Accelerator
Division

Double arm luminometer for DAΦNE collider

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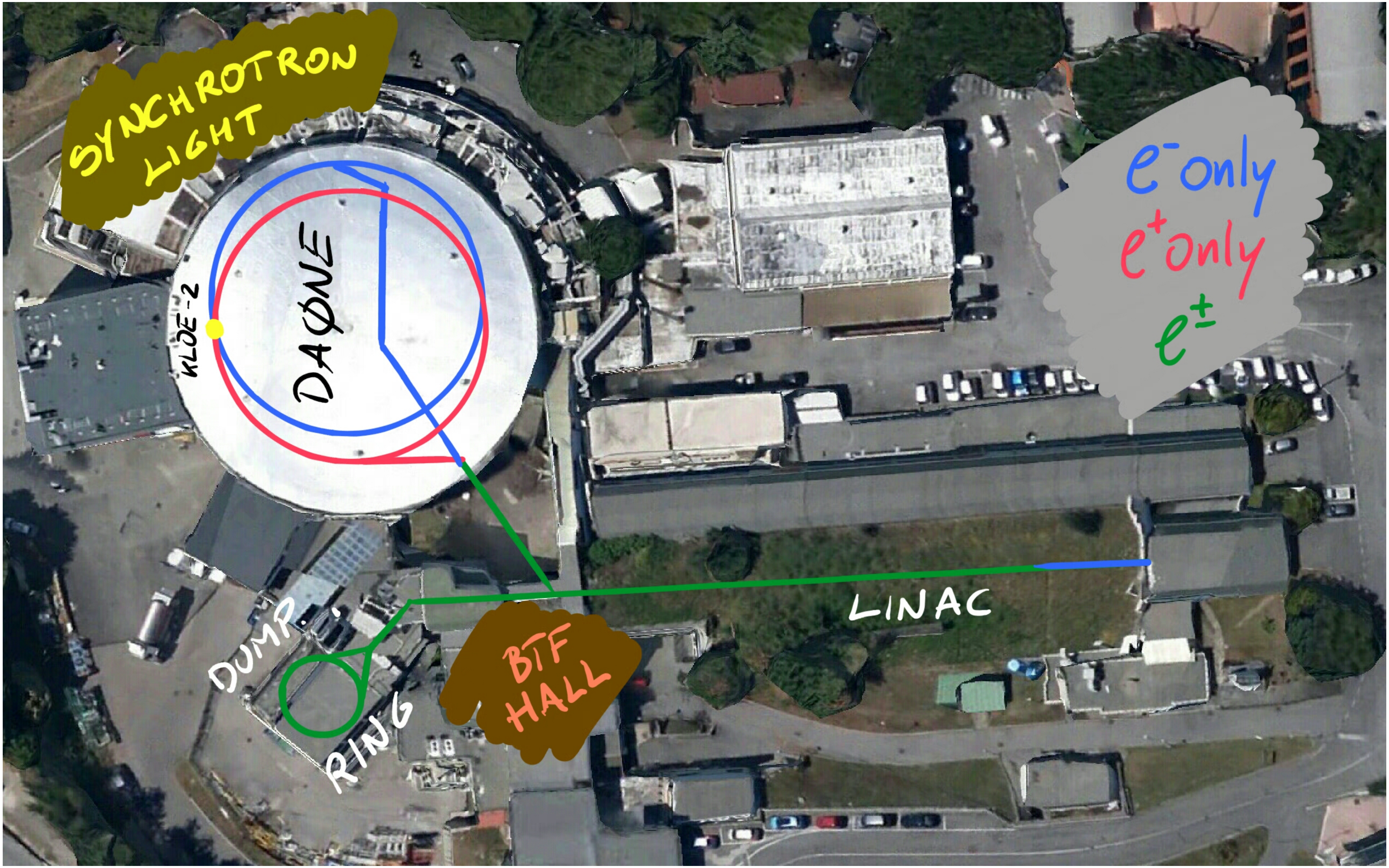
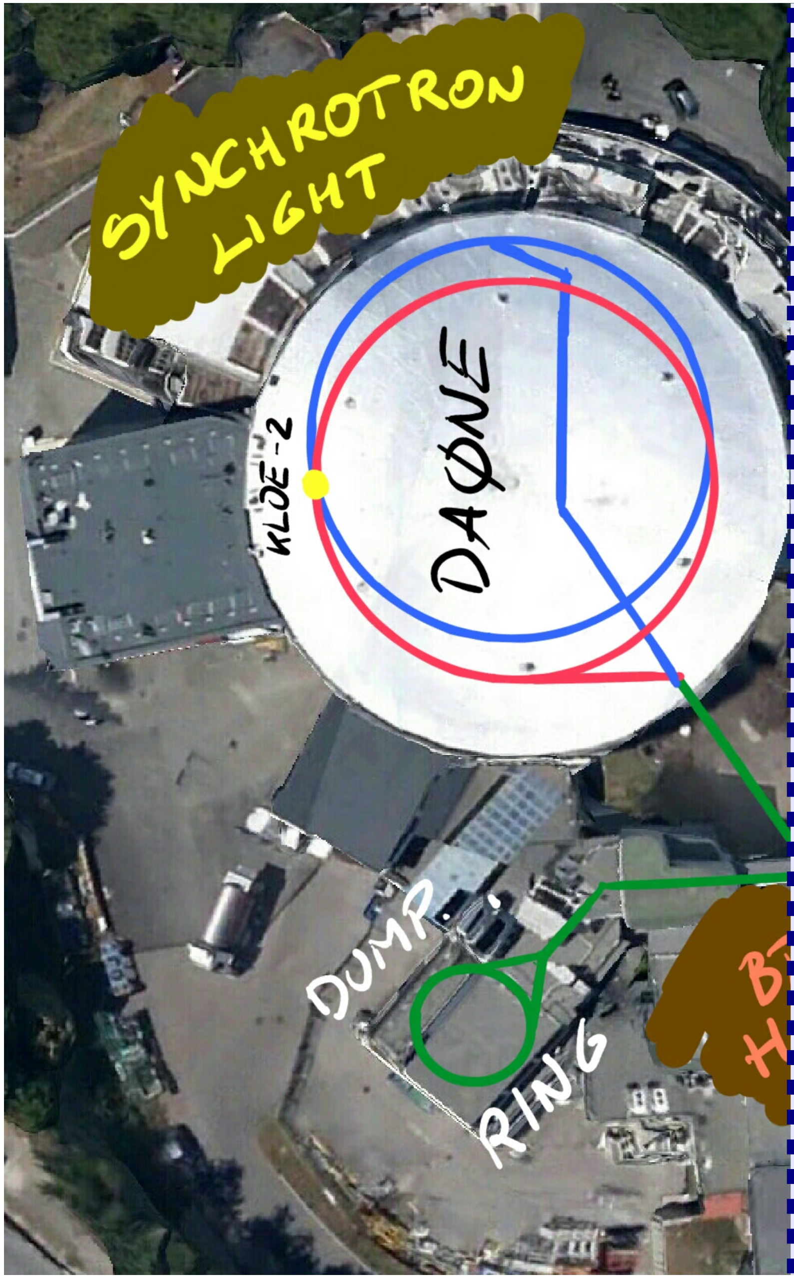
101° Congresso SIF
“Sapienza” Univ. di Roma

DAΦNE: The Frascati ϕ-factory



DAΦNE: The Frascati ϕ-factory



DAFNE Parameters

Crab-Waist interaction scheme

Length: 98 m

T_{RF}: 2.7 ns

N_{bunch}: 120

Beam energy: 510 MeV

Injection in Topping-up mode

COM Energy: 1020 MeV (ϕ resonance)

Beam crossing: π-50 mrad (CW)

COM mom. (LAB frame): -30 MeV (hor)

Max beam curr. (CW): 2 A (e-) 1.5 A (e+)

Max luminosity (CW): 4.5×10^{32} $cm^{-2}s^{-1}$

Motivation

DAΦNE Collider perfomance tuning:

Precise and fast determination of the instantaneous luminosity is mandatory for machine fine-tuning.

Beam lifetime at high current ranges between 300-600 s.

Expected luminosity variation during performance fine tuning ranges between 5% and 10%

Needs:

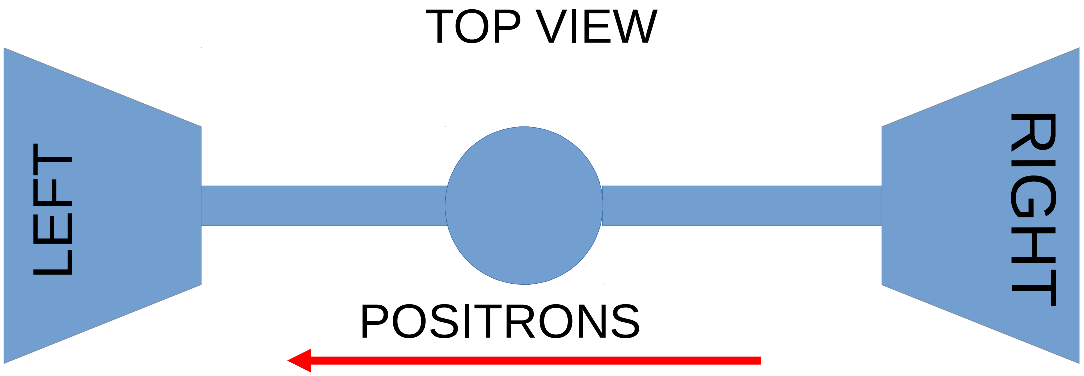
- **+ Single point statistical accuracy below 3%**
- **+ Sampling rate of the order of 1 Hz at least**

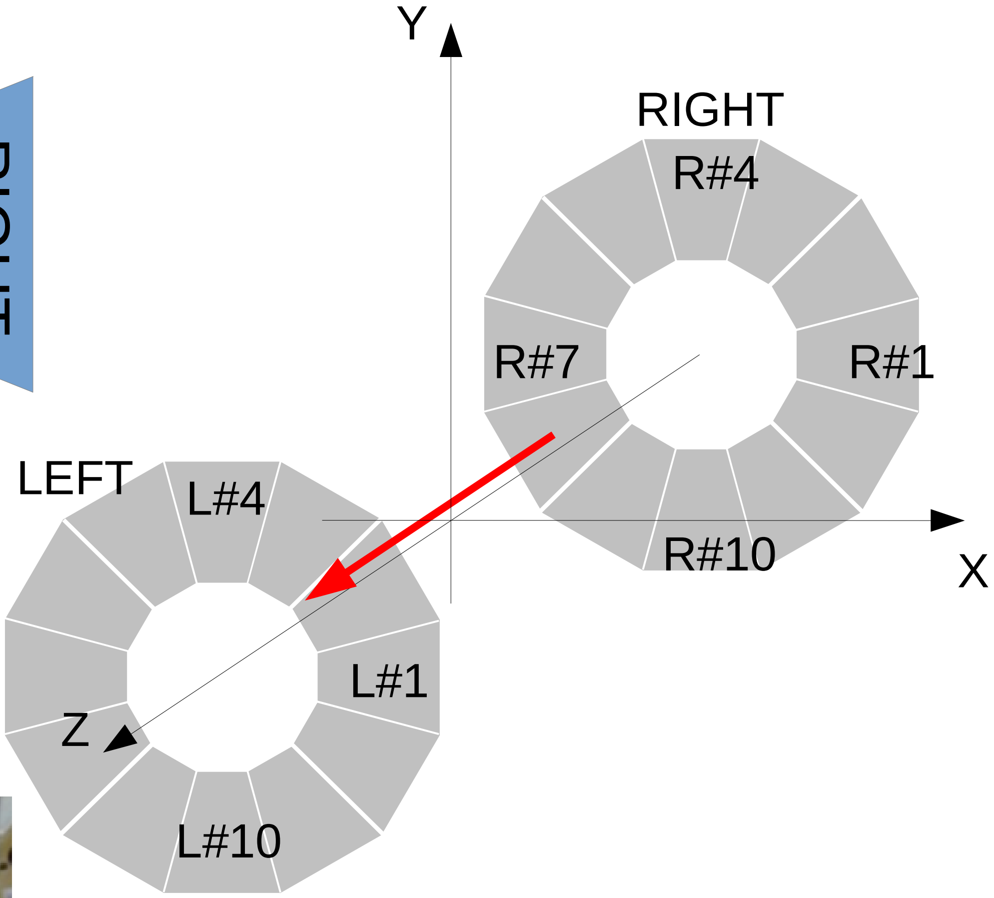
→ **~1kHz counts**

Available:

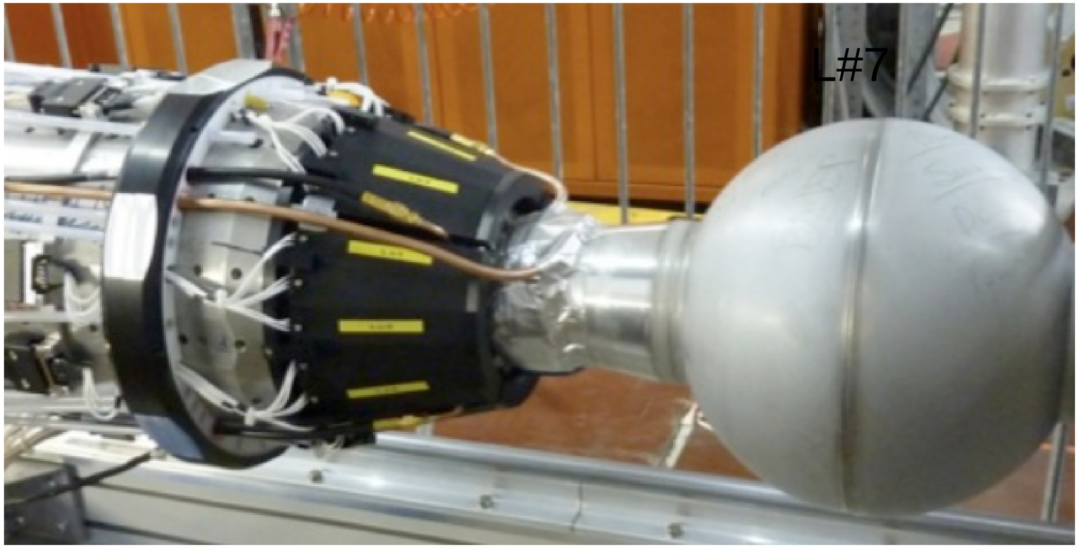
- + KLOE-2 luminosity meas: 4-5% stat accuracy, 1/15 Hz
- + Single Brems γ-monitor: 2 Hz, large systematics

