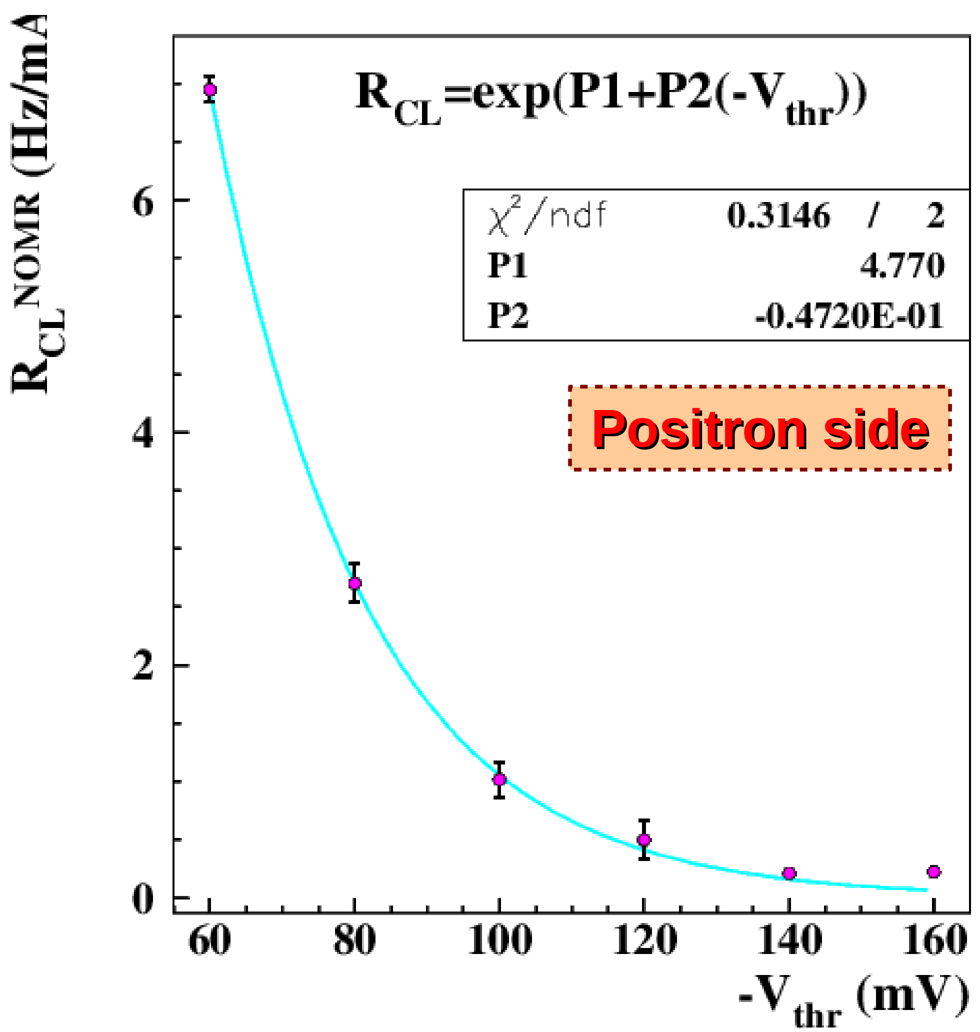
Positron side Rate

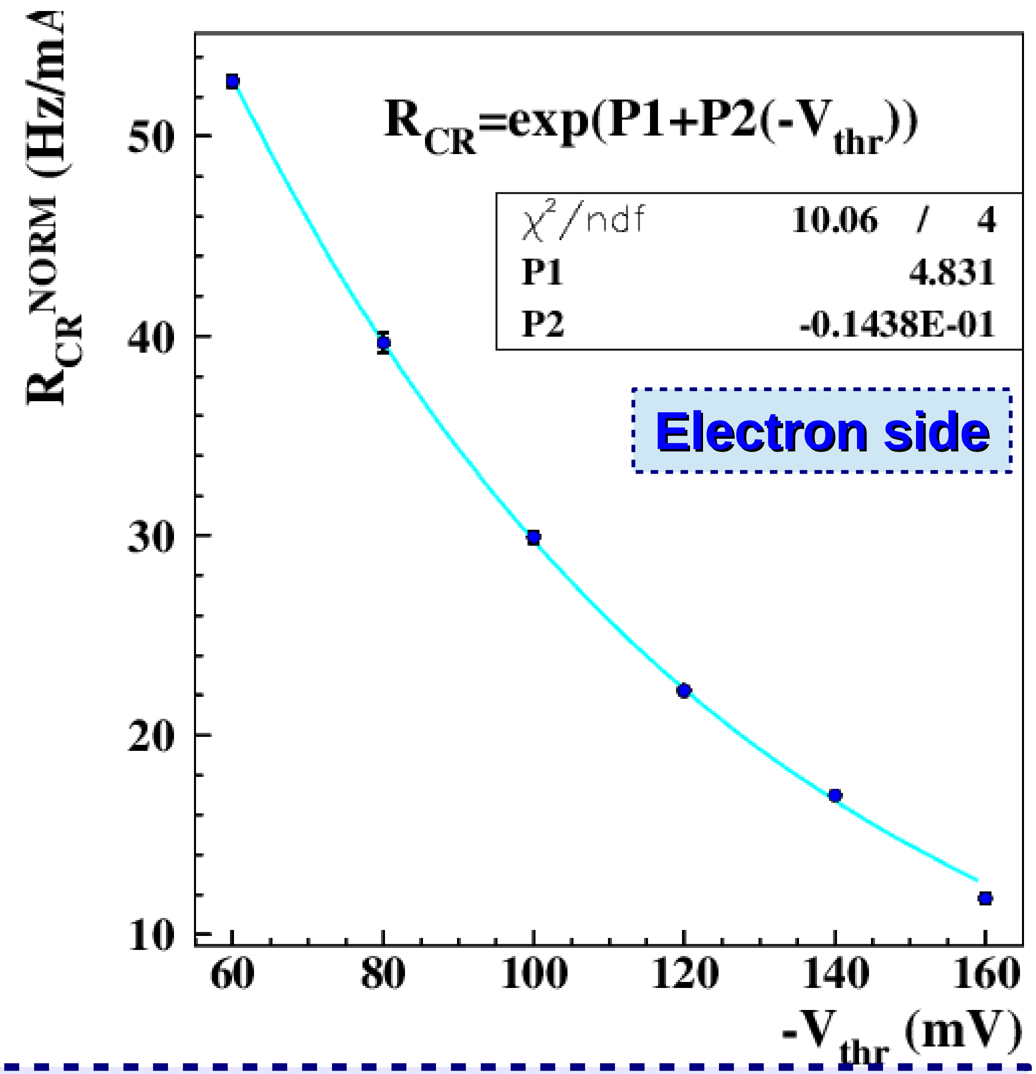
Coincidence rate

Estimated accidental Rate

Rate/Trg Lum ratio

Thresholds scan with single beams (electron)



