BEAST Crystal Update
May 31, 2016

CSI - BEAST Group

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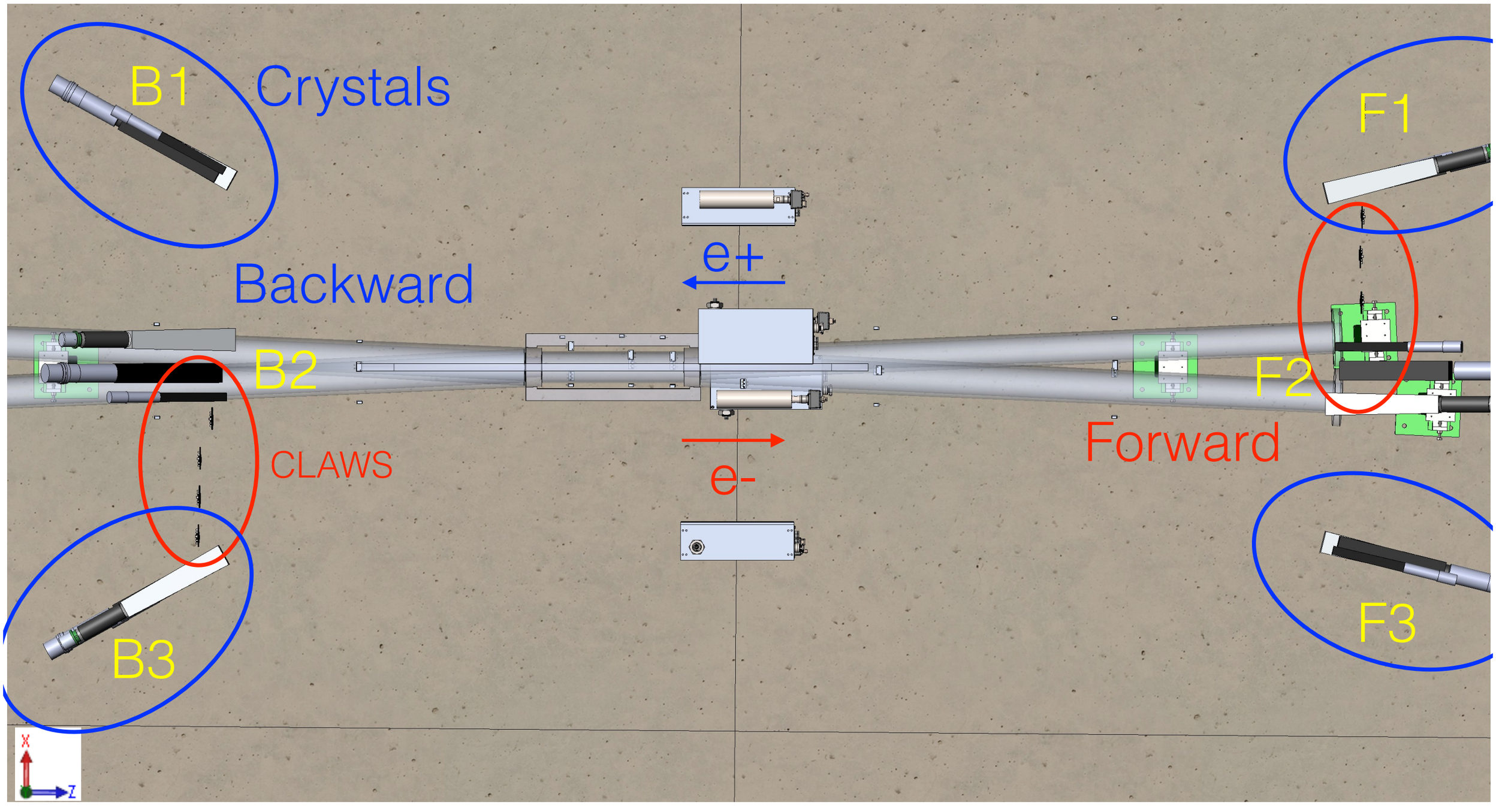
Outline

- Crystals Setup
- Background Study
  - Touschek
  - Beam gas
  - Coulomb
- Injection Background Study
- Summary