KLOE-2 CCAL-T geometry





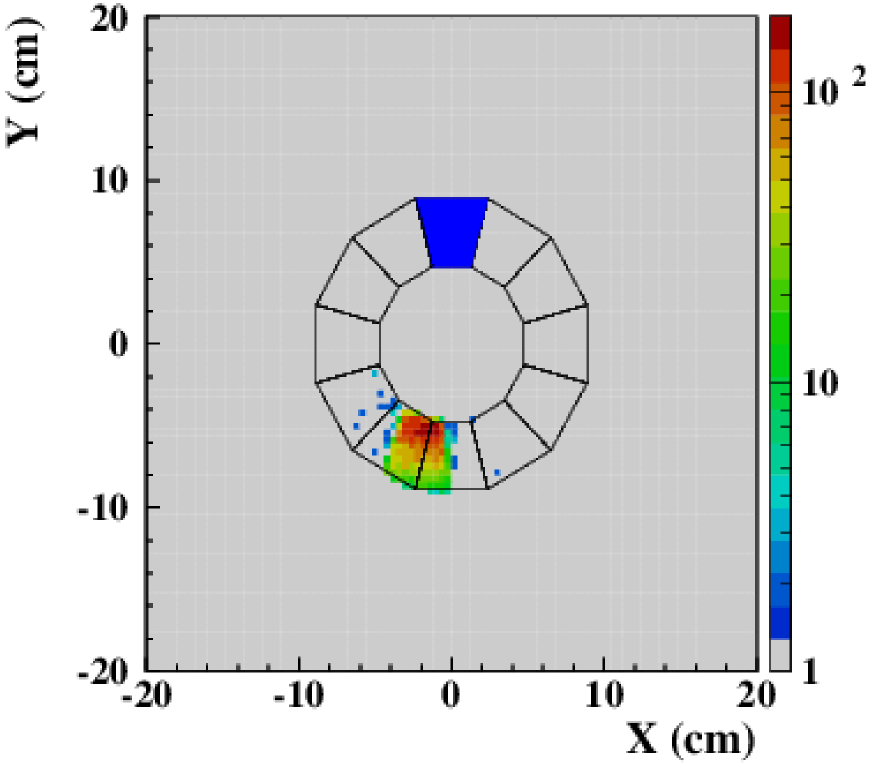
12 Sector per side
LYSO Crystals (4 per sector)
FEE: SiPM each Crystal
Polar angle acceptance: 9°-18°

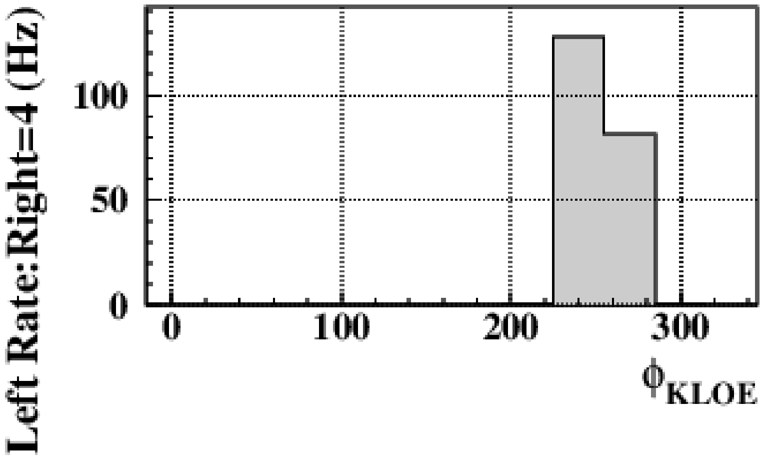


KLOE-2 experiment use the full granularity of the CCAL-T detector, while the analog sum over sectors is left available for luminometer setup.

TOY MC expectation

R#4 coincidence distribution



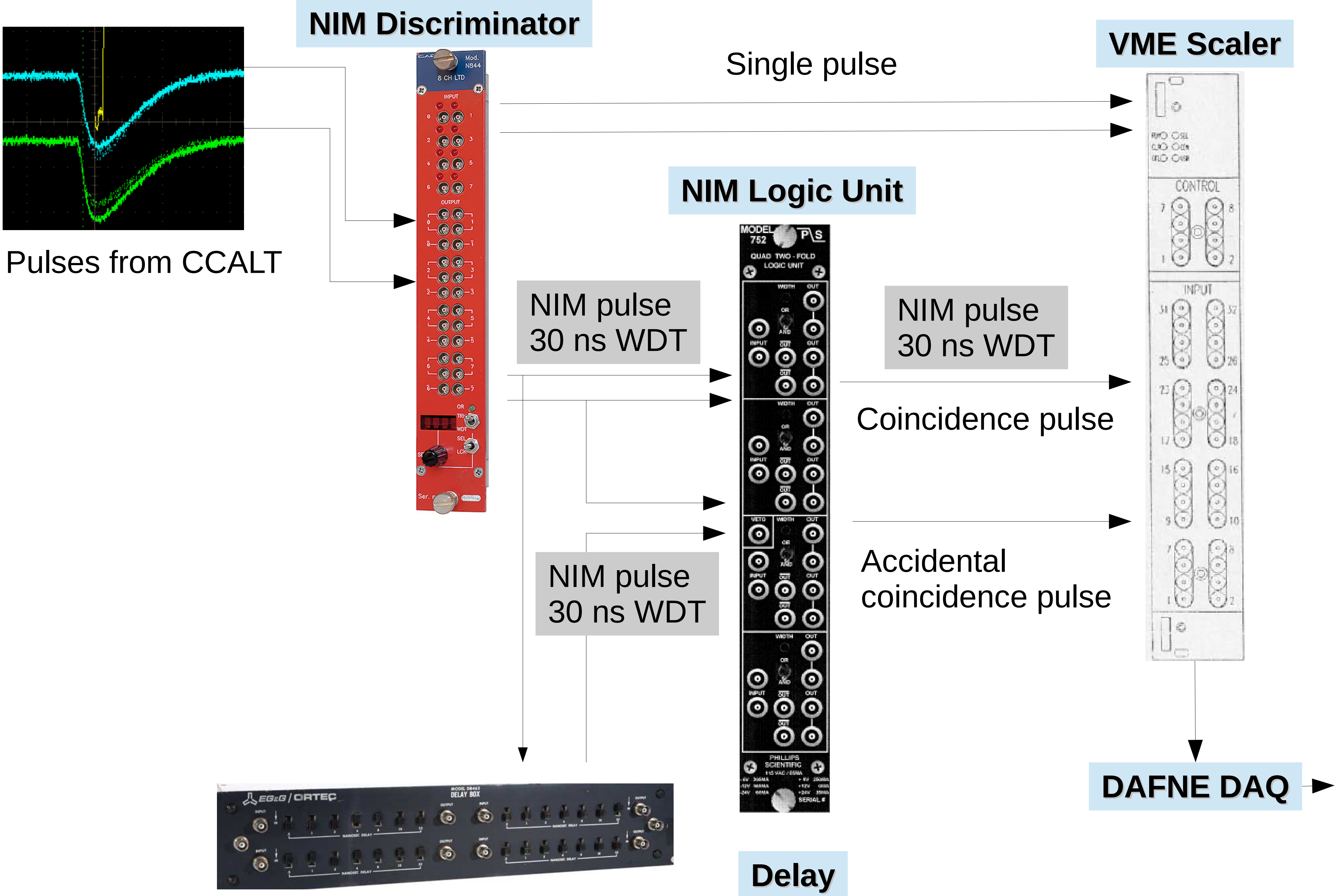


MC Simulation of Bhabha events:

- BABAYAGA generator (ISF+FSR included);
- simplified geometry (only end-plane of sectors fired and sectors have been assumed homogeneously filled with LYSO)
- no LYSO/SiPM or FEE inefficiency taken into account
- no threshold effects on the outgoing signals;
- realistic IR distributions (space and momentum)

MC expected rate:
70-180 Hz per sector pair.

Single sector pair coincidence experimental setup



NIM Discriminator

VME Scaler

Single pulse

Pulses from CCALT

NIM Logic Unit

NIM pulse
30 ns WDT

NIM pulse
30 ns WDT

Coincidence pulse

NIM pulse
30 ns WDT

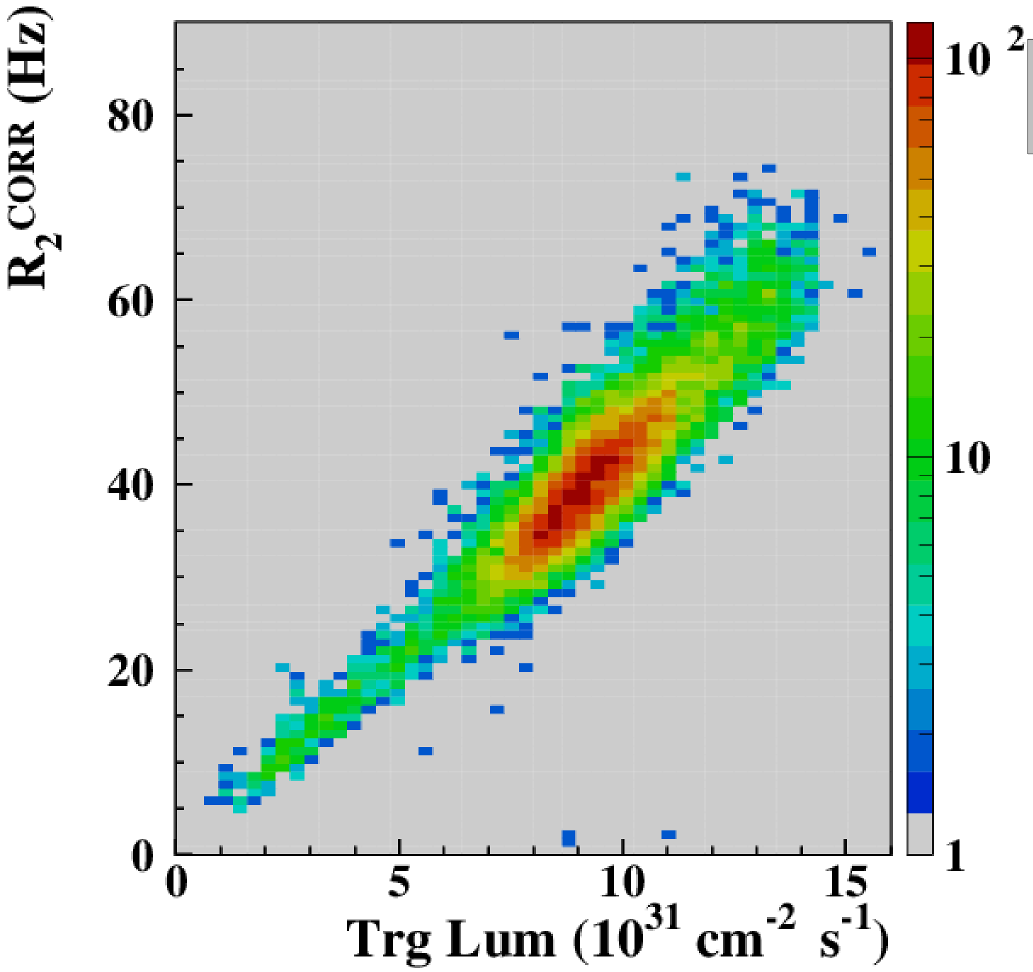
Accidental
coincidence pulse

DAFNE DAQ

Delay

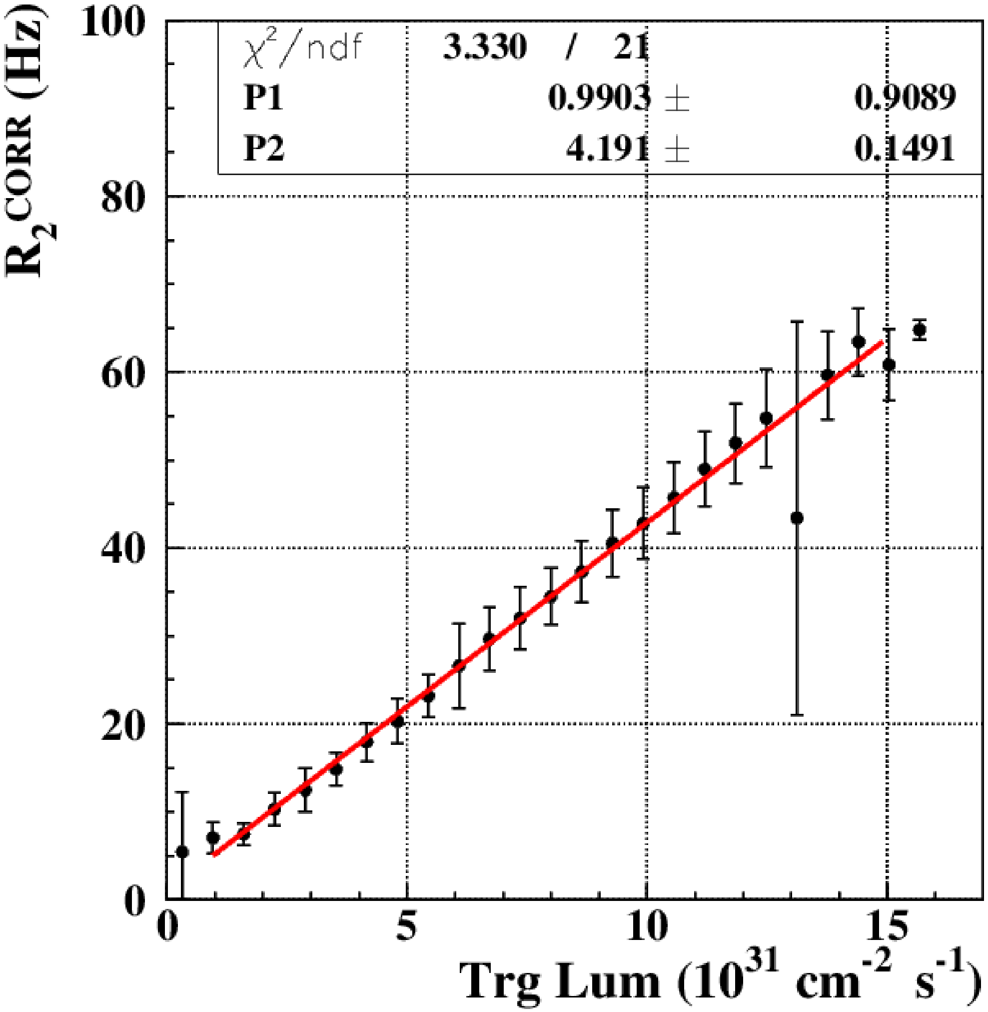
Single pair coincidence: experimental setup

R#3-L#9 coincidence rate



Preliminary

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.