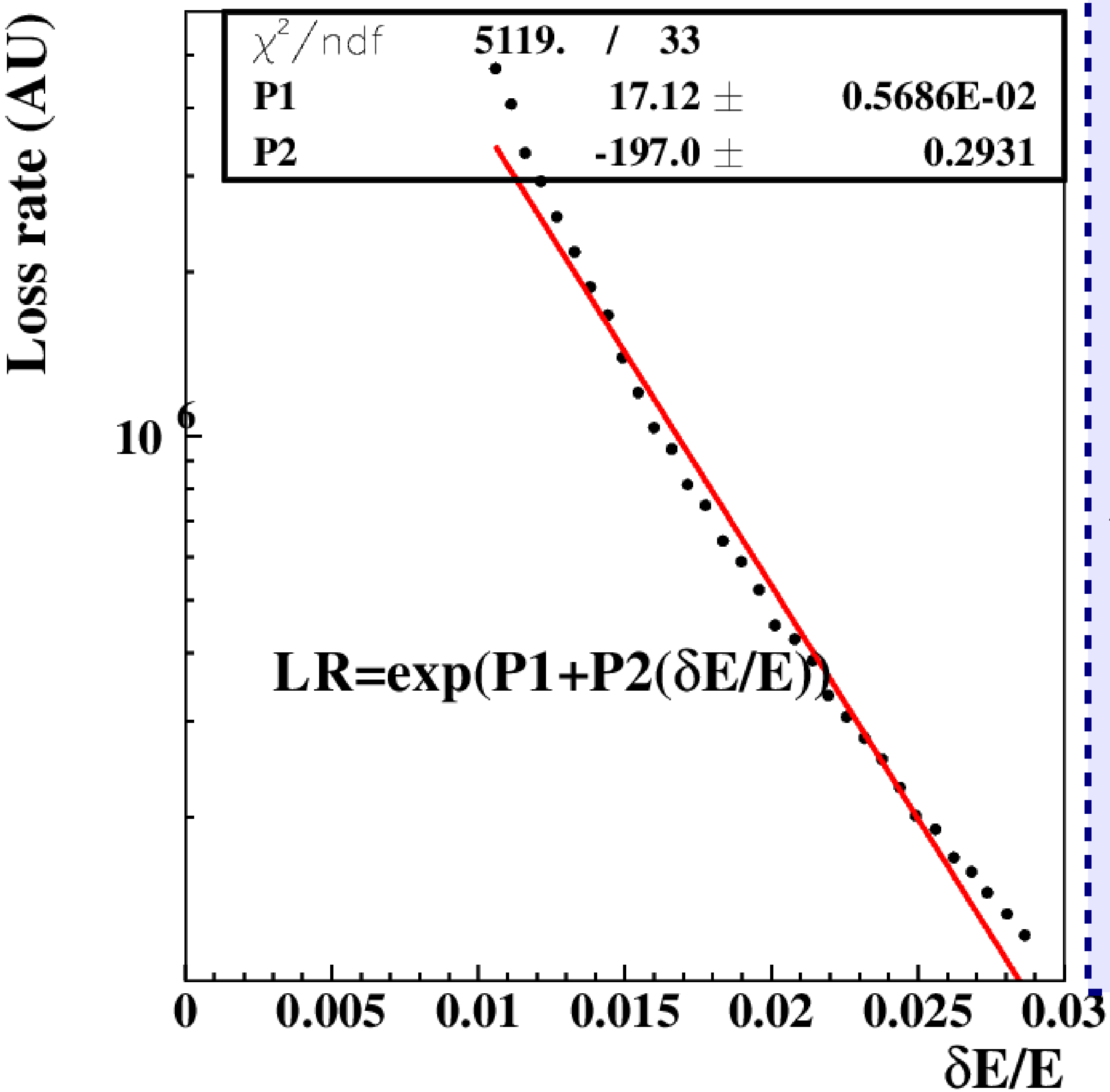


Normalized rates on the two sides as a function if the threshold.

Rate dependence from the current has been taken out also in the width evaluation.

Tousheck effect on MC

Phys. Rev. ST Accel. Beams 15, 104201
SuperB case study



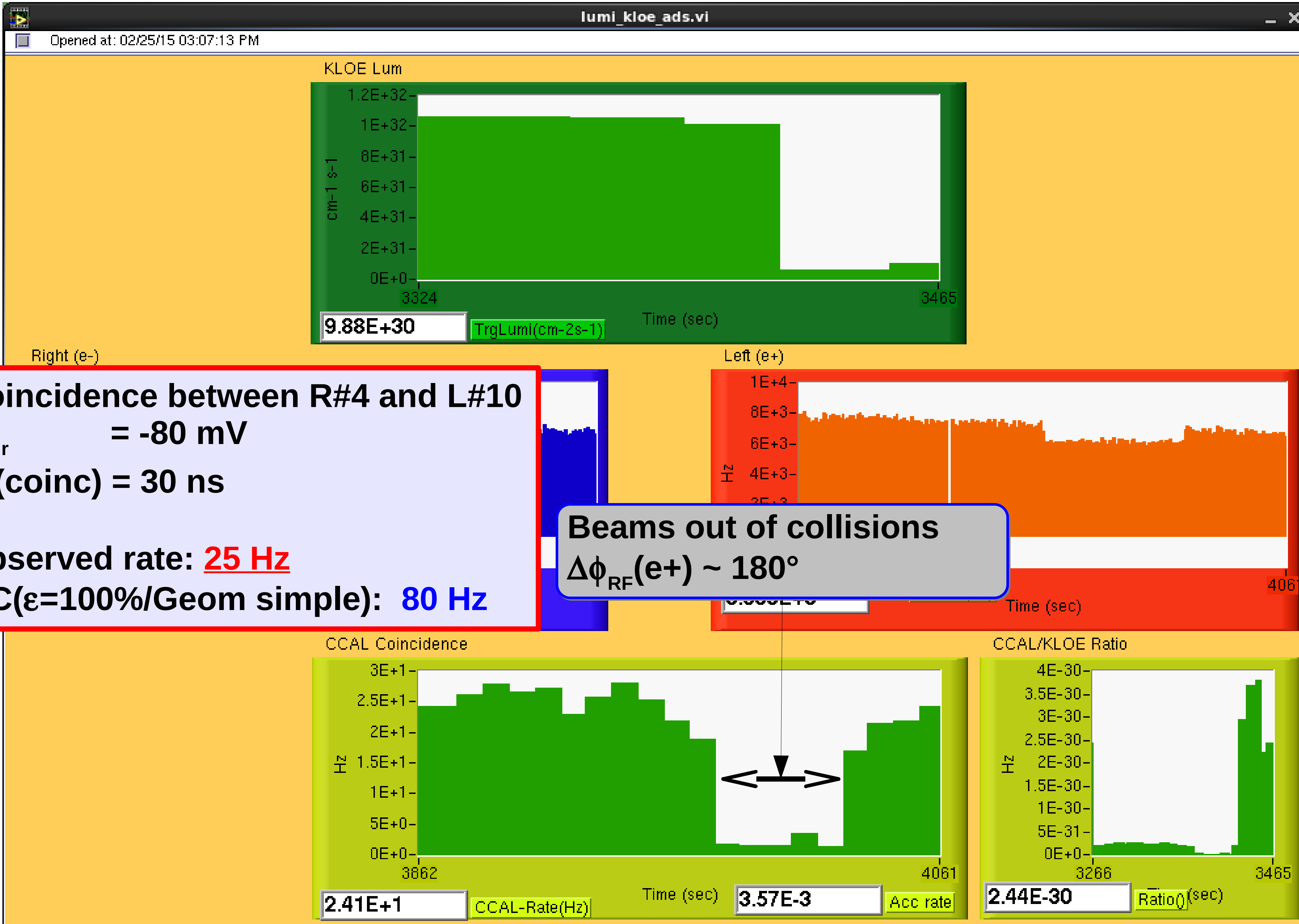
Fit is performed with exponential decay as observed in the real data from CCAL-T:

$$R = e^{P_1 + P_2 \delta(E)/E}$$

The simulation shows a slightly different behavior.