Project Timeline

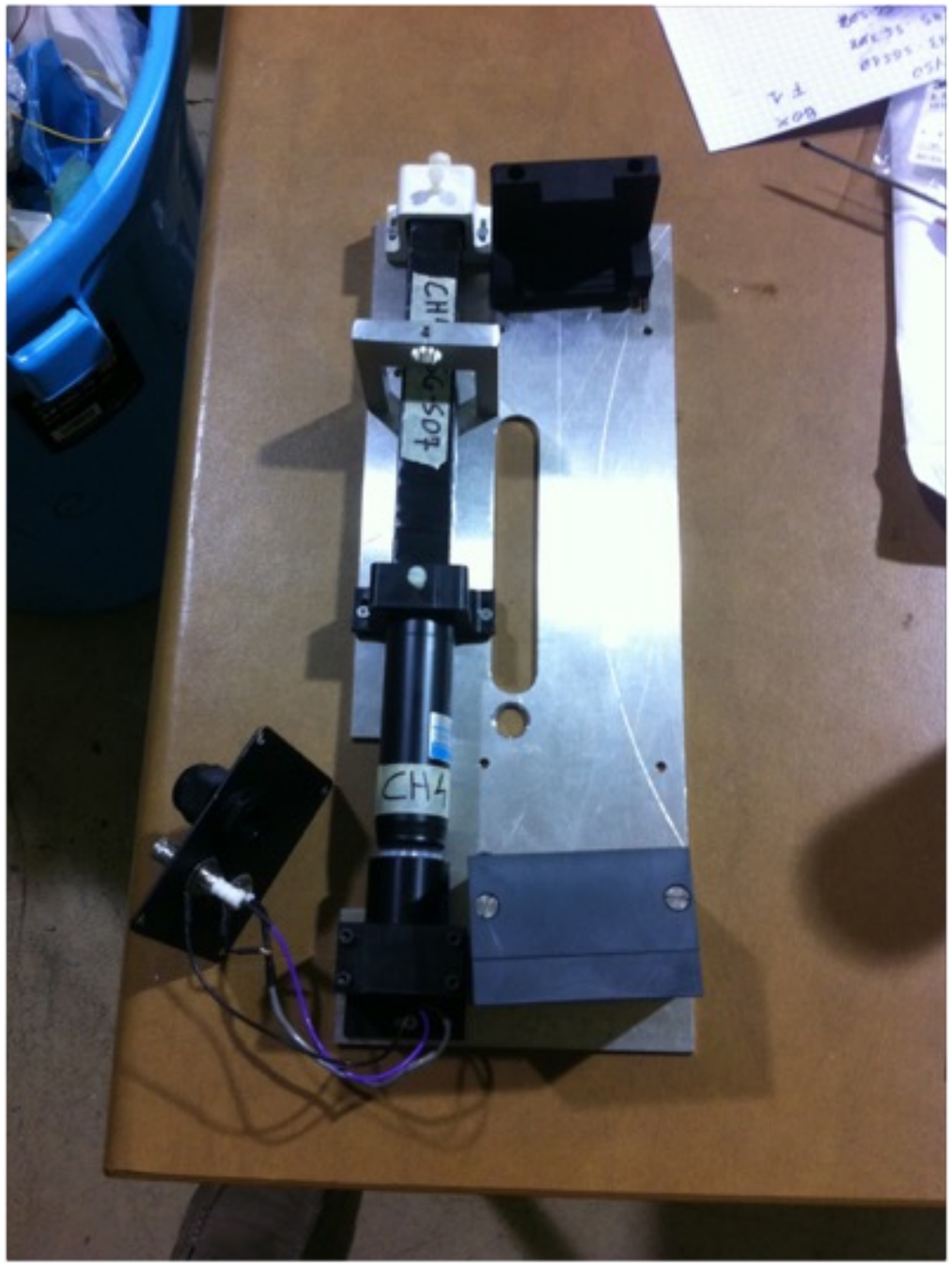
- February 2015: decision to contribute to BEAST with 6 pure CsI and 6 LYSO crystals with PMT readout, DAQ and slow PTH monitoring with uSOP
- May 2015: First crystal at UH, with readout chain
- June-July 2015: Calibration with source in Italy
- August 2015: Installation in Tsukuba Hall on IP
- December 2015: Calibration runs with source
- January 2016: Second calibration runs with source
- 1 February 2016: SuperKEKB turn on, BEAST online!
- February-June 2016: BEAST run, measurement of machine backgrounds during SuperKEKB commissioning
- May 2016 Dedicated injection background study