Conclusions & Plans

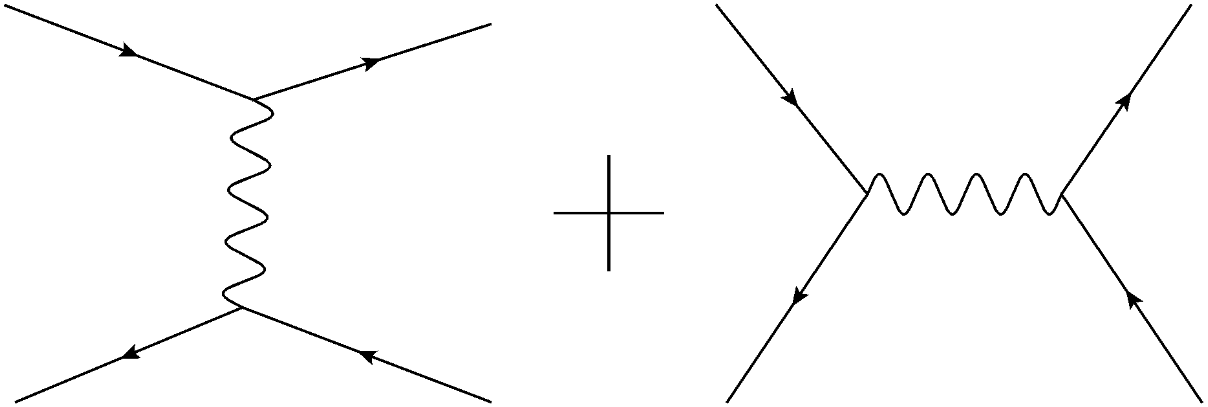
- The CCAL-T sector pulses from KLOE-2 FEE are very clean
- The background rate observed does not exceed few tenth of kHz, allowing for fast coincidence formation without significant noise
- MC simplified simulation give a estimate of the expected rate substantially in agreement w.r.t. the observed rate (relative ratios)
- Coincidence rate linearity w.r.t. KLOE-2 trigger luminosity very good
- Dedicated HW and DAQ system under development to include all the channels

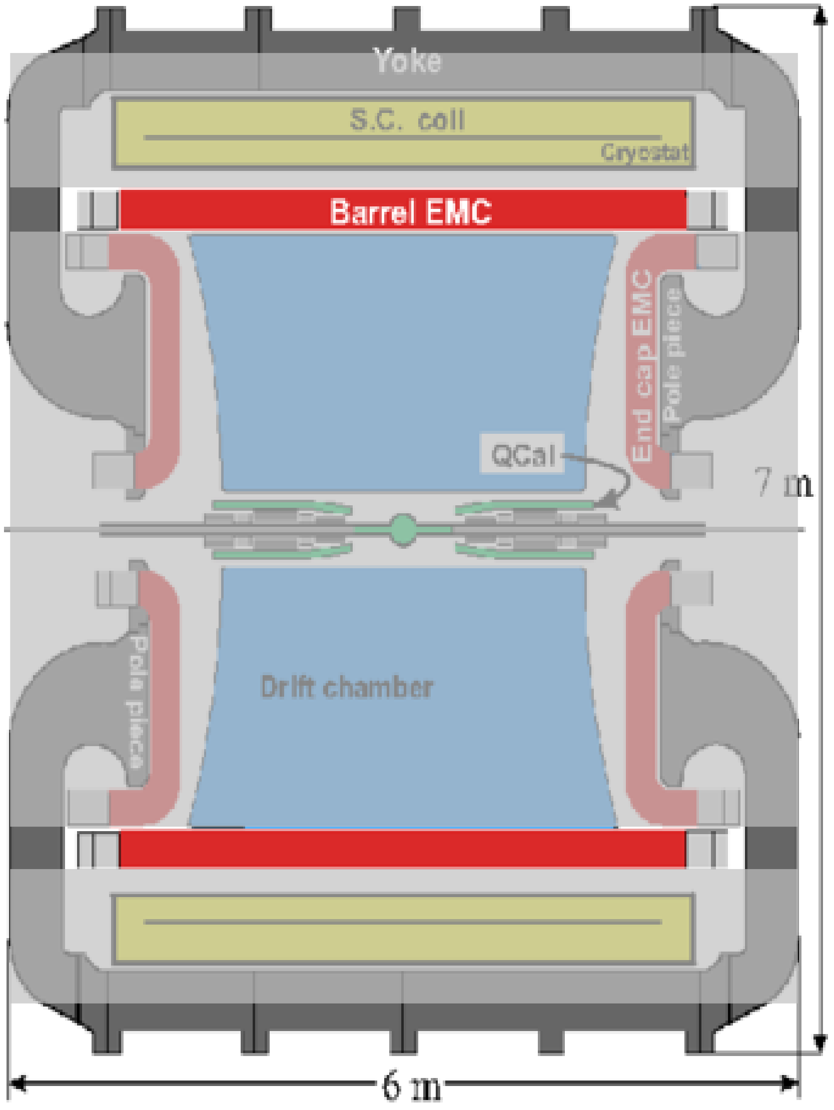
- Improved offline study of the acquired data (more data with increased number of parameter are needed)
- Full setup assembling

BACKUP SLIDES

Precise luminosity monitor: Large Angle Bhabha

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





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:

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

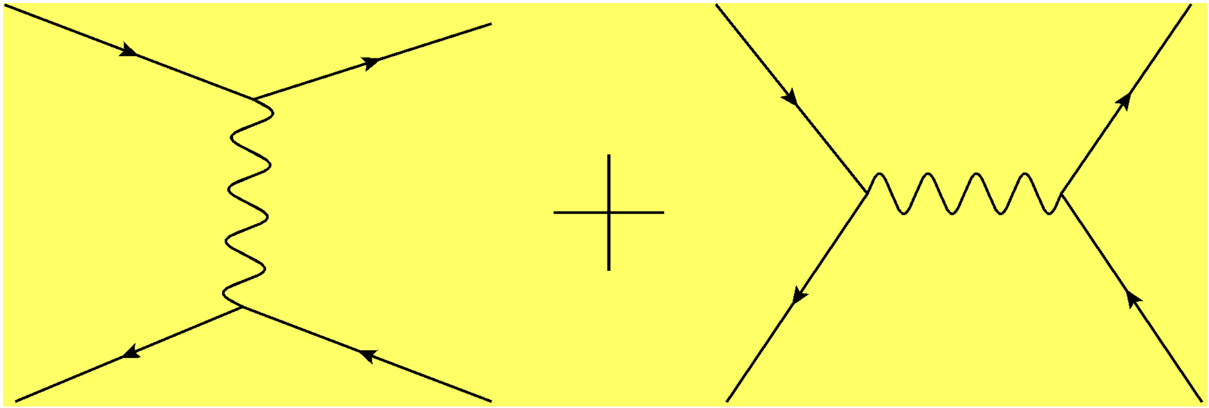
Fast luminosity monitor(2): Small Angle Bhabha

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)

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



Simulation

Monte-Carlo simulation

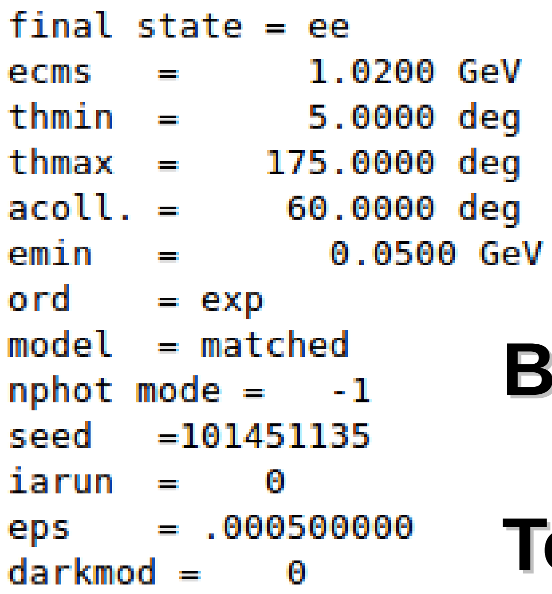
Event simulation based on **“BABAYAGA”** (*ref. Nucl. Phys. B758(2006) 227*) event generator with:

- $\theta_{p(e)} > 5°(\pi\text{-}5°)$
- 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)

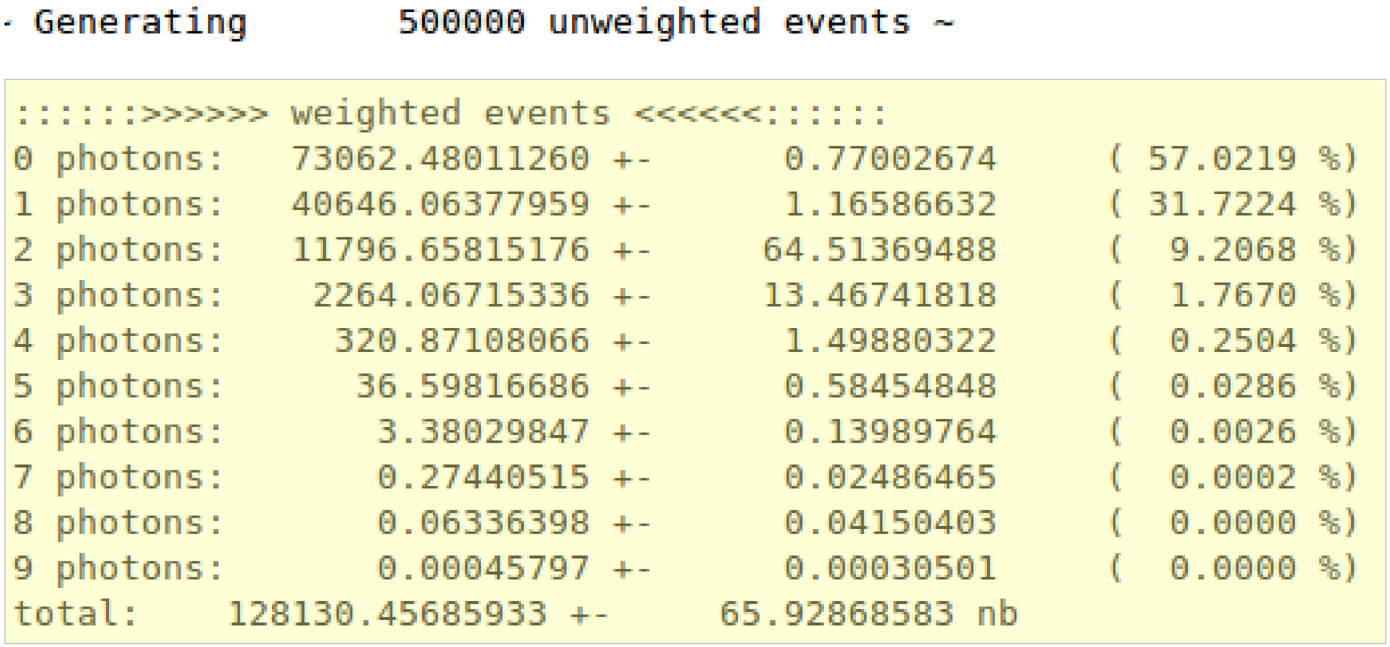
Simulation outcome



```
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



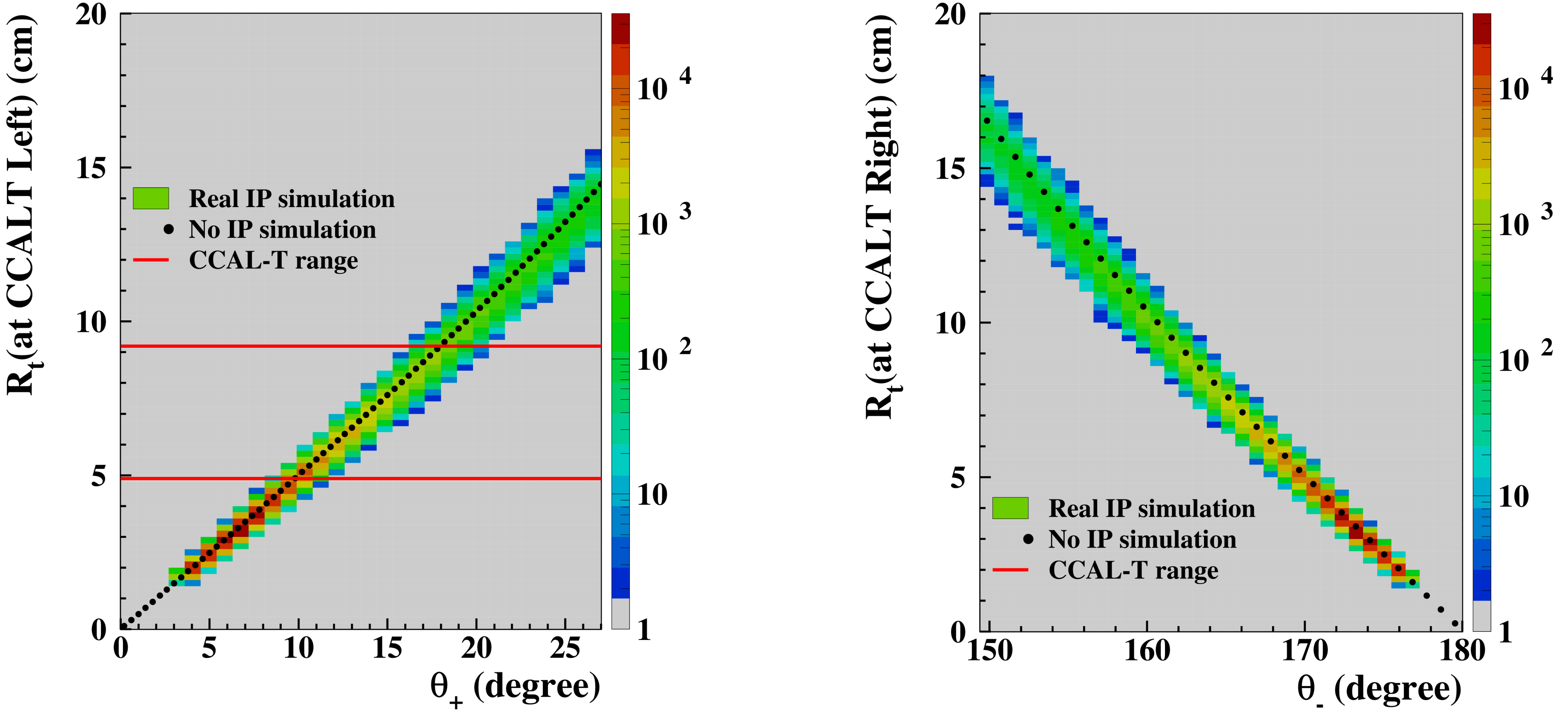
```
- Generating      500000 unweighted events ~