Asked to M. Boscolo to recover some data from old DAFNE simulation to understand if the observed rate matches the expectation.

First observations with beams



Coincidence between R#4 and L#10

V_{thr} = -80 mV

Δt(coinc) = 30 ns

Observed rate: 25 Hz

MC(ε=100%/Geom simple): 80 Hz

Beams out of collisions

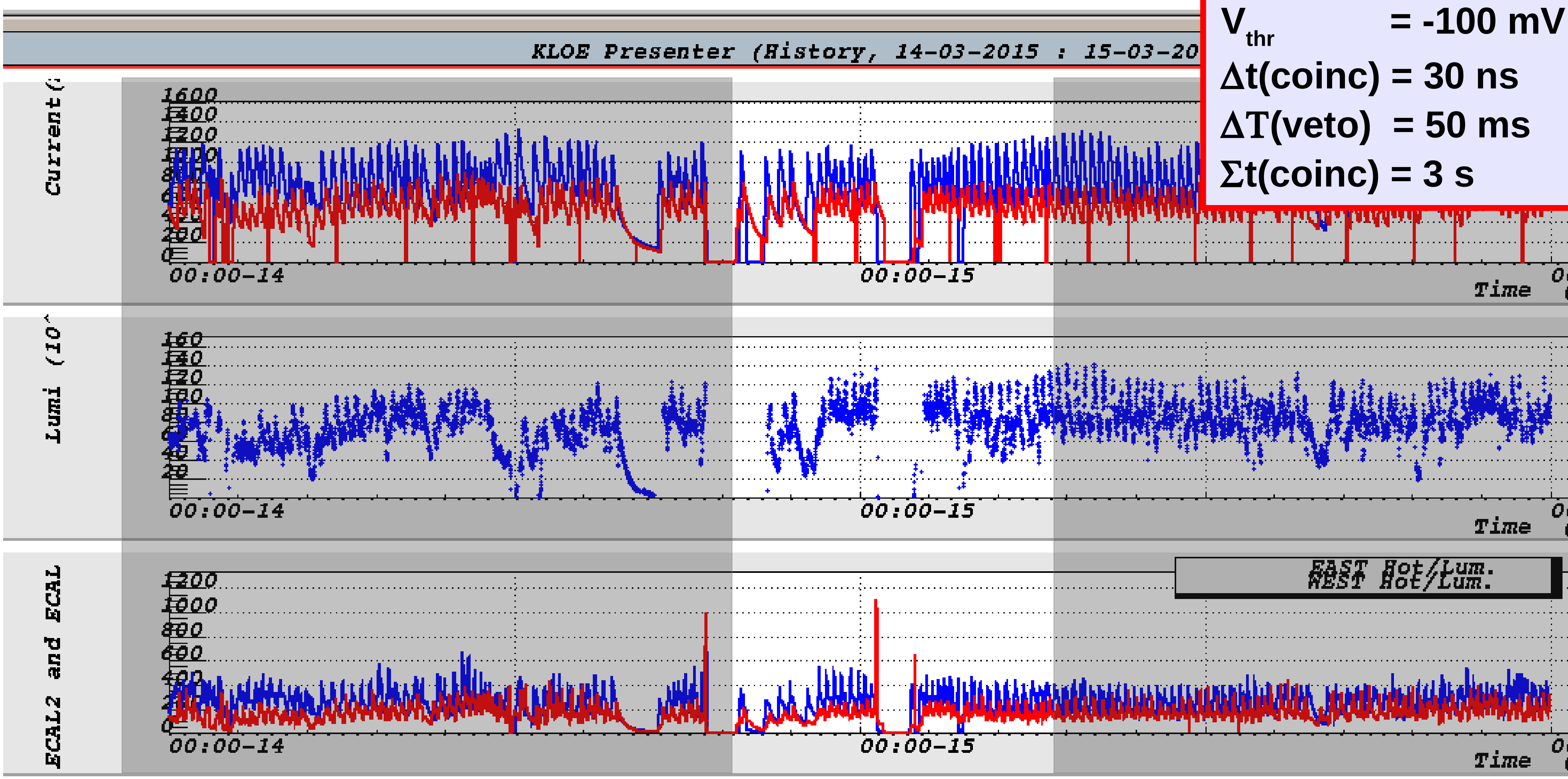
$\Delta\phi_{RF}$(e+) ~ 180°

Luminosity measurement application (v1.3)

Further developments include the simultaneous acquisition of the currents.
A "online" calibration of the rate with the available KLOE Trg Luminosity has been Implemented. Offline study are needed to determine the best parameter to optimize the calibration.