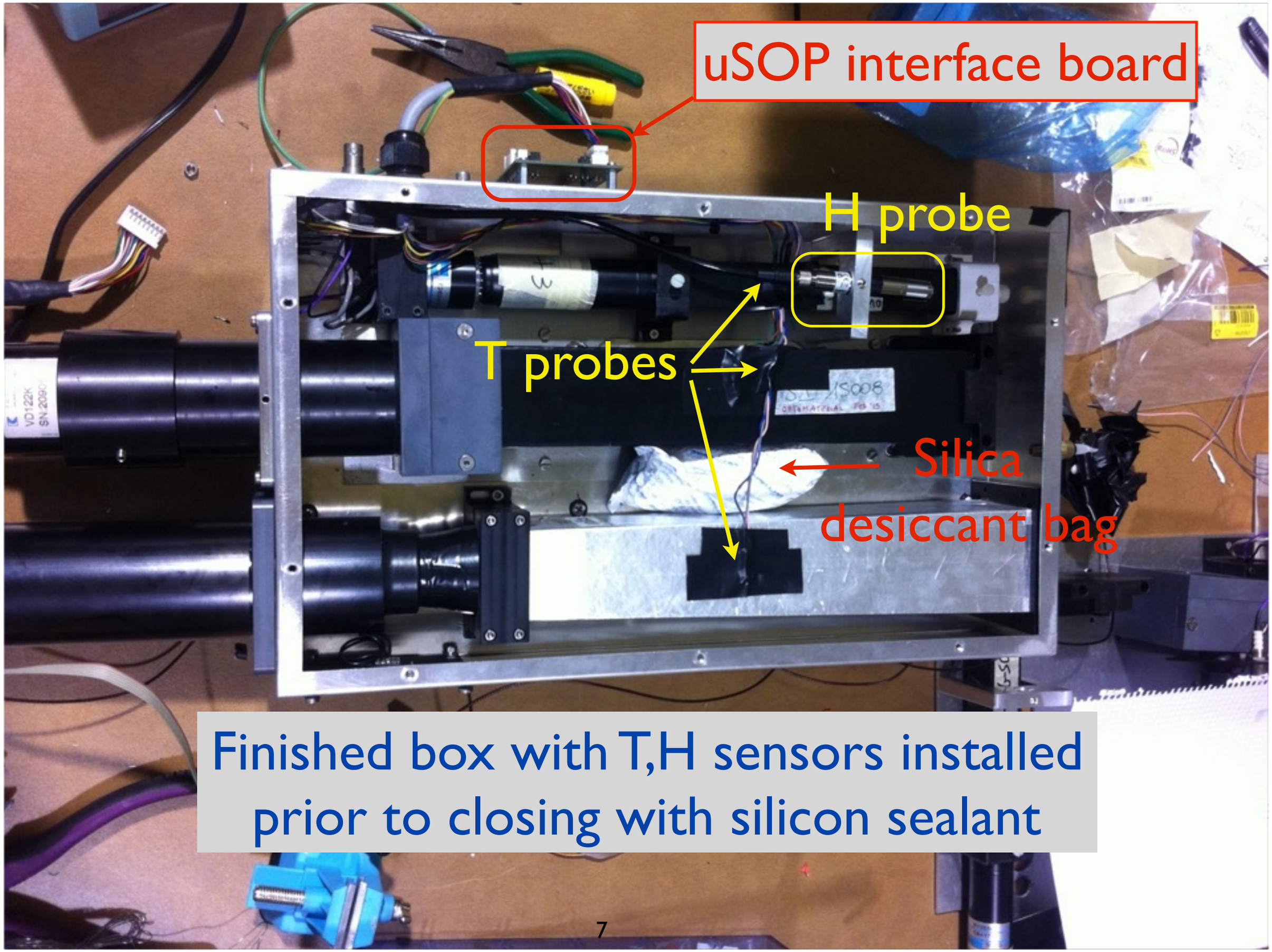
BEAST CsI System



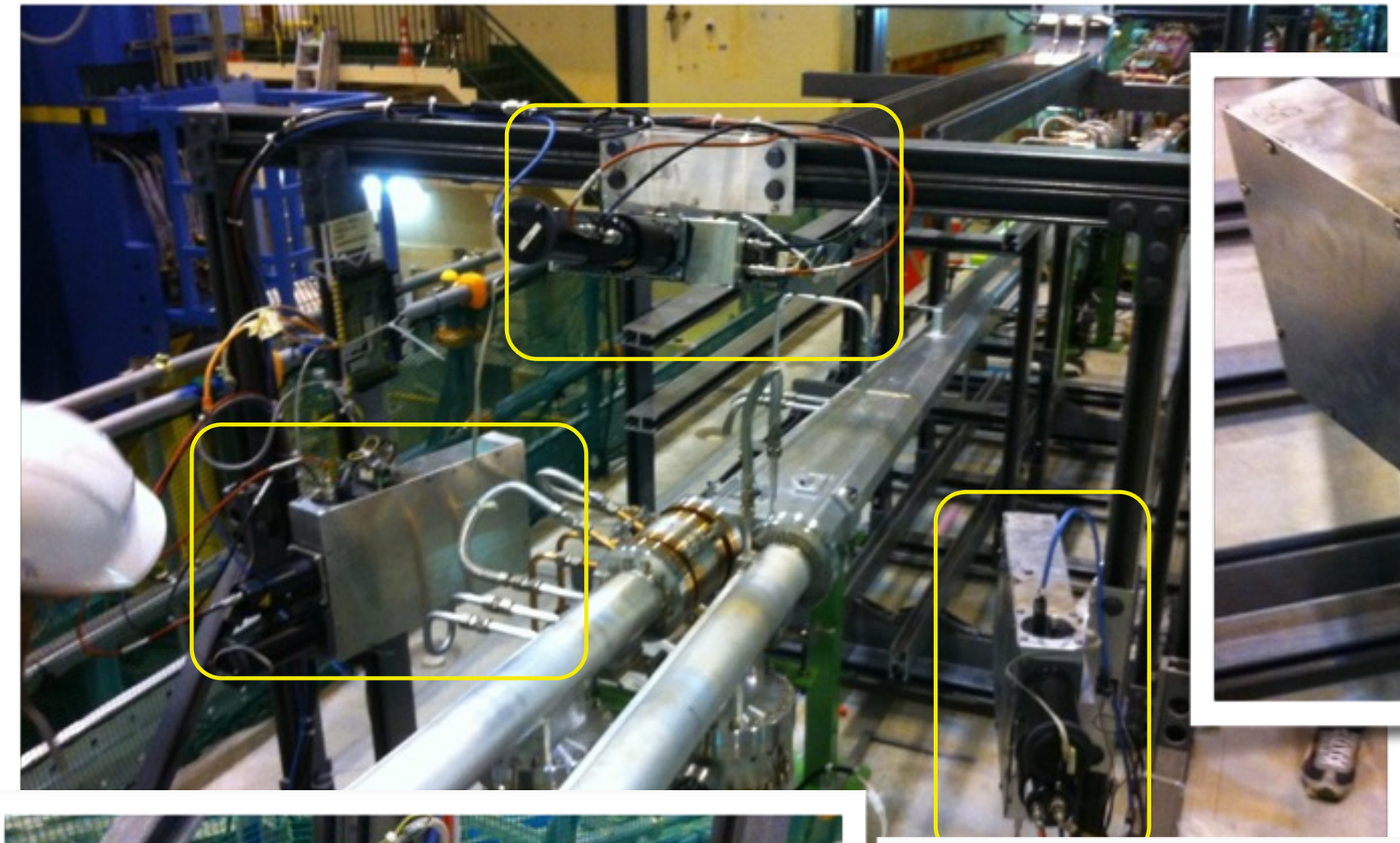
Installation Team

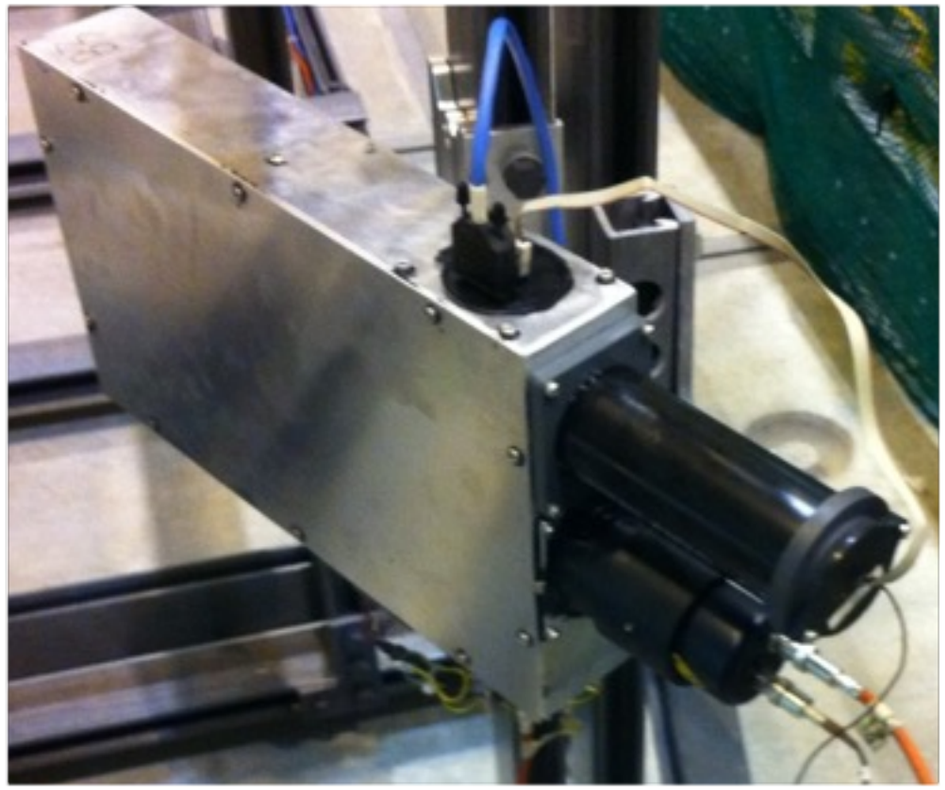
- CANADA (U. of Victoria)
  - A. Beaulieu
- ITALY
  - INFN - LNF Frascati
    - R.de Sangro, A. Russo (Tech)
  - U. of Naples & INFN Naples
    - R. Giordano
  - U. of Perugia & INFN Perugia
    - A. Rossi, G. Scolieri (Tech)
  - INFN Roma 3
    - P. Branchini