::::::>>>>>> 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

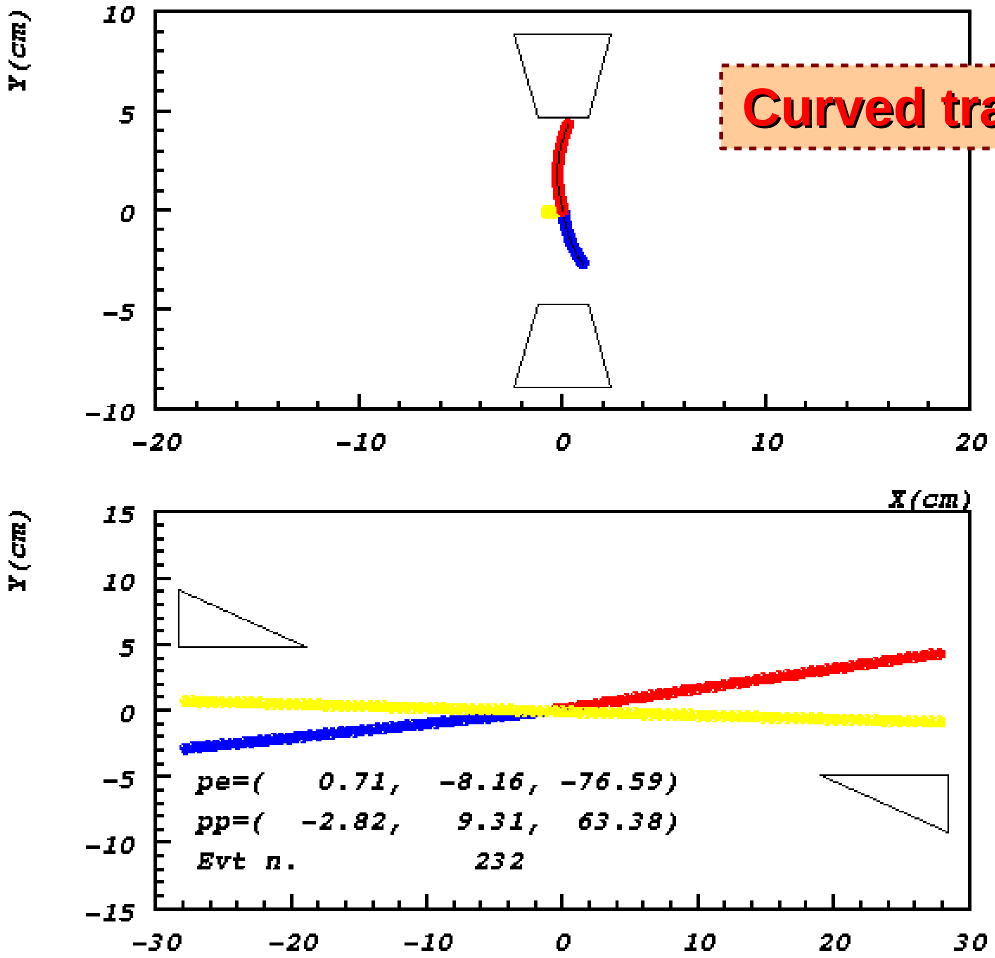
Charged particles tracking



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

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

Particle tracking



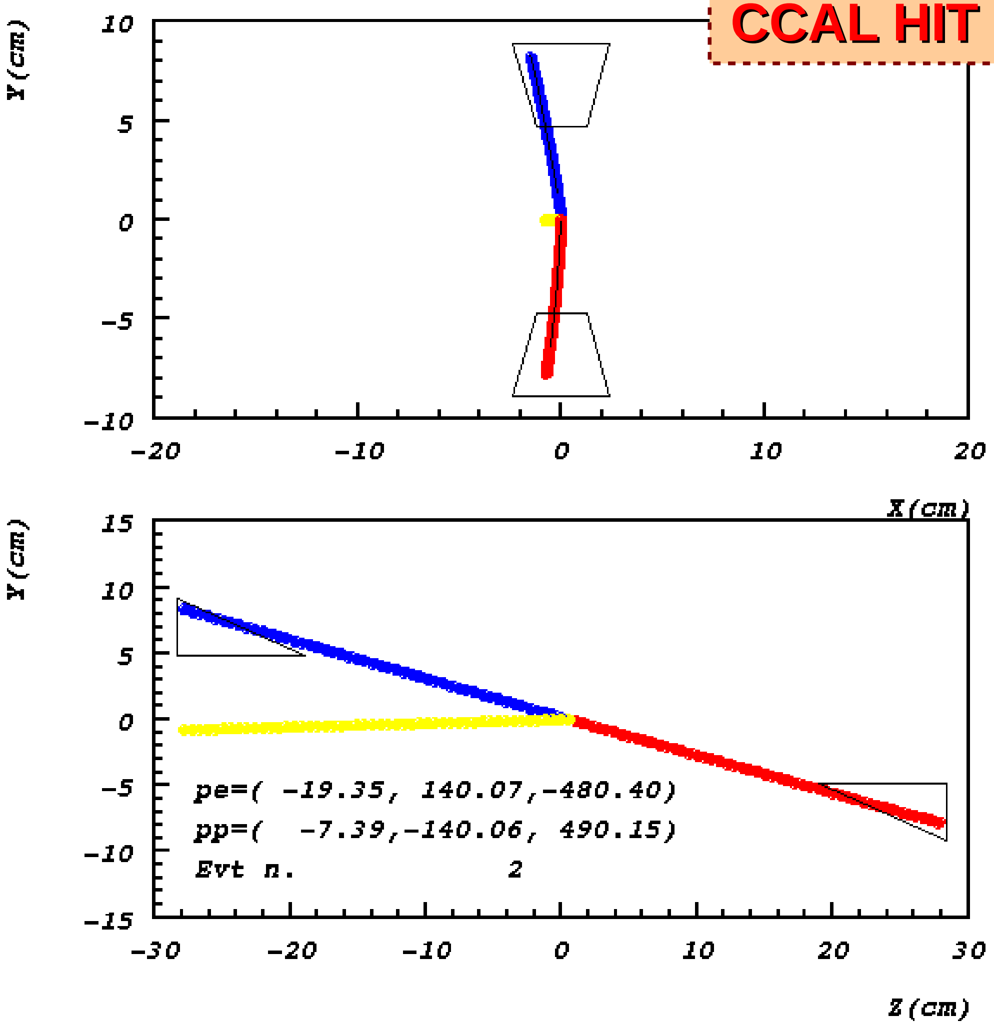
Curved tracks

●●●●● Electron

●●●●● Positron

●●●●● Photon

CCAL HIT

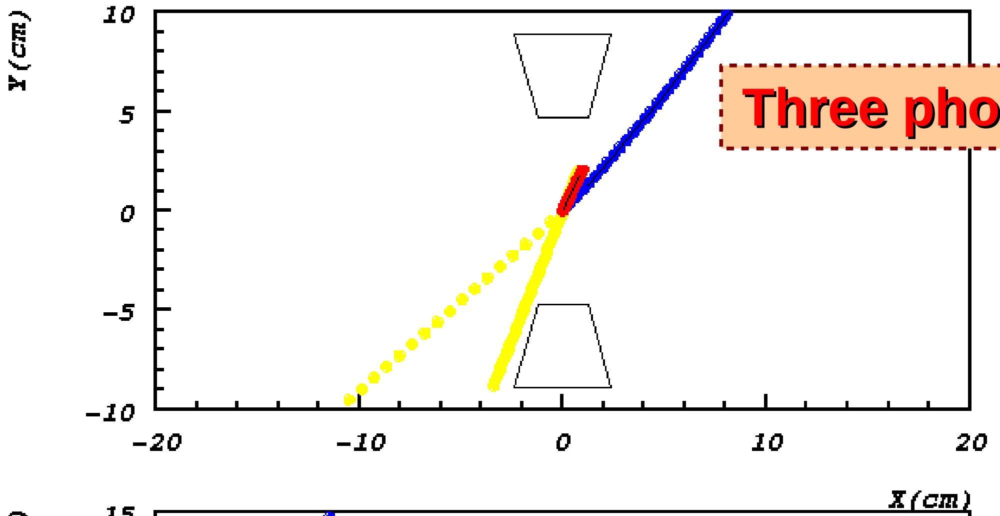


Example of simulated events

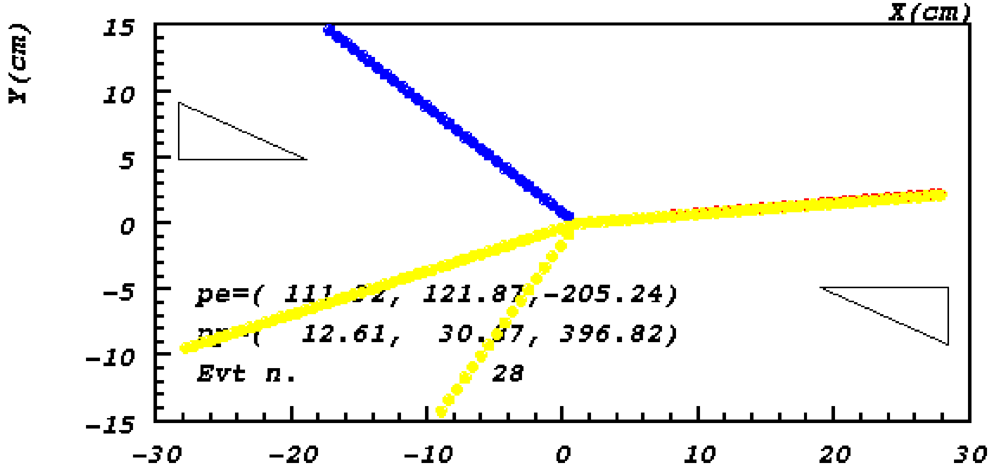
CCAL-T silhouette is shown

Charged particle “arcs” drawn

Particle tracking



Three photons

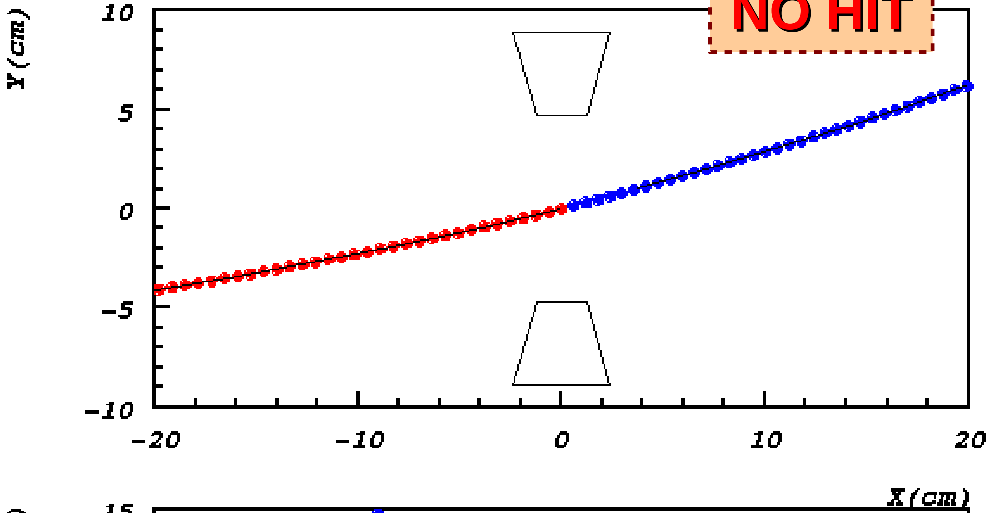