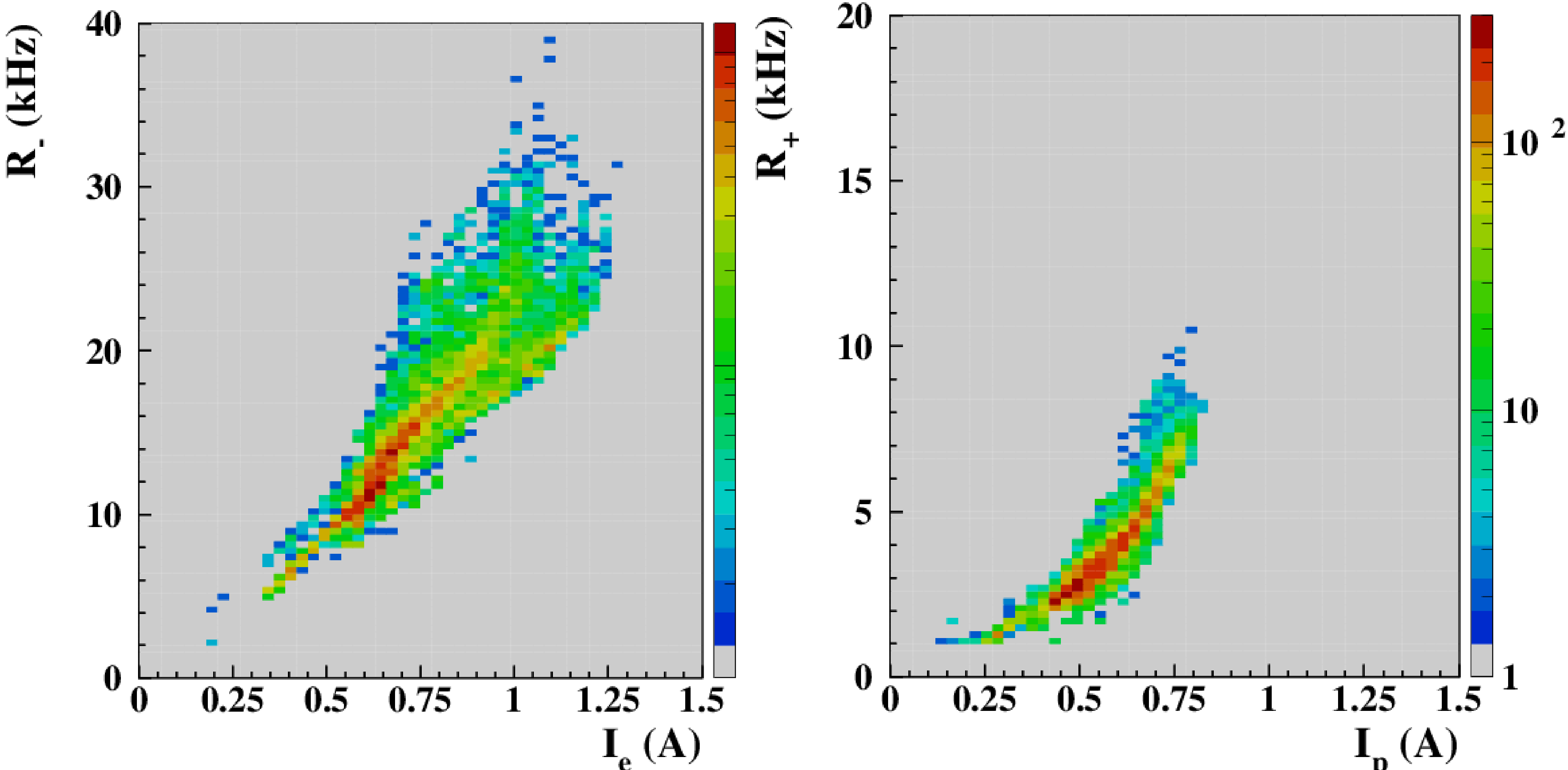
Datataking range

Data acquired during the afternoon of 14/03/2015 and the morning of 15/03/2015
Application left in acquisition.
Beam injection time window vetoed for coincidence only.



V_{thr} = -100 mV
Δt(coinc) = 30 ns
ΔT(veto) = 50 ms
Σt(coinc) = 3 s

Single arm signal rates



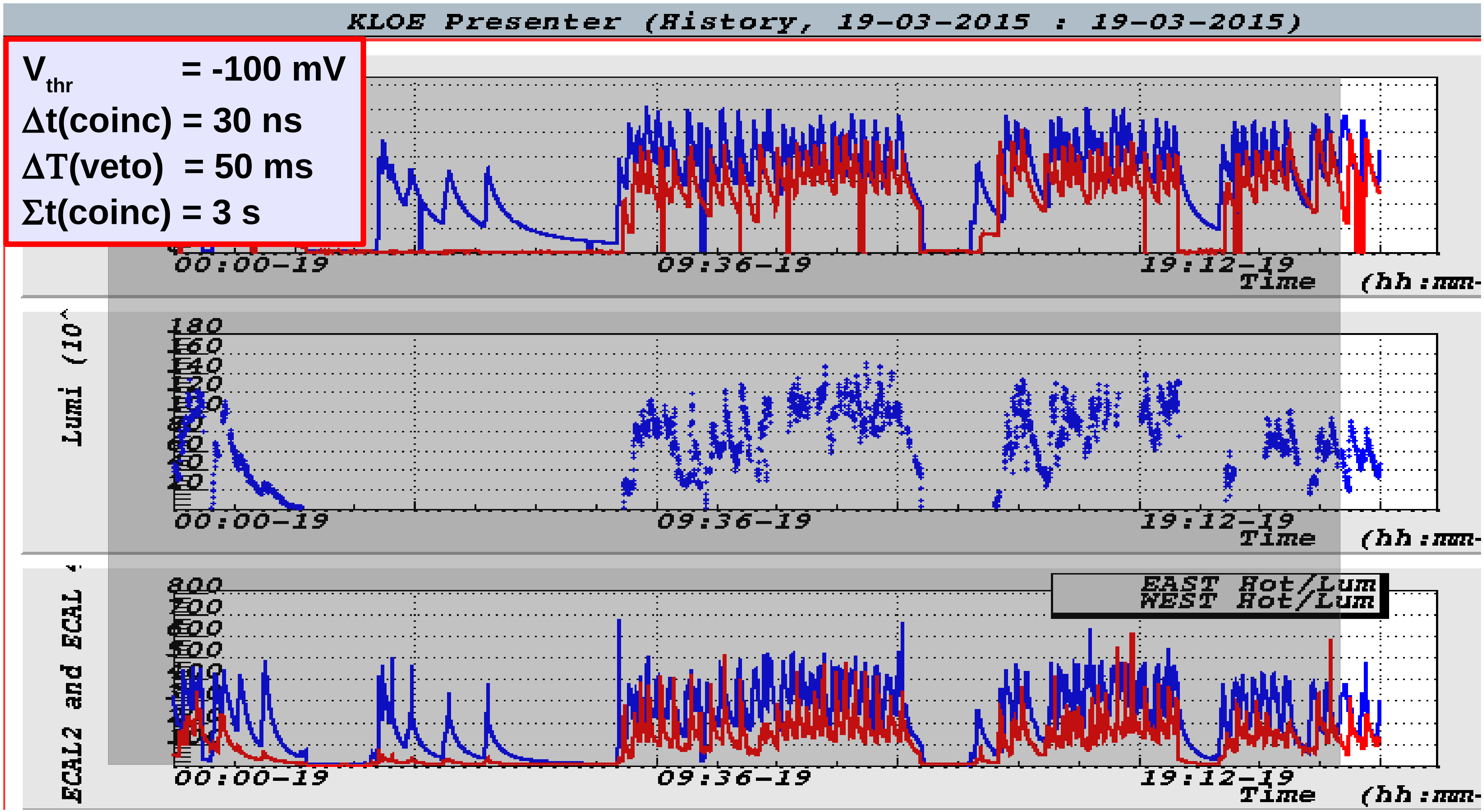
Single rate as a function of the corresponding current.
As seen from single beam data a contribution of ~1kHz on each side is expected from the opposite beam.
The different behavior is not understood