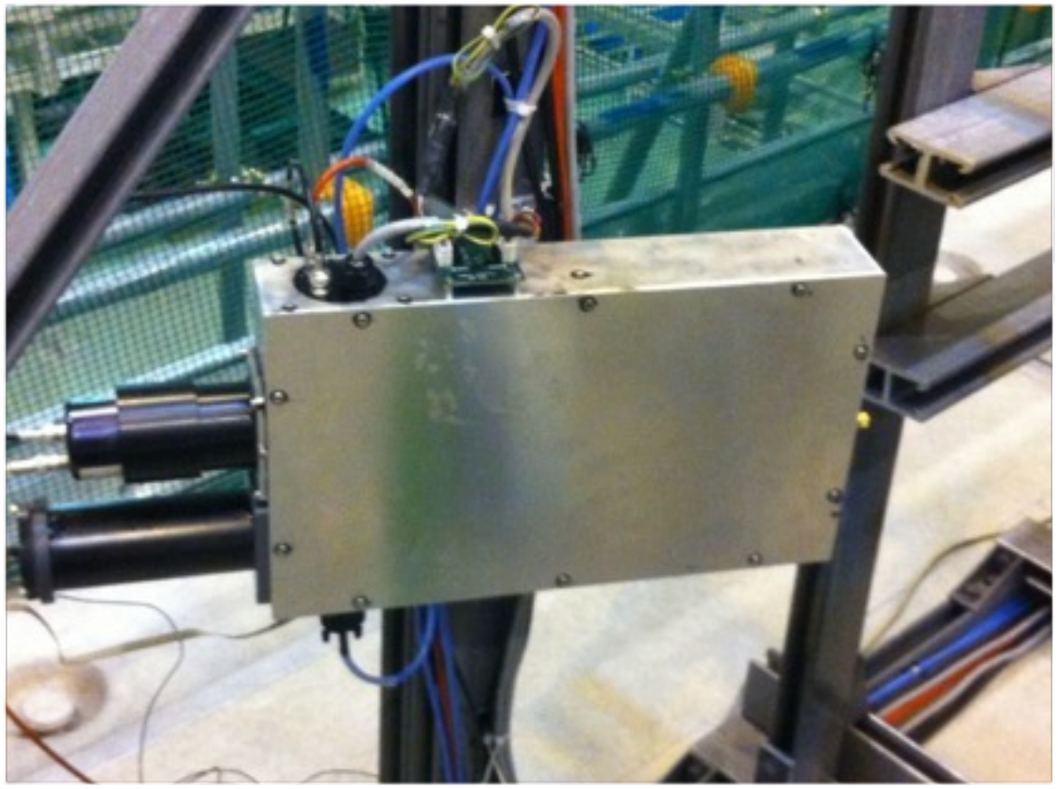

CH4

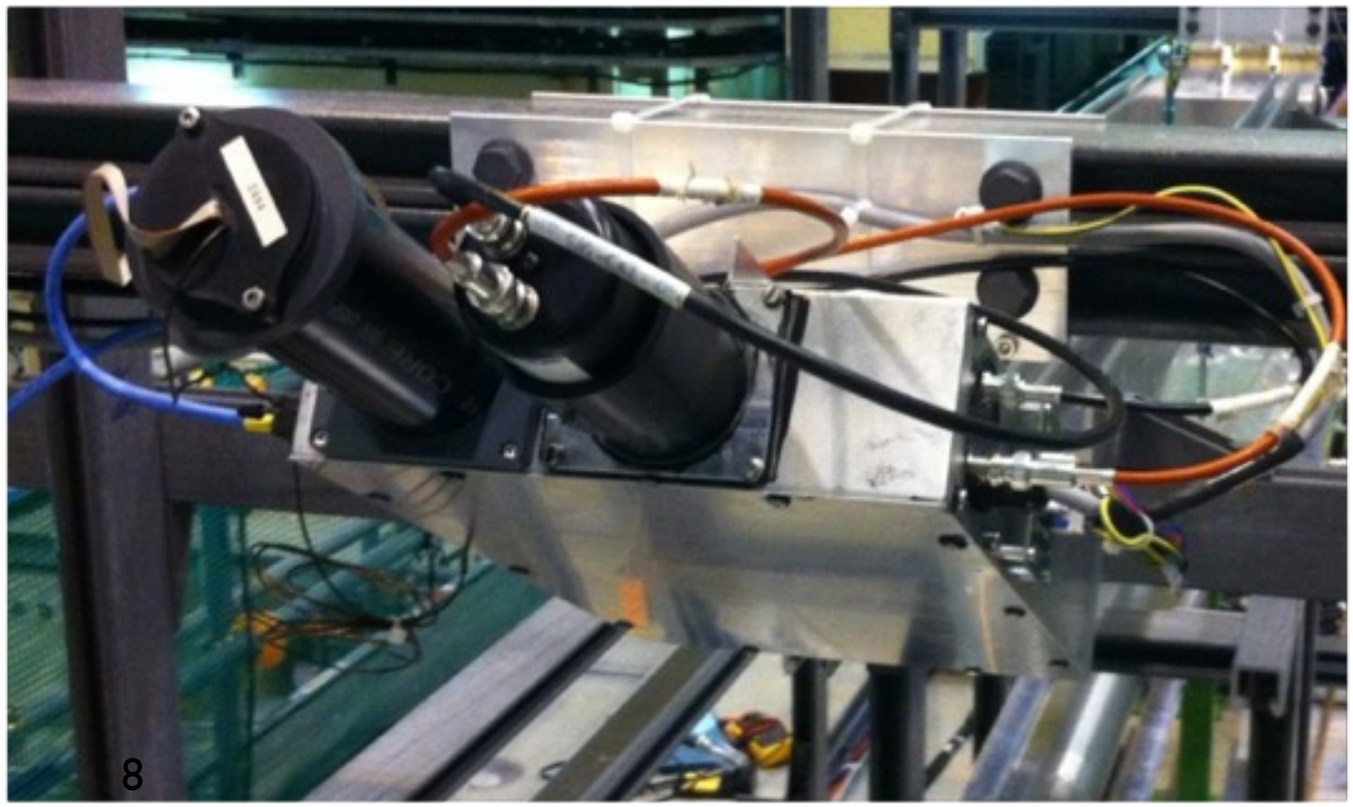