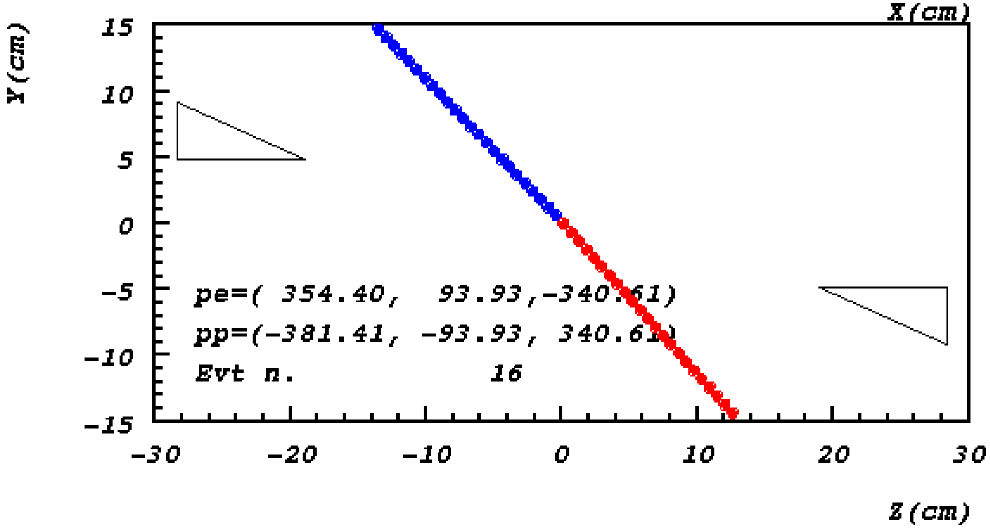
● Electron

● Positron

● Photon

NO HIT



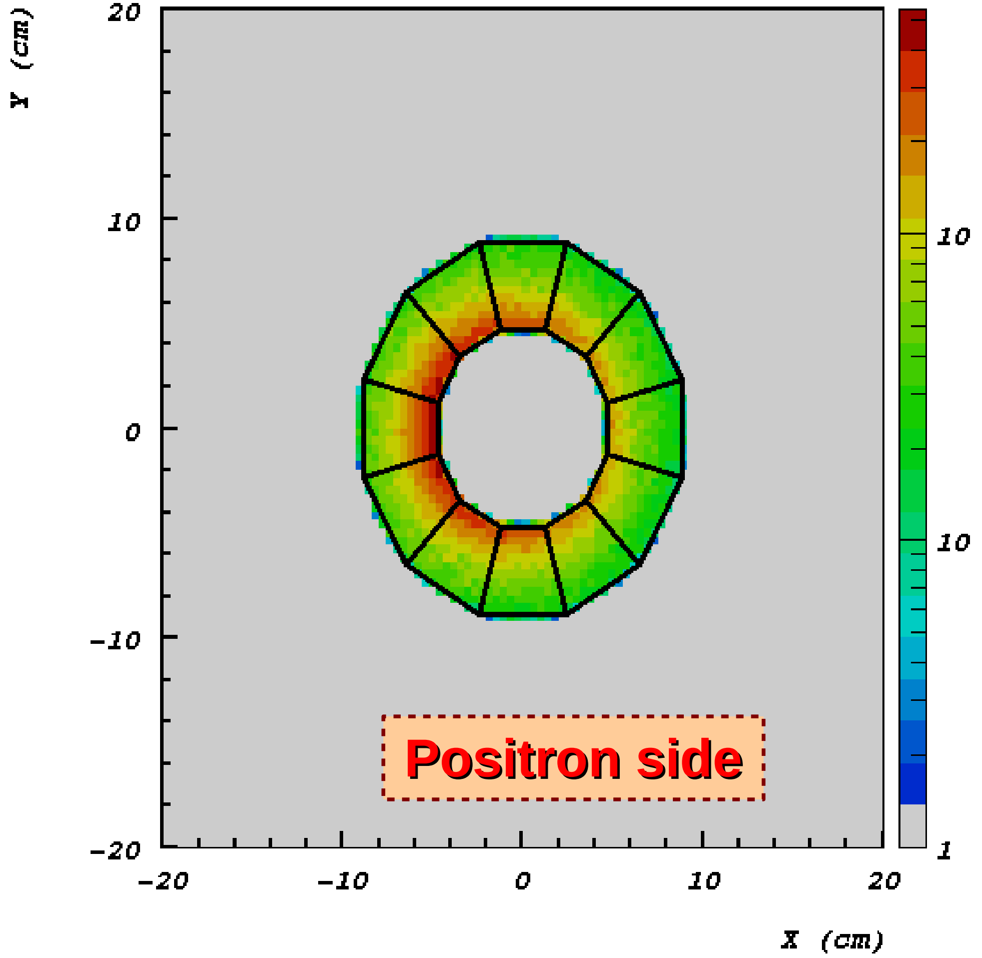


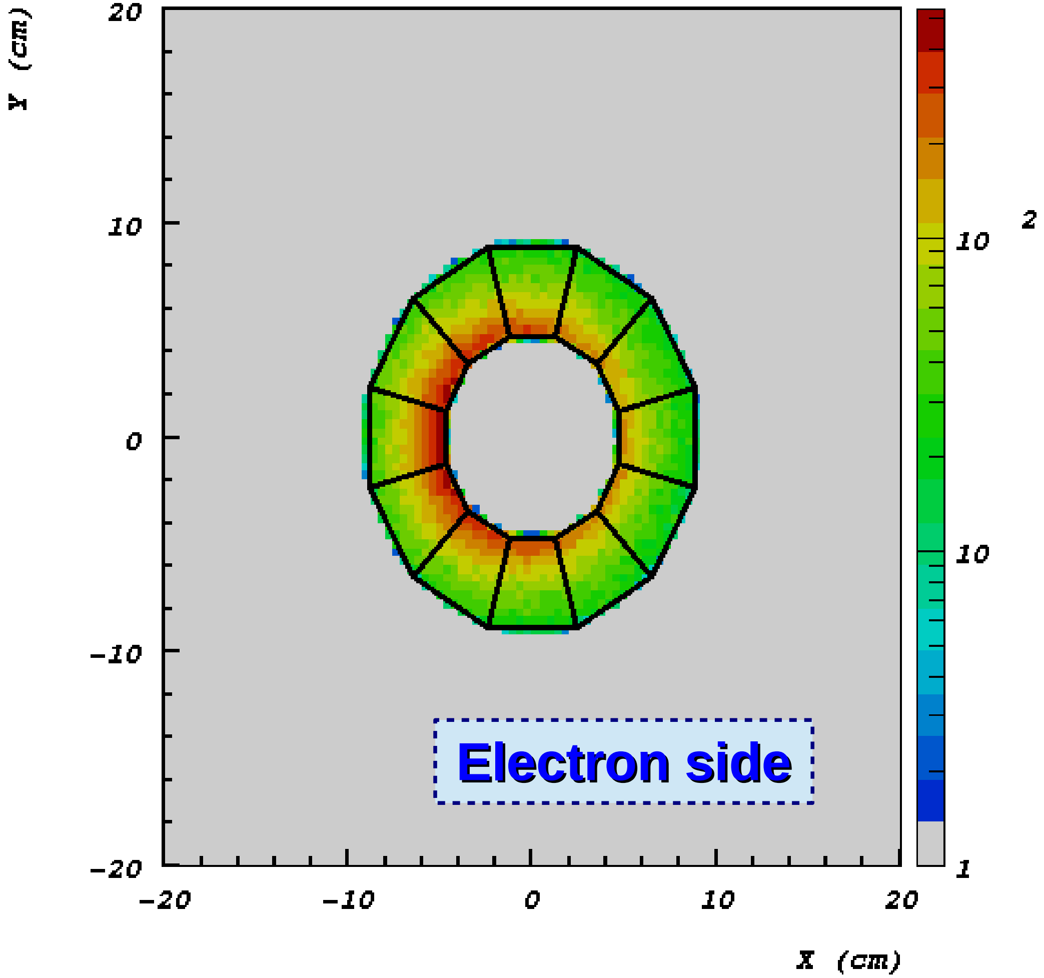
Example of simulated events

CCAL-T silhouette is shown

Charged particle “arcs” drawn

Hit distribution





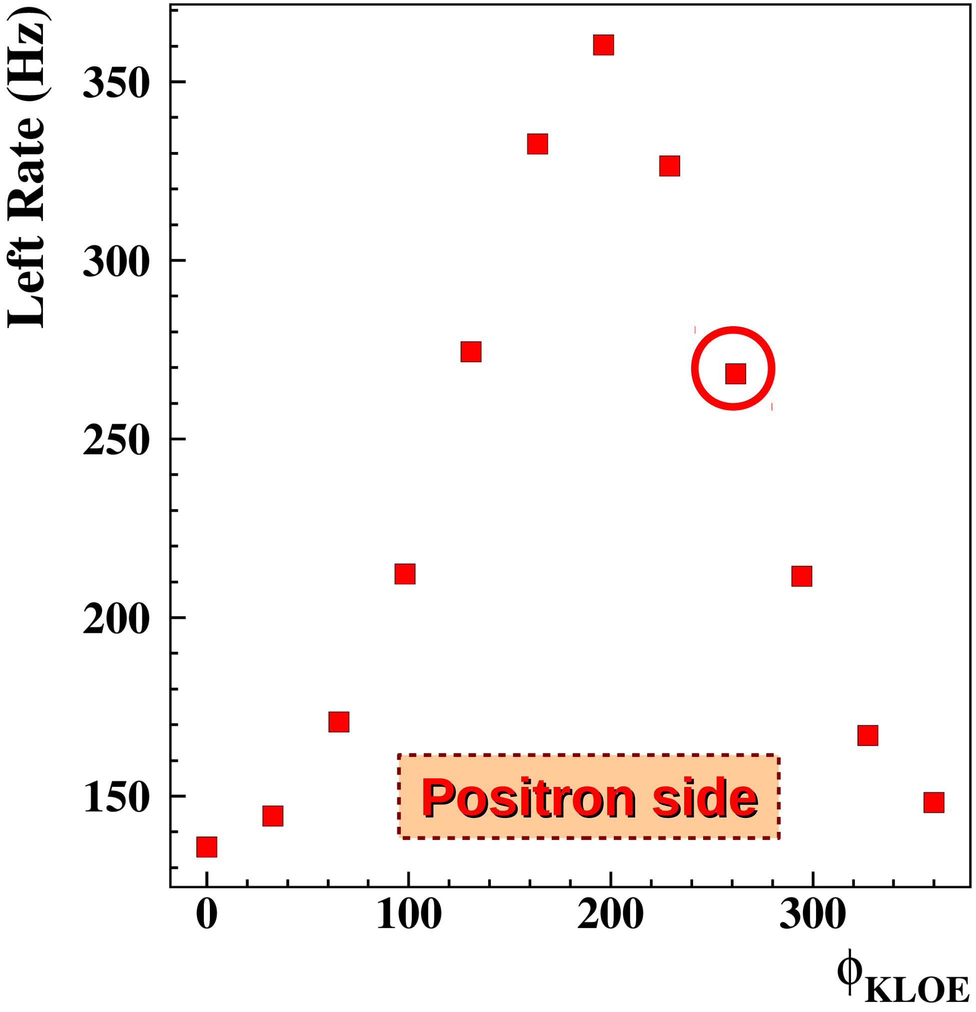
Distribution of hits on the CCAL-T end plate.

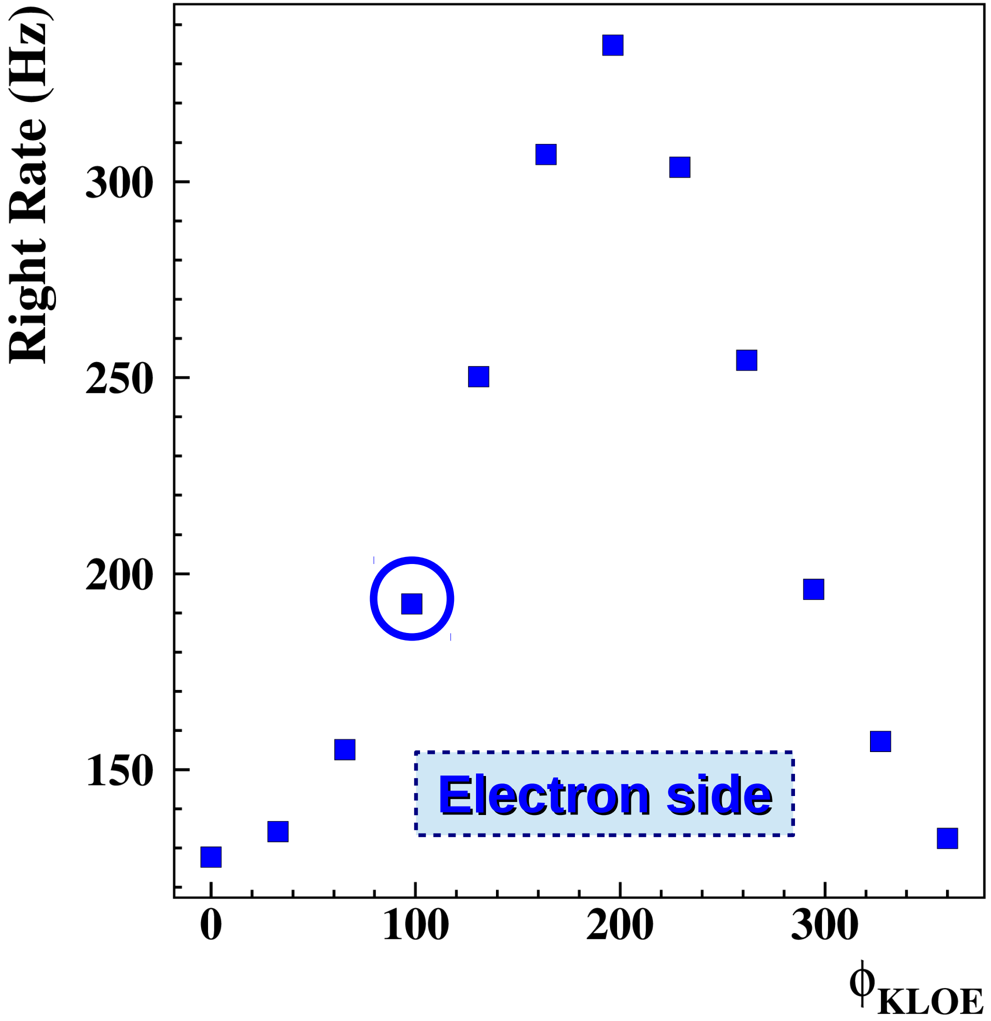
CoM momentum effect is clearly visible.

TOY MC expectation: single rate

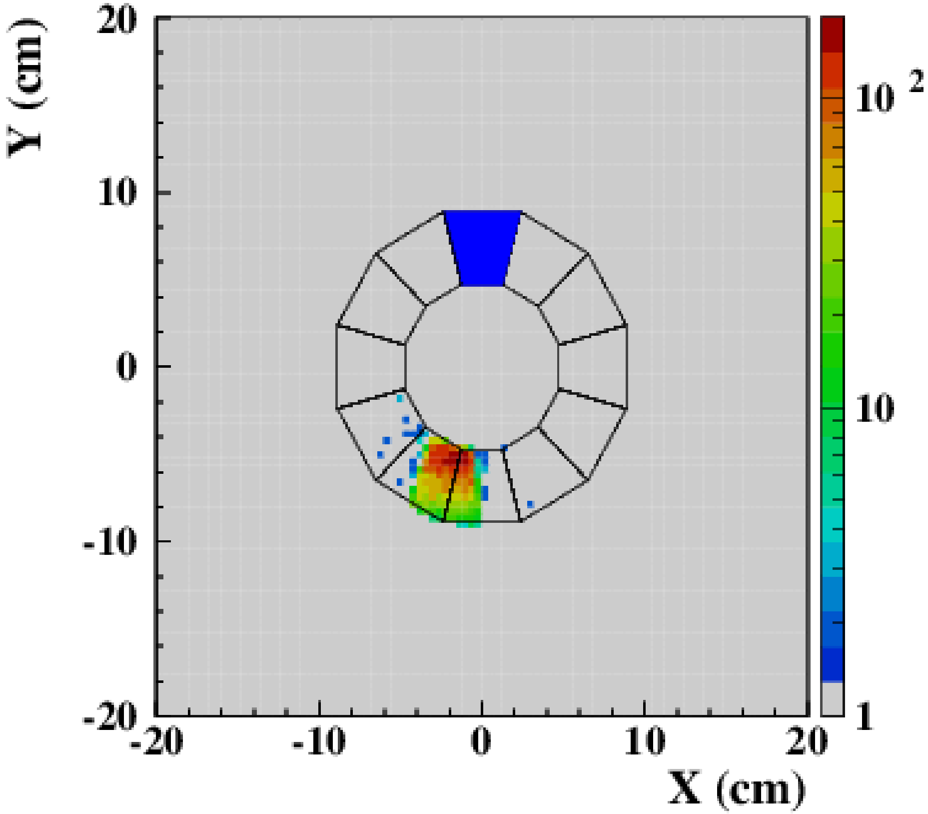
A small asymmetry is observed in the simulation. Further checks on the tracking has to be done in order to be sure about this point.