V_{thr} = -100 mV
Δt(coinc) = 30 ns
ΔT(veto) = 50 ms
Σt(coinc) = 3 s

Datataking range

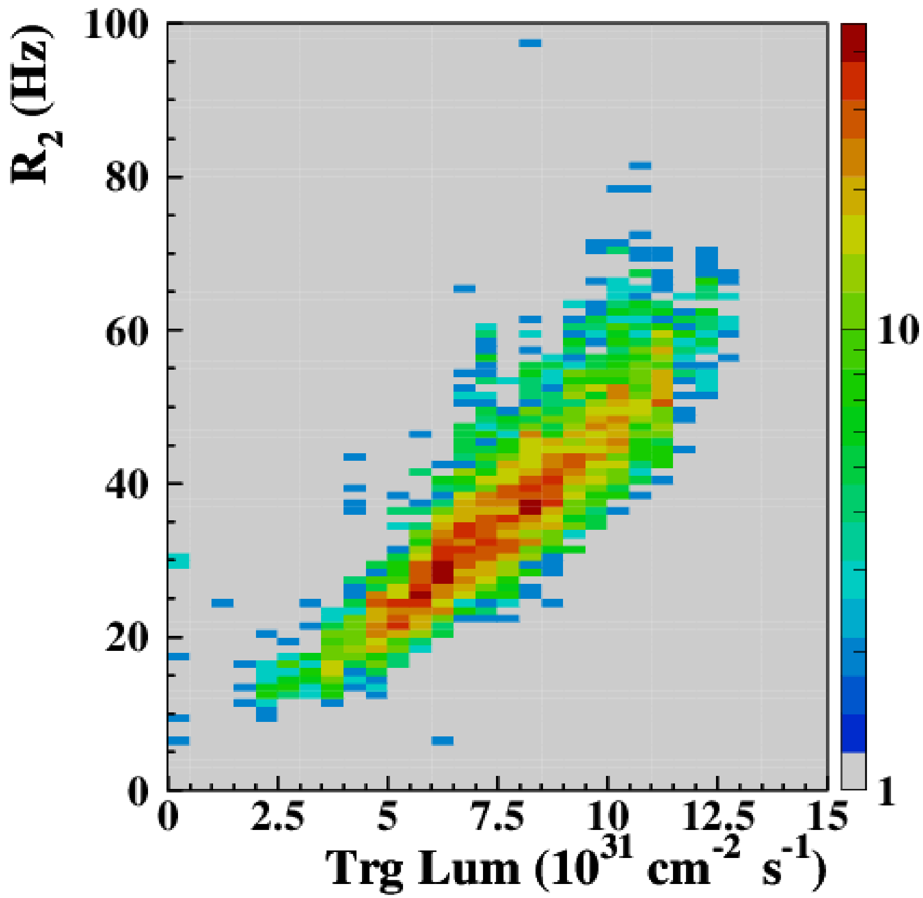
Data acquired during the afternoon of 14/03/2015 and the morning of 15/03/2015
Application left in acquisition.
Beam injection time window vetoed for coincidence only.

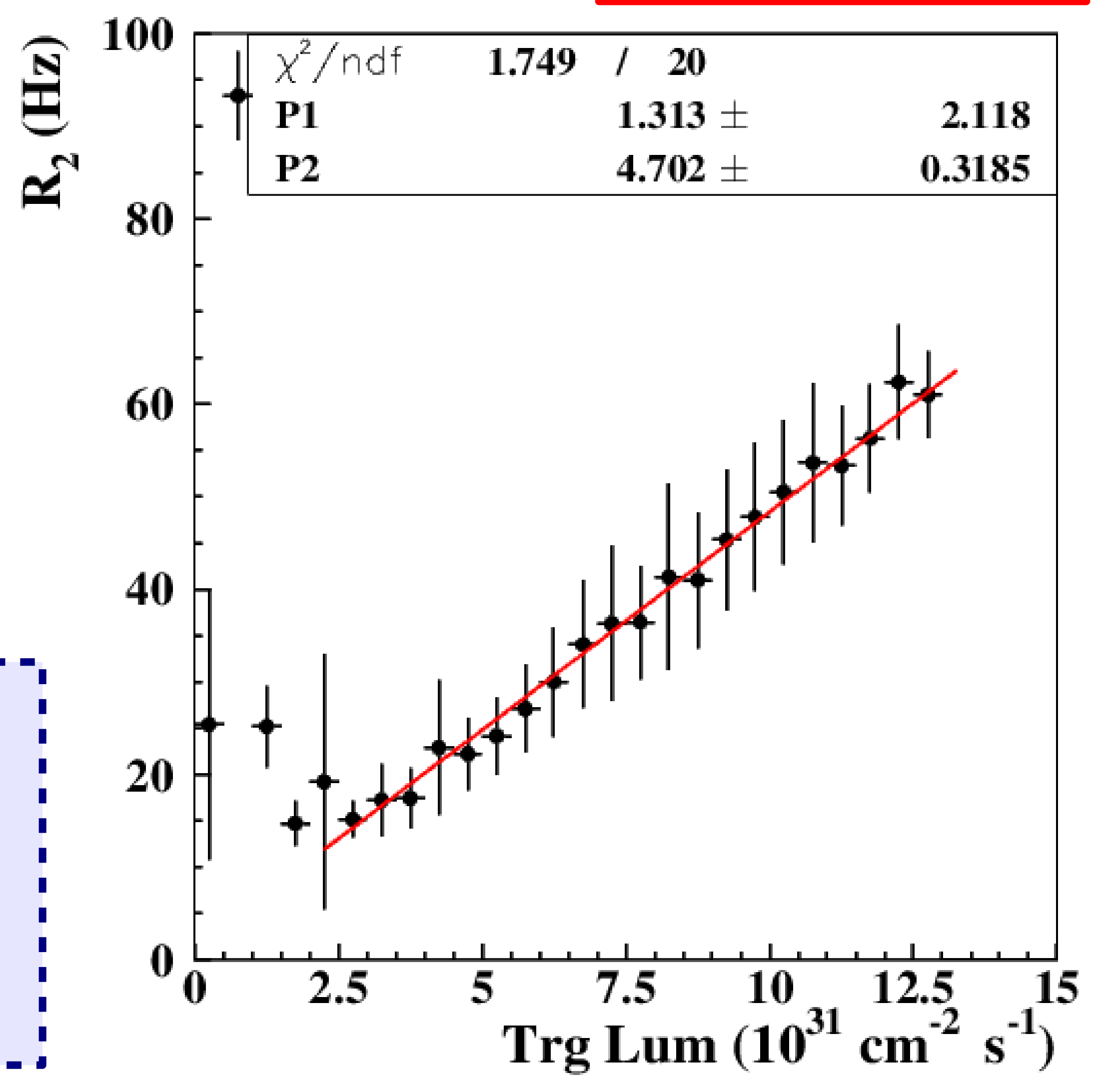
V_{thr} = -100 mV
Δt(coinc) = 30 ns
ΔT(veto) = 50 ms
Σt(coinc) = 3 s