Finished box with T,H sensors installed prior to closing with silicon sealant



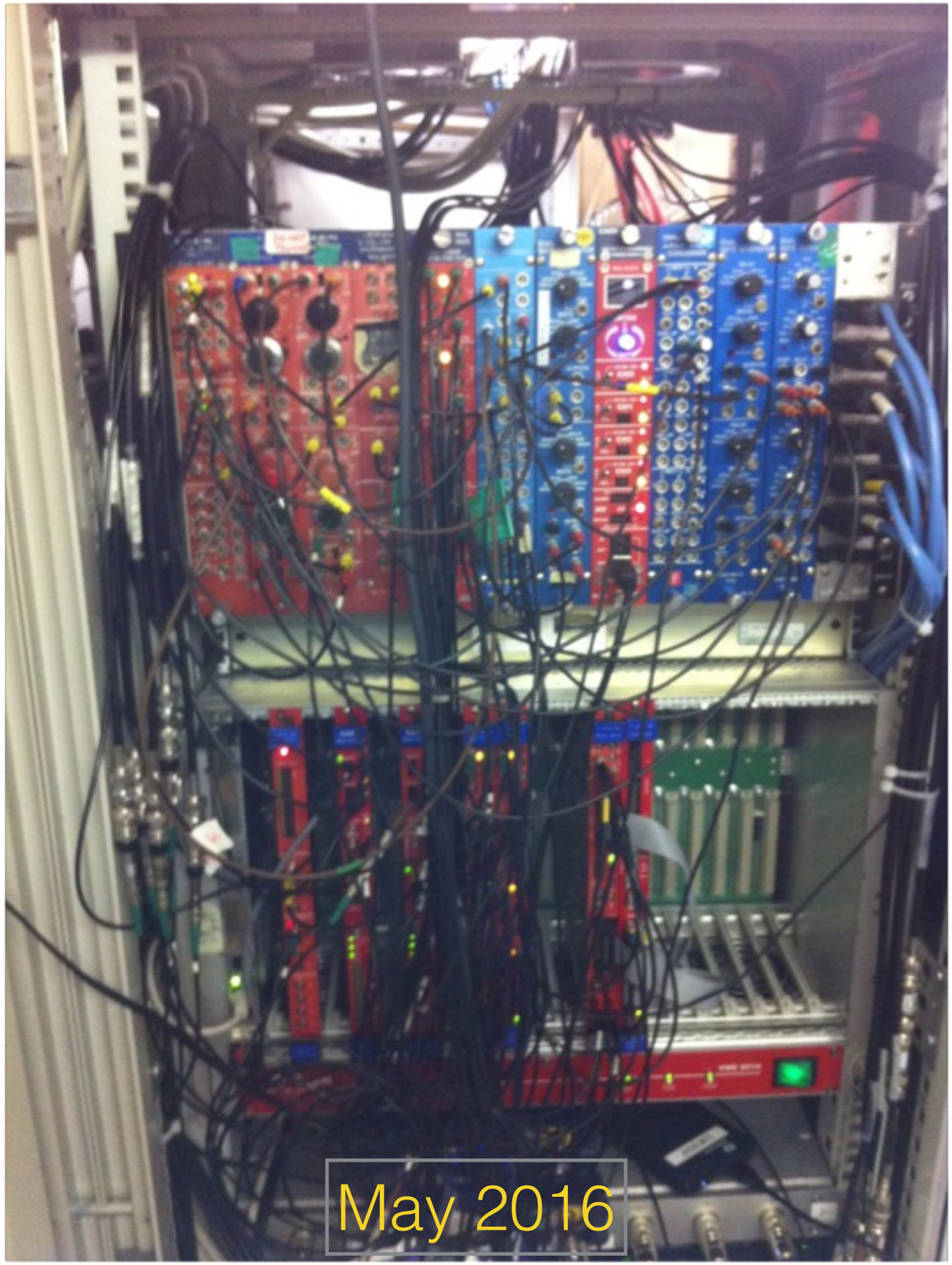






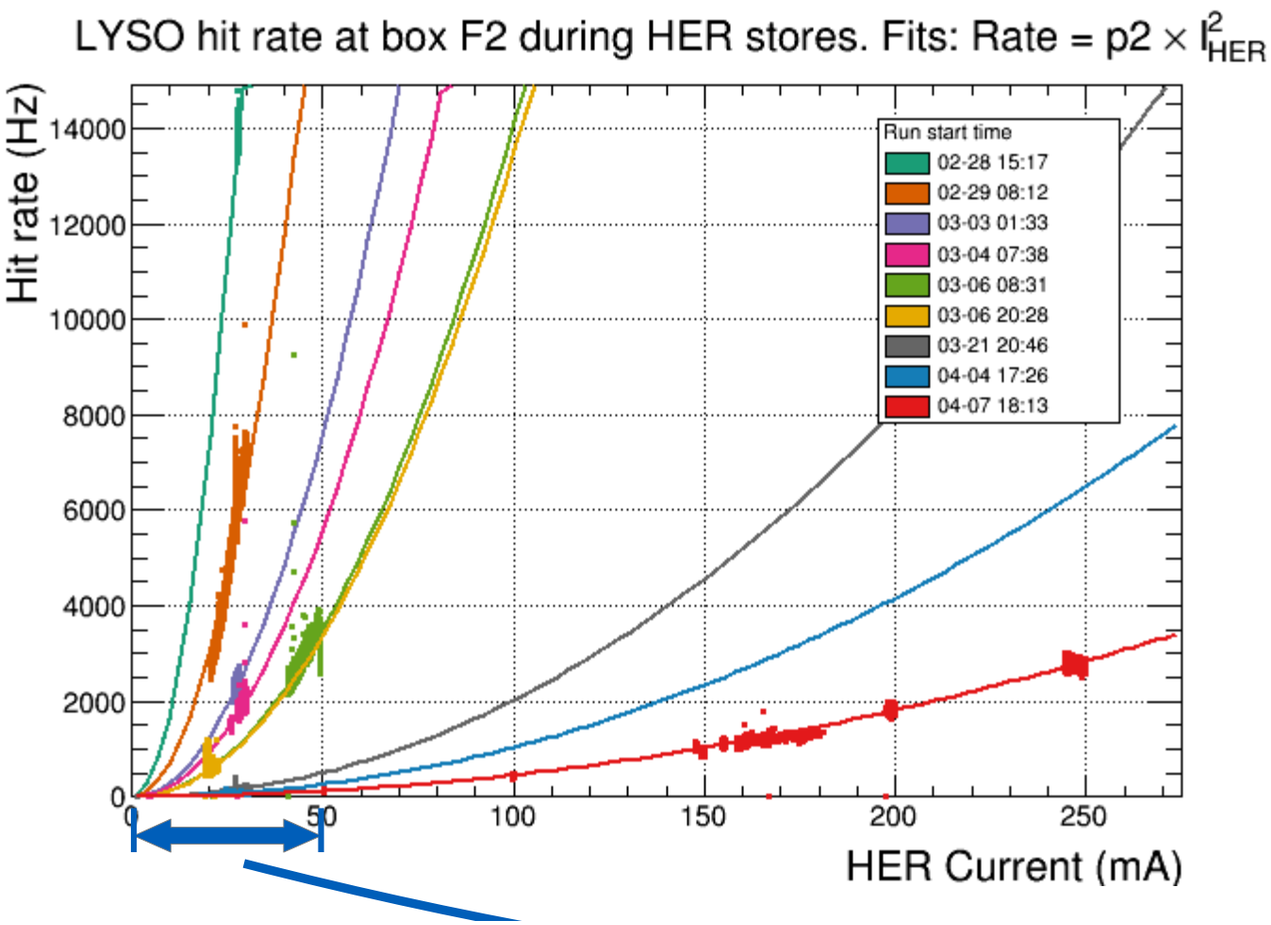
DAQ