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





MC expectation: coincidence

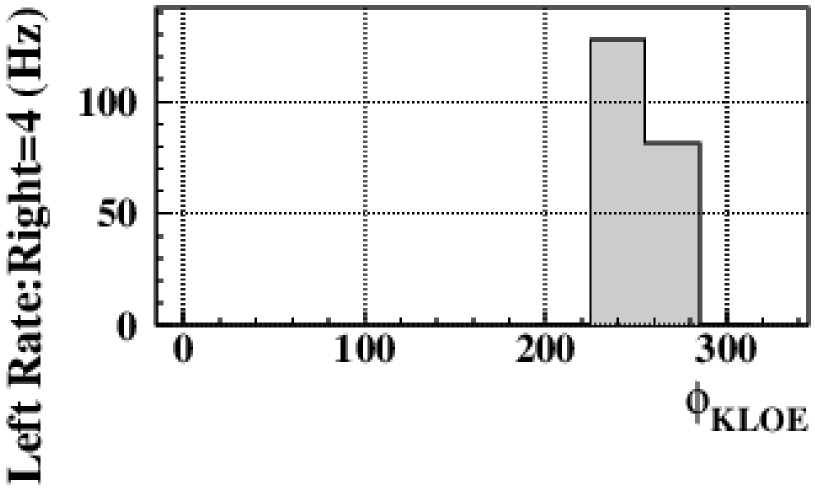


HITS on CCALT-L

Coincidence with CCAL-R#4

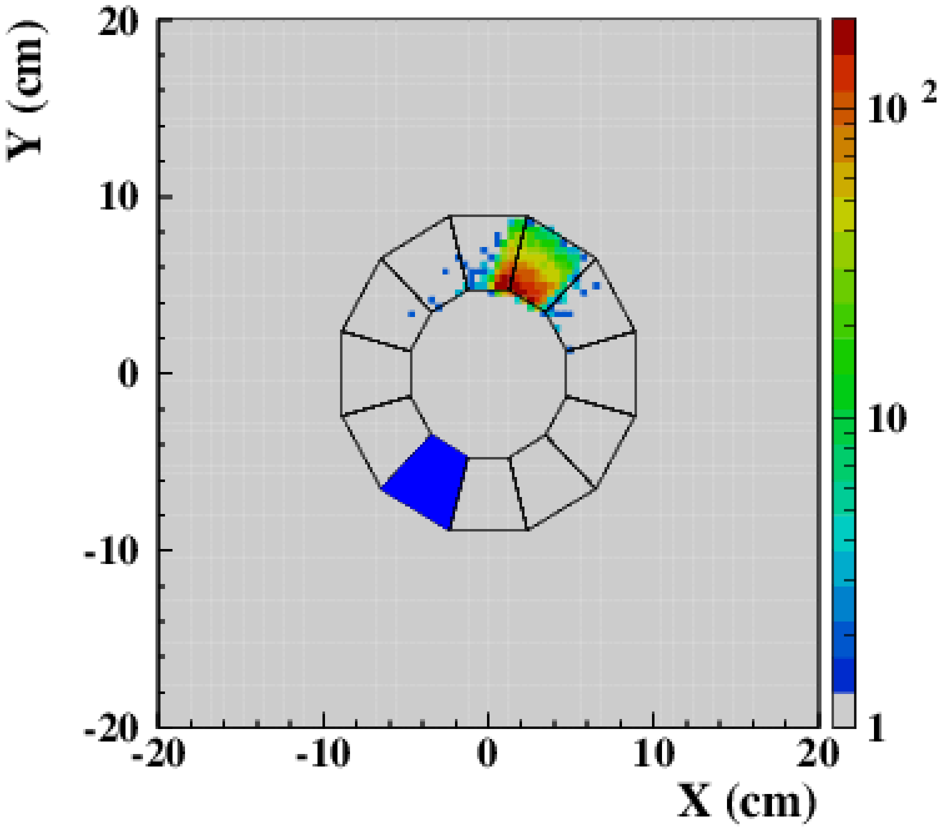
Expected rate:
- **80 Hz on L#10 (bottom) sector**
- 130 Hz on L#9 (bottom-left)

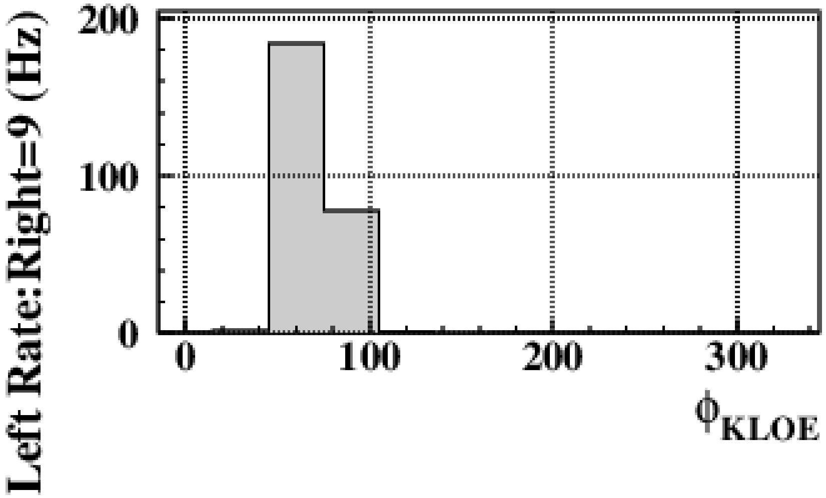
Assumed 100% efficiency and simplified geometry.



L#10 is currently acquired together with R#4

MC expectation: best coincidence rate





HITS on CCALT-L

Coincidence with CCAL-R#9

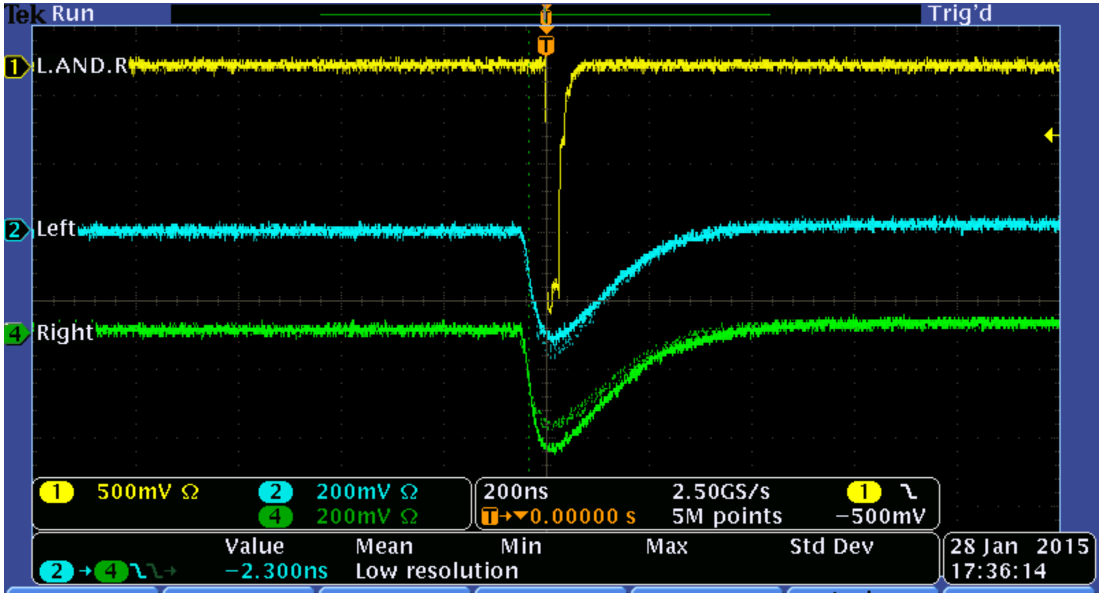
Expected rate:

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

Assumed 100% efficiency and simplified geometry.

Data acquisition

Signal pulses from CCAL-T



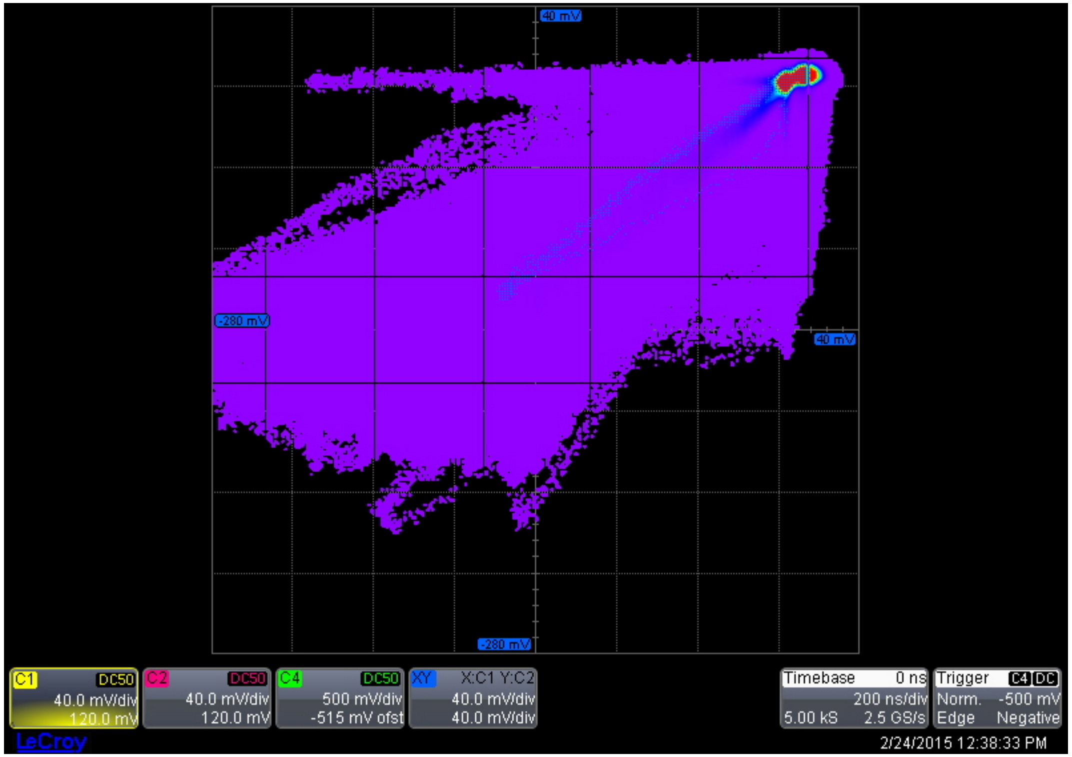
Pulses from CCAL-T sectors seen at the scope with beam operations.

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

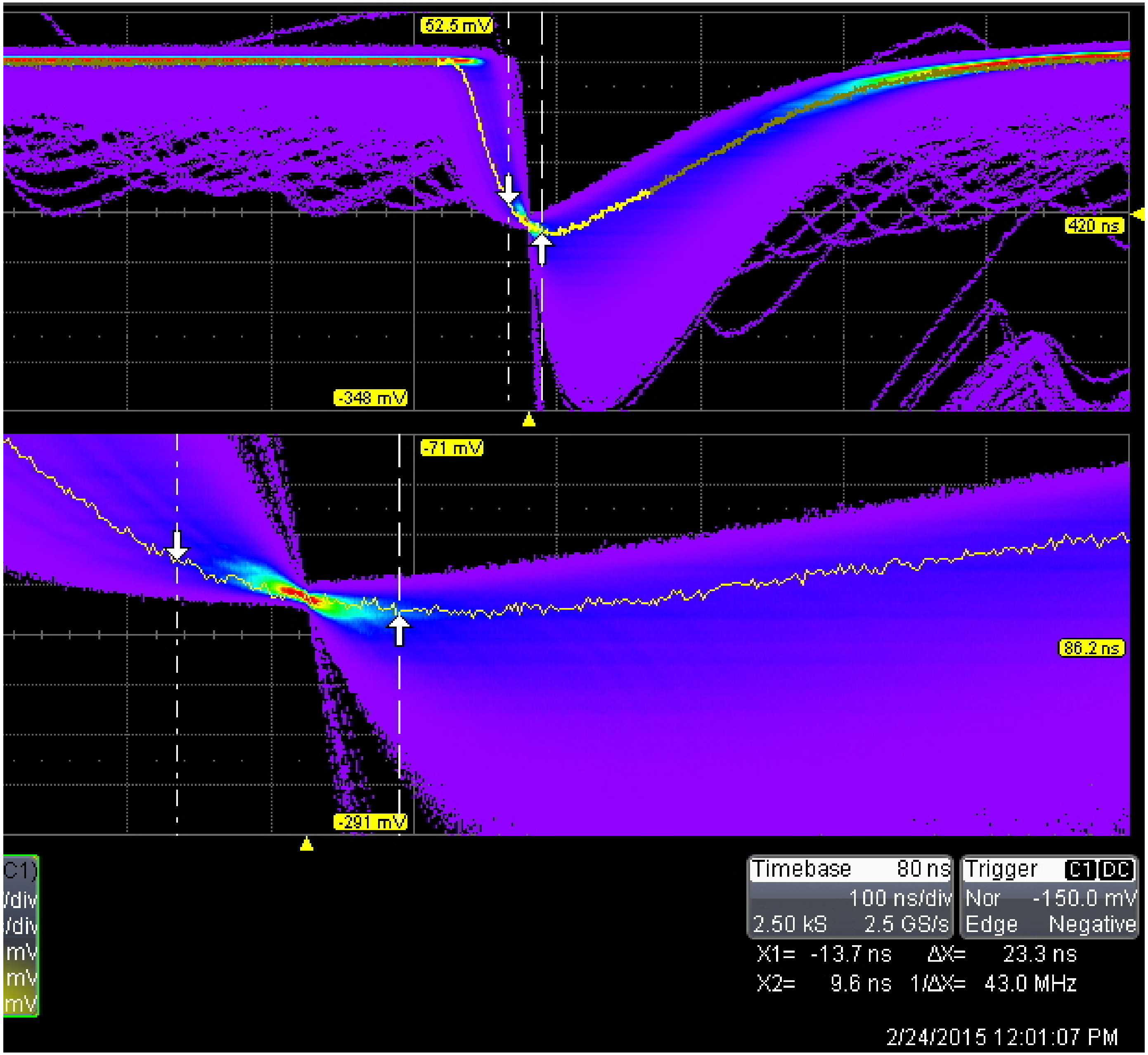
(Scope: Tecktronix DPO 3054
Courtesy of S. Miscetti)

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



```
Timebase        80 ns   Trigger      C1 DC
            100 ns/div  Nor     -150.0 mV
2.50 kS      2.5 GS/s   Edge     Negative
X1=  -13.7 ns     ΔX=     23.3 ns
X2=      9.6 ns  1/ΔX=   43.0 MHz

2/24/2015 12:01:07 PM
```