Luminosity measurement calibration

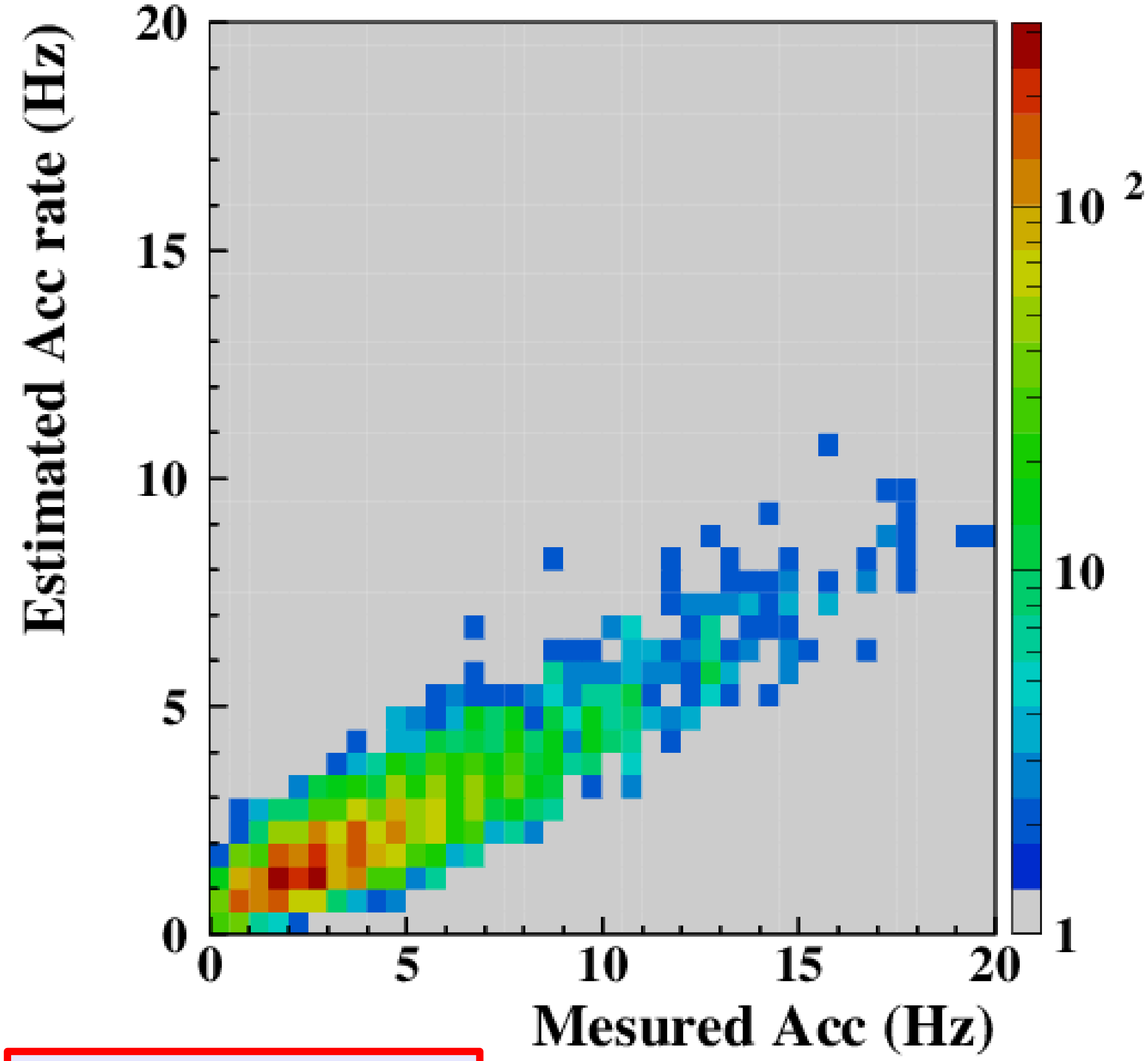
V_{thr} = -100 mV
Δt(coinc) = 30 ns
ΔT(veto) = 50 ms
Σt(coinc) = 3 s





Coincidence rate as a function of the KLOE-2 trigger luminosity.
The single measurement accuracy is ranging between 7% and 12%.
RMS has been taken as uncertainty for the projection.

Accidental rate estimation



Accidental rate estimated as:

$$R_{acc} = f_+ \times f_- \times \Delta t$$

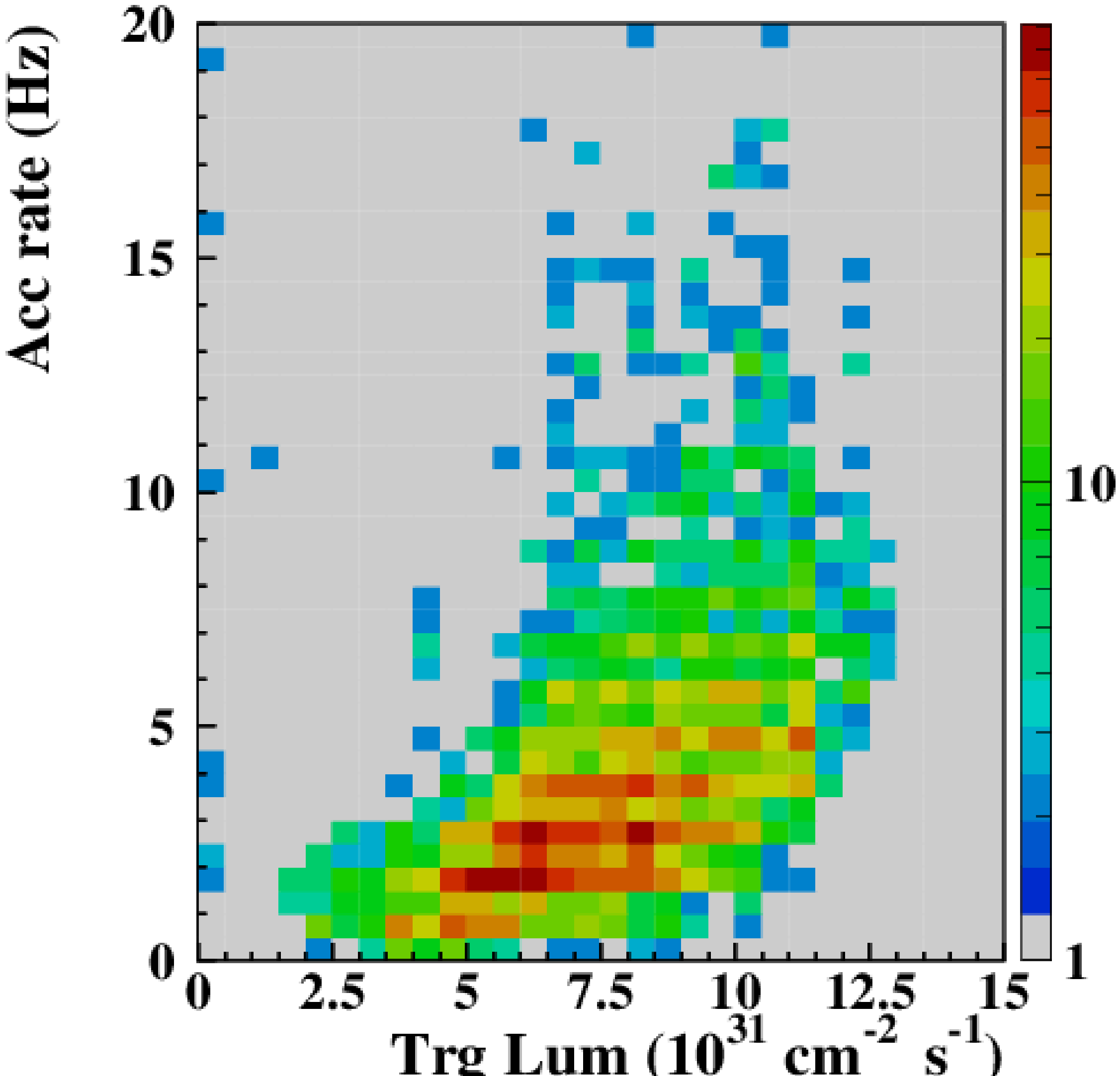
As a function of the measured accidental rate.