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

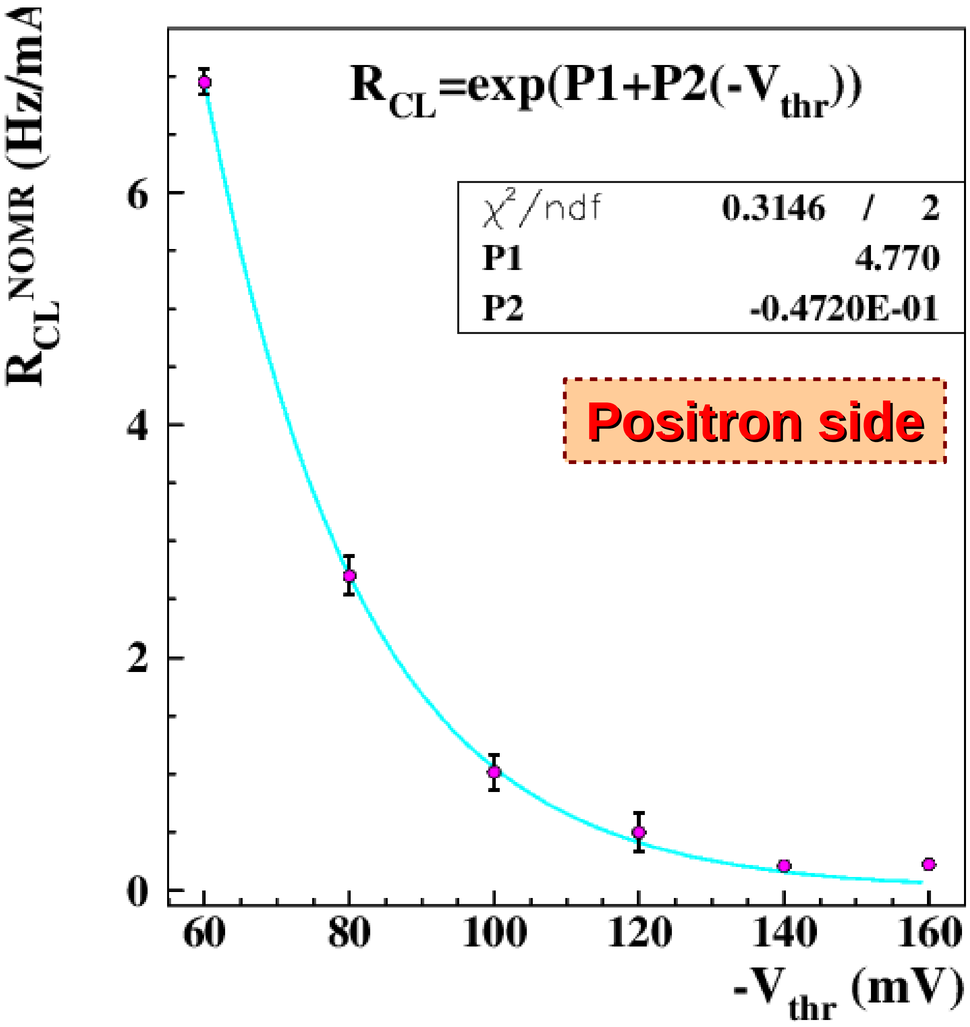
In this picture the threshold was set at -150 mV on the negative edge of the signal coming from one of the two CCAL-T sectors.

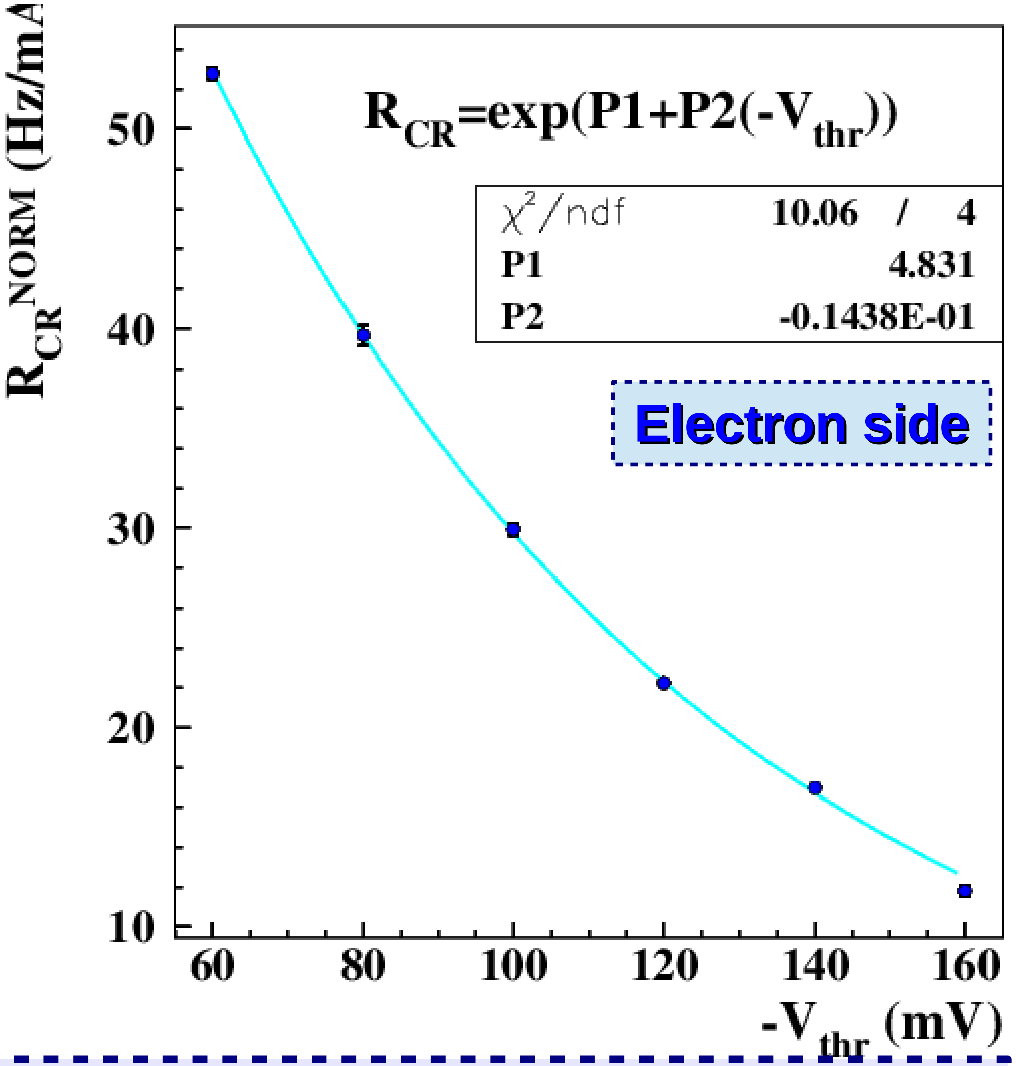
The width is well represented by the two cursors line: 23 ns

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

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

Thresholds scan with single beams (electron)

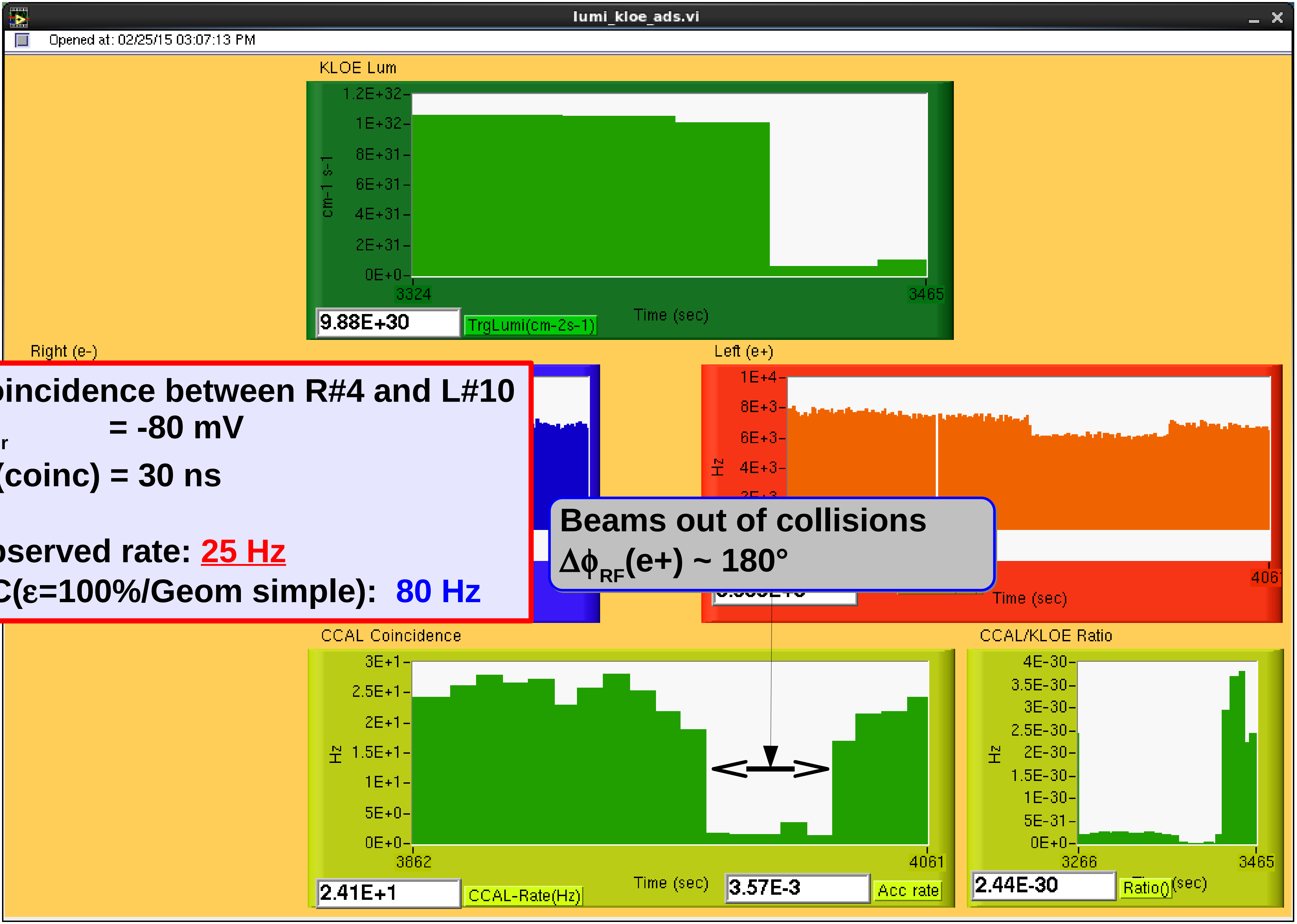




Normalized rates on the two sides as a function if the threshold.

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

First observations with beams



9.88E+30 TrgLumi(cm-2s-1)

2.41E+1 CCAL-Rate(Hz)

3.57E-3 Acc rate

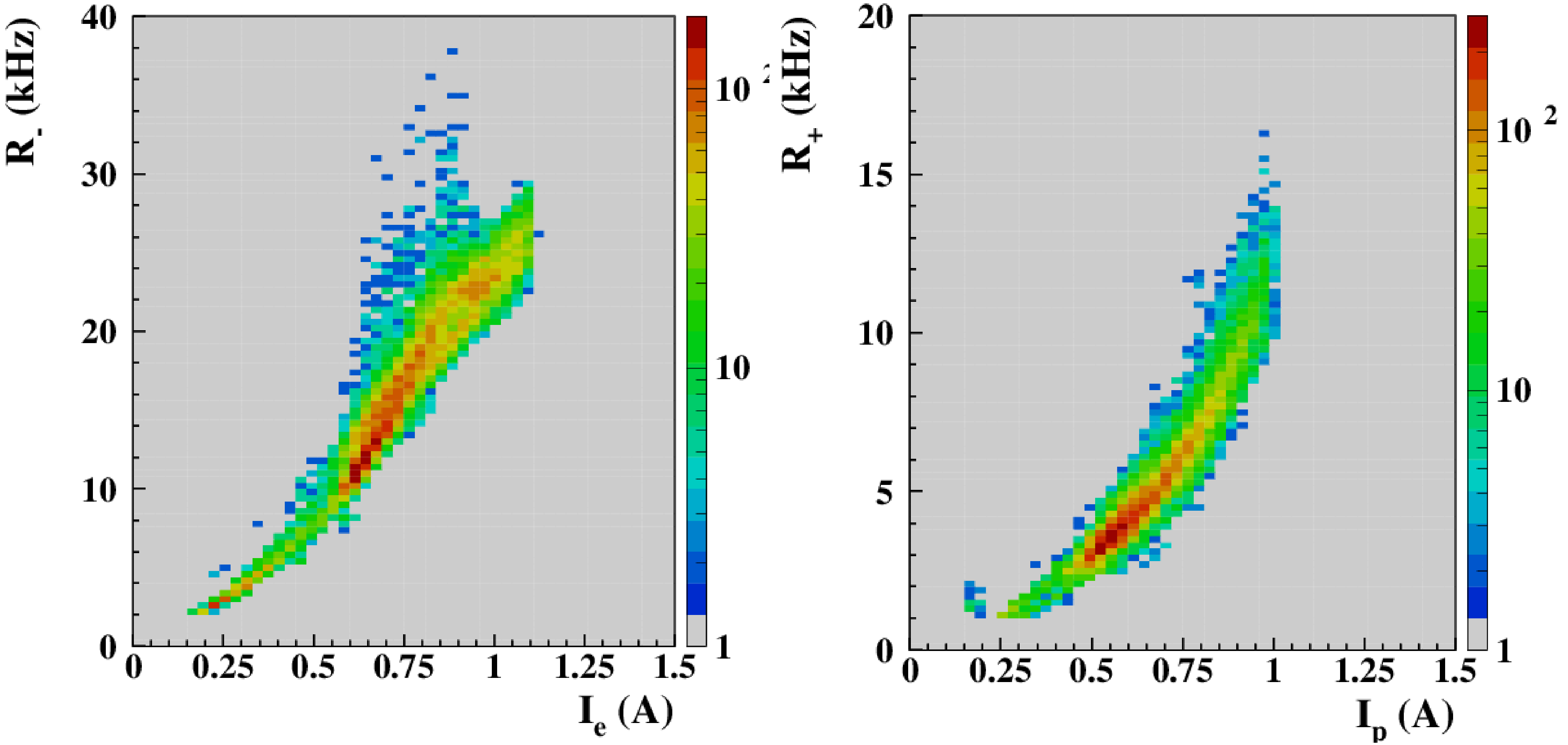
2.44E-30 Ratio()