Good linear behavior-> no time dependent effect in the accidental rate.

Angular coefficient lower than one implies an effective time window for the coincidence larger than 30 ns.

V_{thr} = -100 mV
Δt(coinc) = 30 ns
ΔT(veto) = 50 ms
Σt(coinc) = 3 s

Accidental rate measurement



V_{thr} = -100 mV
Δt(coinc) = 30 ns
ΔT(veto) = 50 ms
Σt(coinc) = 3 s

Accidental rate estimated as:

$$R_{acc} = f_+ \times f_- \times \Delta t$$

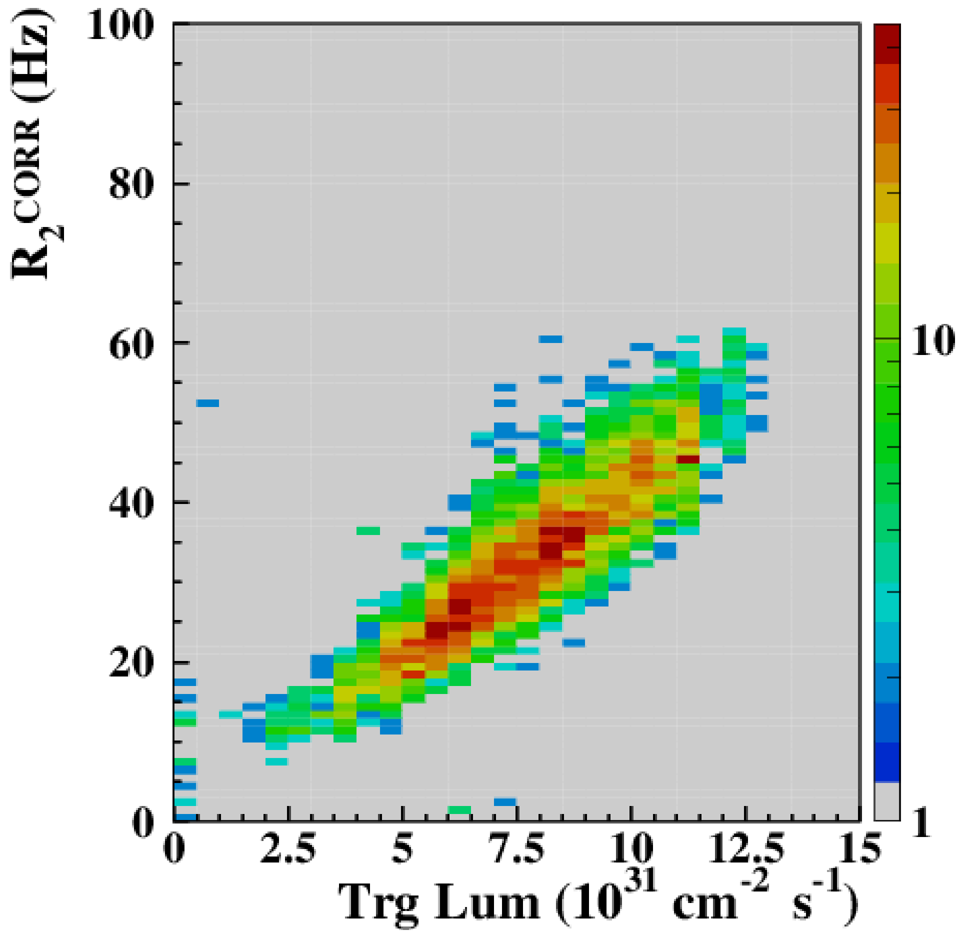
As a function of the KLOE-2 trigger luminosity.

Strong non-linear behavior and large spread (mainly due to not vetoed injection).

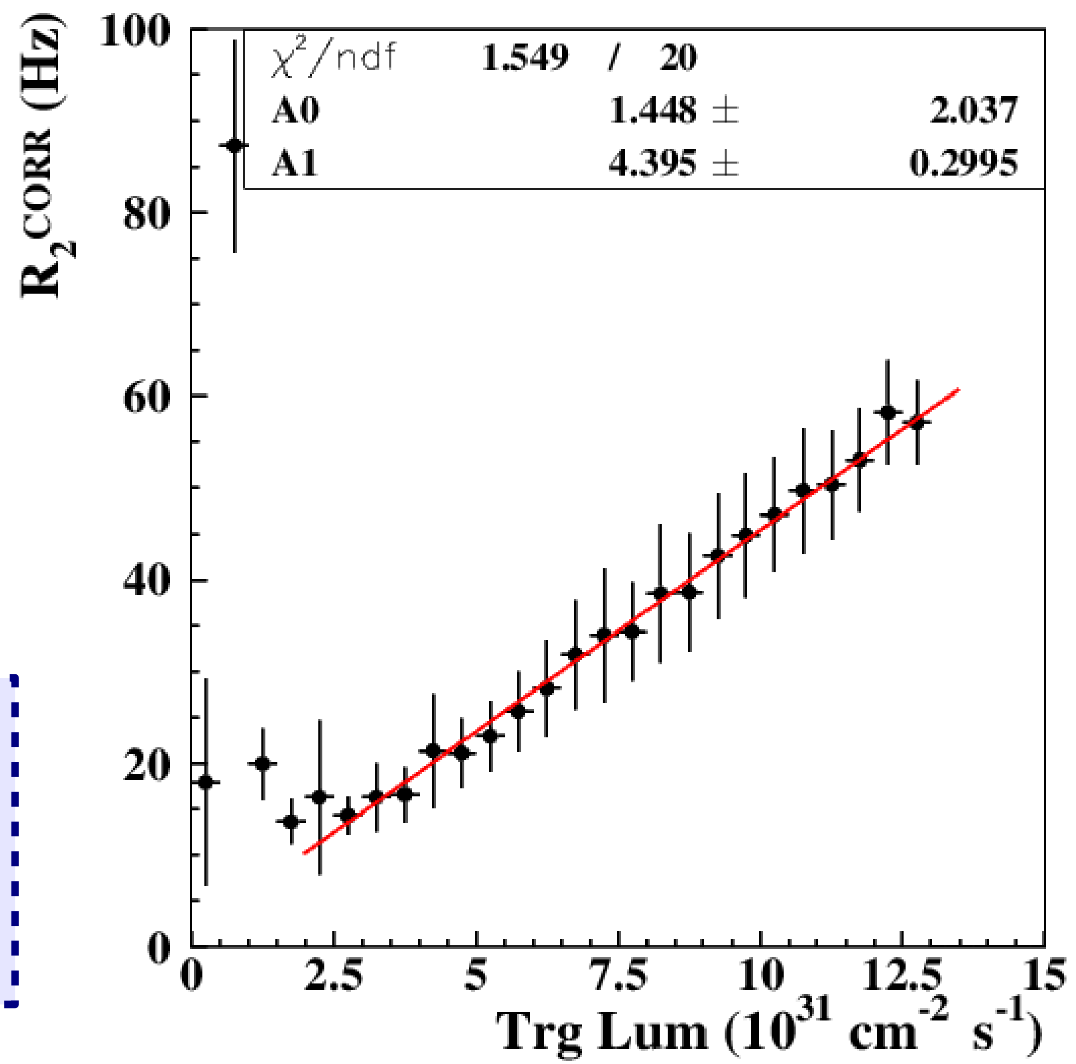
Need to measure directly the accidental rate using out of time signals from a delay line.

Direct measurement of the accidental rate will reduce noise on the coincidence measurement (apart for statistical fluctuation).

Accidental coincidence removal



V_{thr} = -100 mV
Δt(coinc) = 30 ns
ΔT(veto) = 50 ms
Σt(coinc) = 3 s



Coincidence rate corrected by subtracting the accidental rate as a function of the KLOE-2 Trigger Luminosity:

$$R_{acc} = R_+ \times R_- \times \Delta t$$

Comparison between R_2 w/wo accidental sub

Accidental rate estimated as:

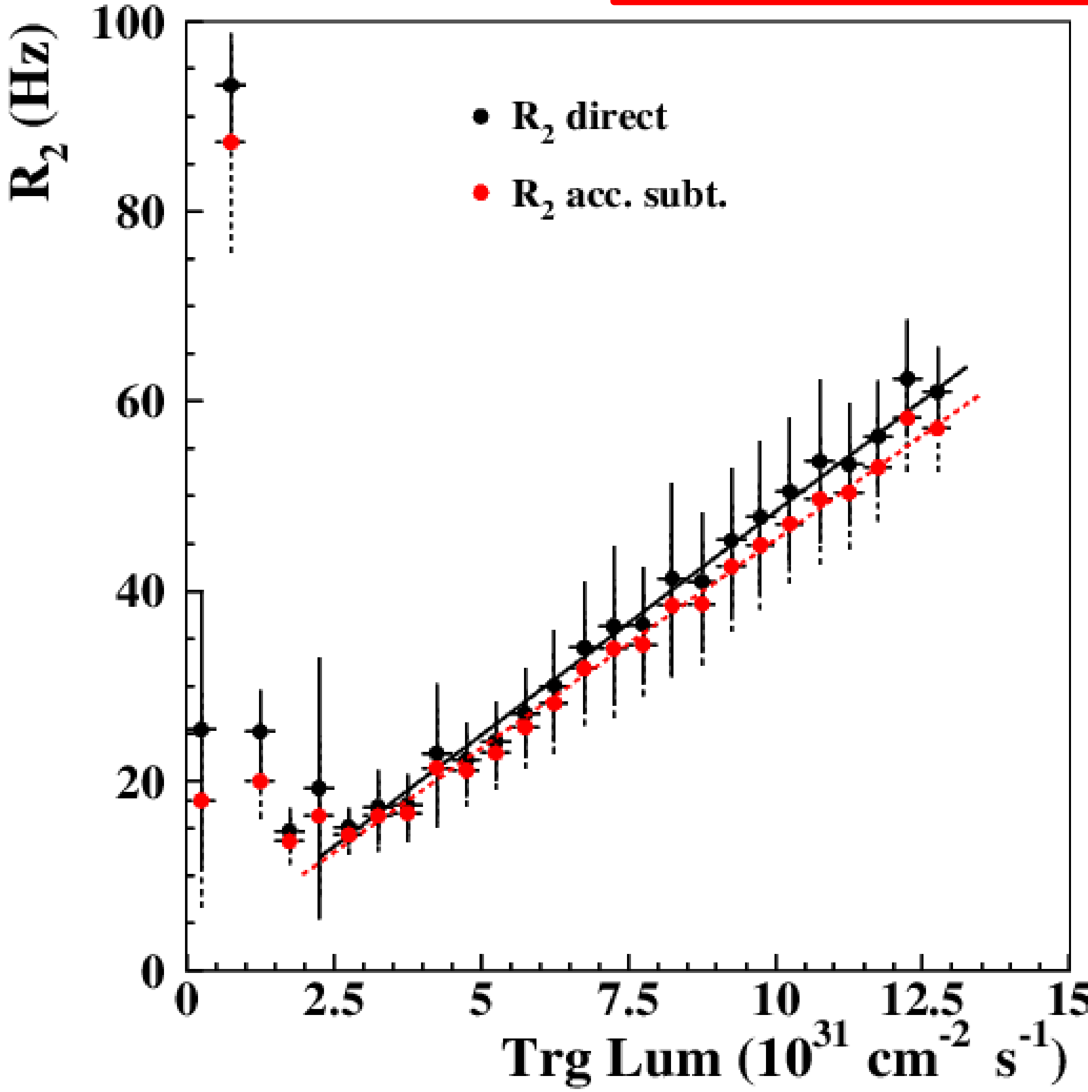
$$R_{acc} = R_{+} \times R_{-} \times \Delta t$$

as a function of the KLOE-2 trigger luminosity.

Need to measure directly the accidental rate using out of time signals from a delay line.

Direct measurement of the accidental rate will reduce noise on the coincidence measurement (apart for statistical fluctuation).

V_{thr} = -100 mV
Δt(coinc) = 30 ns
ΔT(veto) = 50 ms
Σt(coinc) = 3 s



Conclusions & Plans

- The CCAL-T sector sum pulses from SDS are very clean
- The application to handle the luminometer real-time data is almost complete
- The background rate observed does not exceed few tenth of kHz, allowing for fast coincidence formation without significant noise
- MC simplified simulation give a estimate of the expected rate substantially in agreement w.r.t. the observed rate.
- Linearity of the response is quite good
- New 12 cables have been installed on the KLOE platform to bring other channels to the DAFNE CR

- Improved offline study of the acquired data (more data with increased number of parameter are needed)
- Completition of the cabling and operation with other channels

Future plans II

Together with A. Drago is ongoing the development of a system capable to acquire turn-by-turn and bunch-by-bunch the signals from CCAL-T luminometer. (exp. 3L_2D)

This project could lead to a bbb luminosity monitor useful to check effects on the luminosity as a function of the position along the bunch train.

On this respect a deepest offline analysis of the CCAL-T data from our side and Large angle Bhabha on the KLOE-2 side is mandatory to reach the goal (if any).

Acknowledgement

- Technicians from SELCED service (O. Coiro, D. Pellegrini, E. Gaspari, C. Mencarelli) for their work on the cabling the first two channels and the new 12 channels from KLO-2 platform.
- F. Galletti for the support and time spent in understanding and “cracking” the Devil 385.
- S. Gallo and S. Miscetti that provided oscilloscope to check signals from CCAL-T.
- A. Drago and C. Milardi for their support in developing the application and during data acquisition.
- G. Mazzitelli for his support in the luminosity measurement setup knowledge