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°

Single arm signal rates

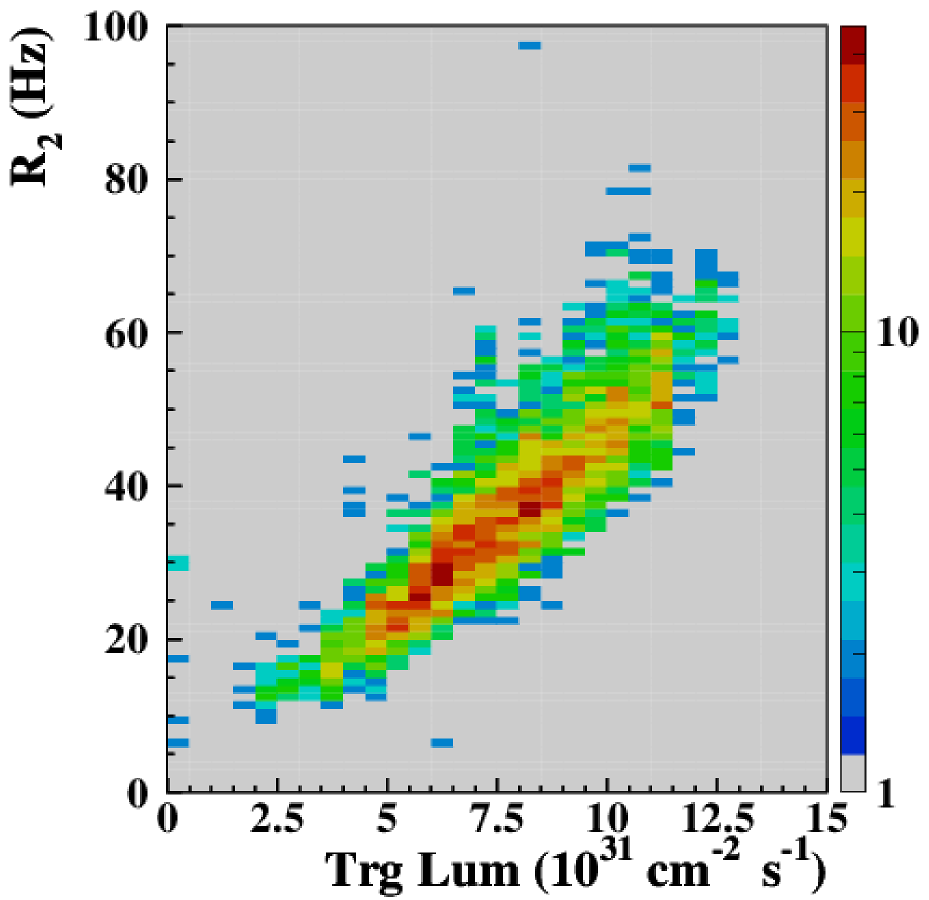


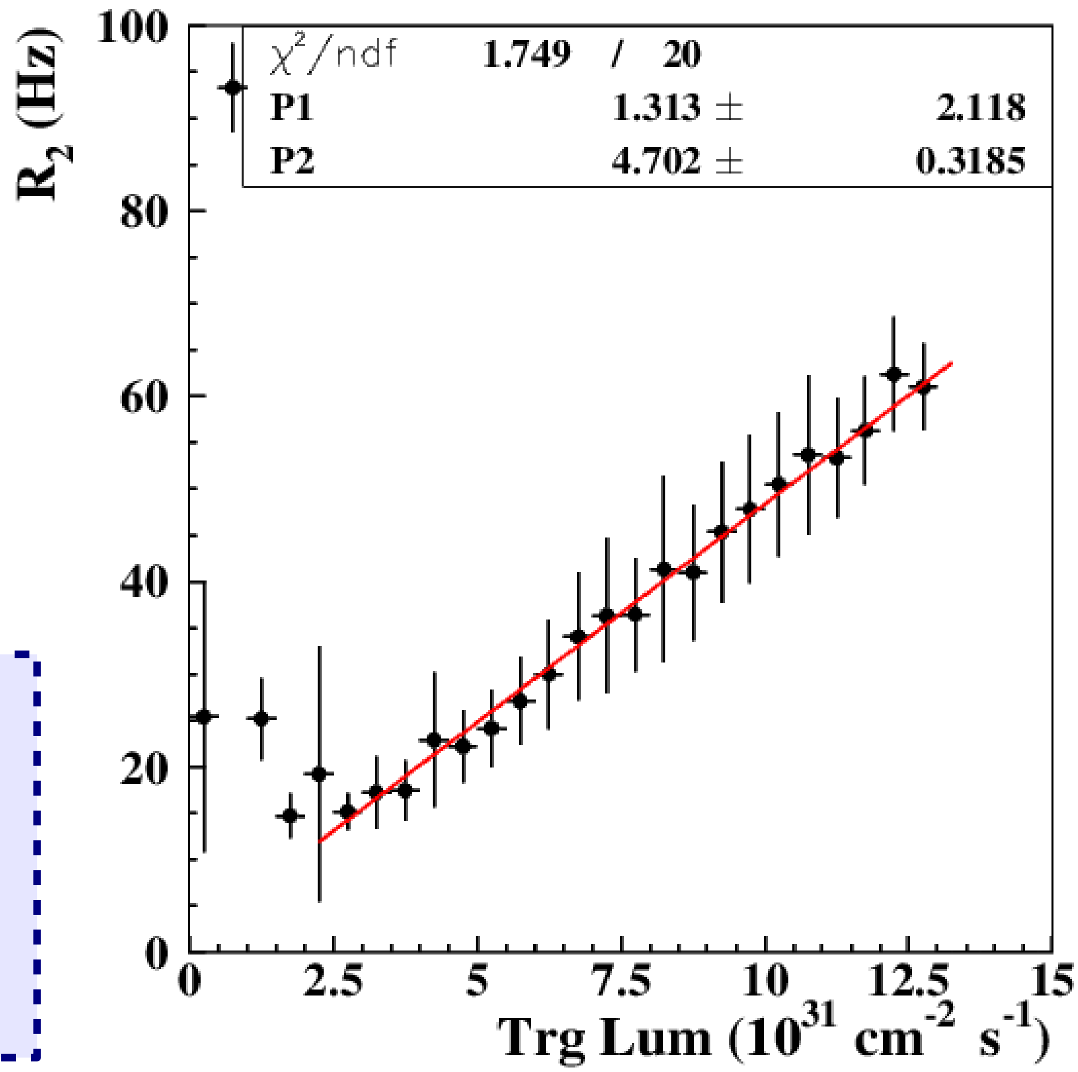
Single rate as a function of the corresponding current.
From single beam data a contribution of ~1kHz on each side is expected from the opposite beam.

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

Luminosity measurement calibration

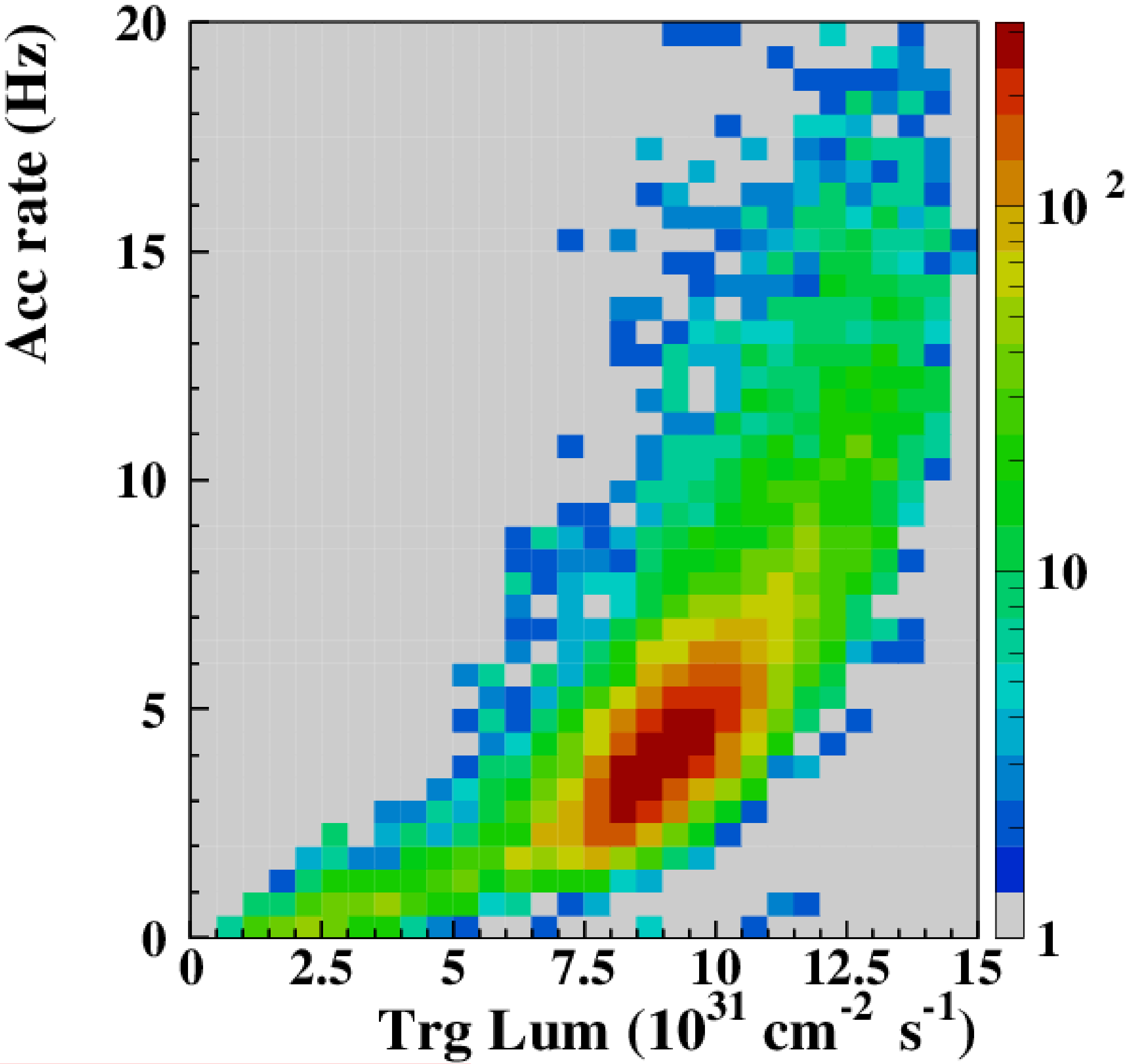
V_{thr} = -100 mV
Δt(coinc) = 30 ns
ΔT(veto) = 50 ms
Σt(coinc) = 3 s





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 measurement

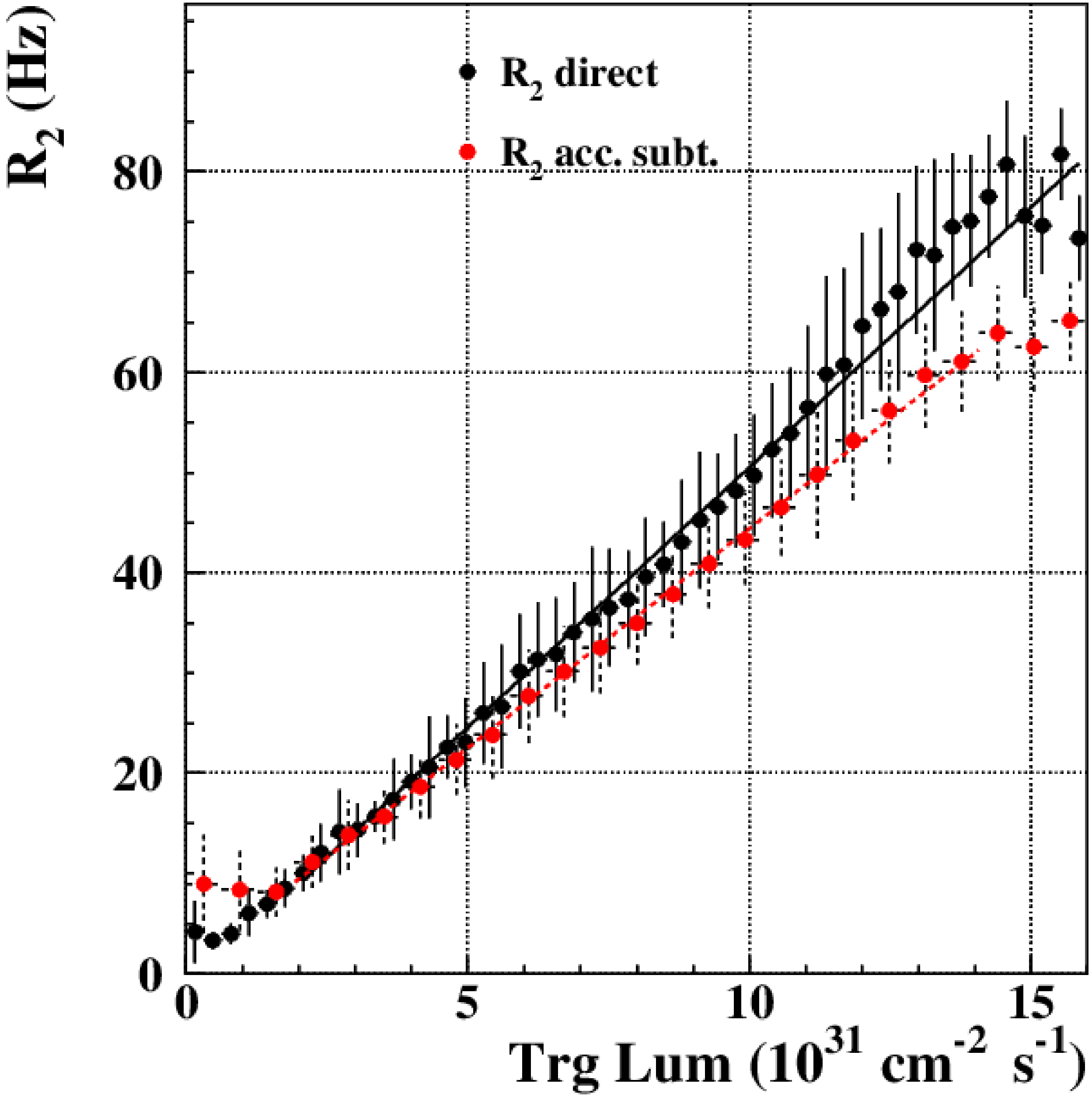


V_{thr} = -100 mV
Δt(coinc) = 30 ns
ΔT(veto) = 50 ms
Σt(coinc) = 3 s

Accidental rate as a function of the KLOE-2 trigger luminosity.

Strong non-linear behavior and large spread. Reduction of the coincidence window is mandatory for good precision at high luminosity.

Comparison between R_2 w/wo accidental sub



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

Effect of the background from accidental coincidence subtraction.

Background introduces deviation from linearity and imply a systematic error on the calibration constants.