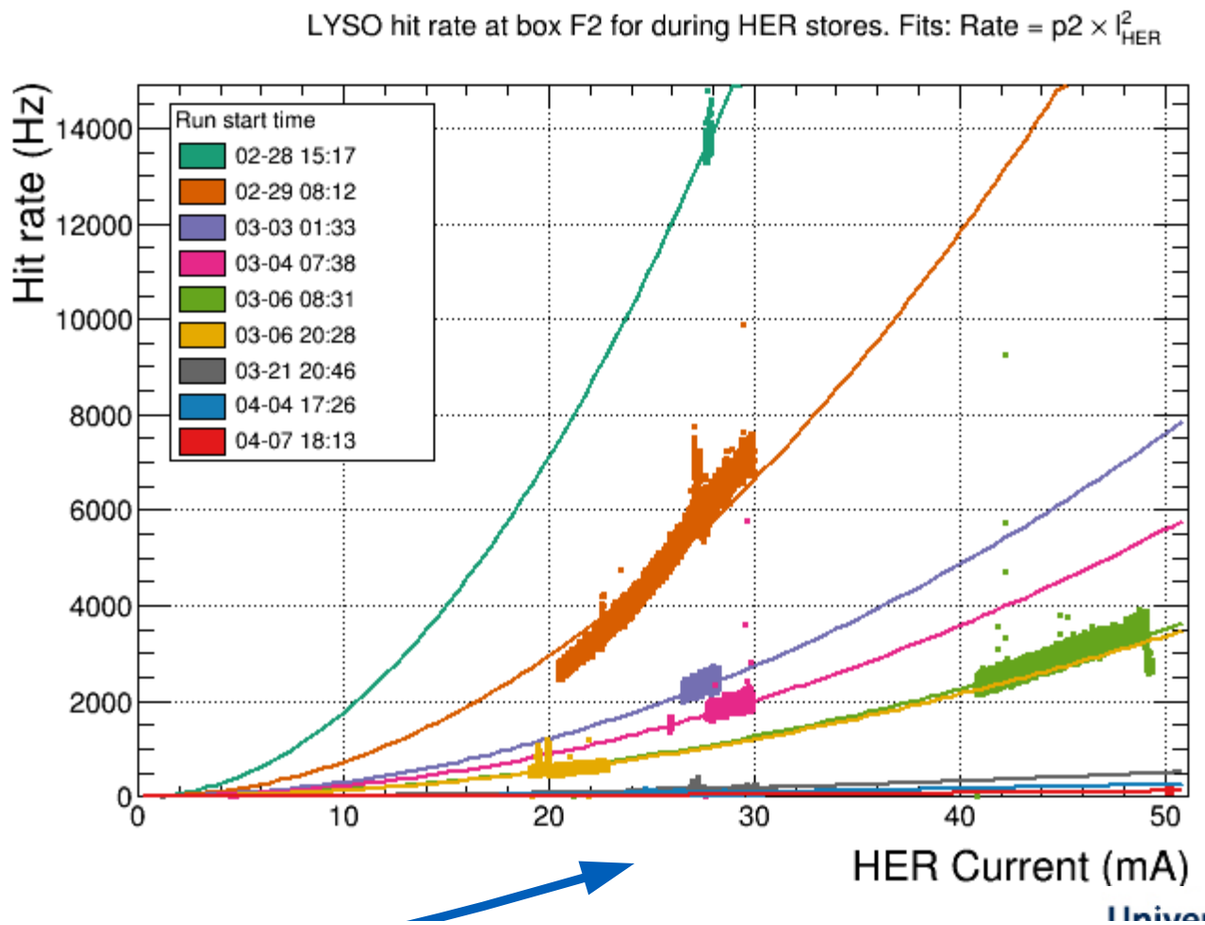
August 2015



Background Study

HER Vacuum Scrubbing

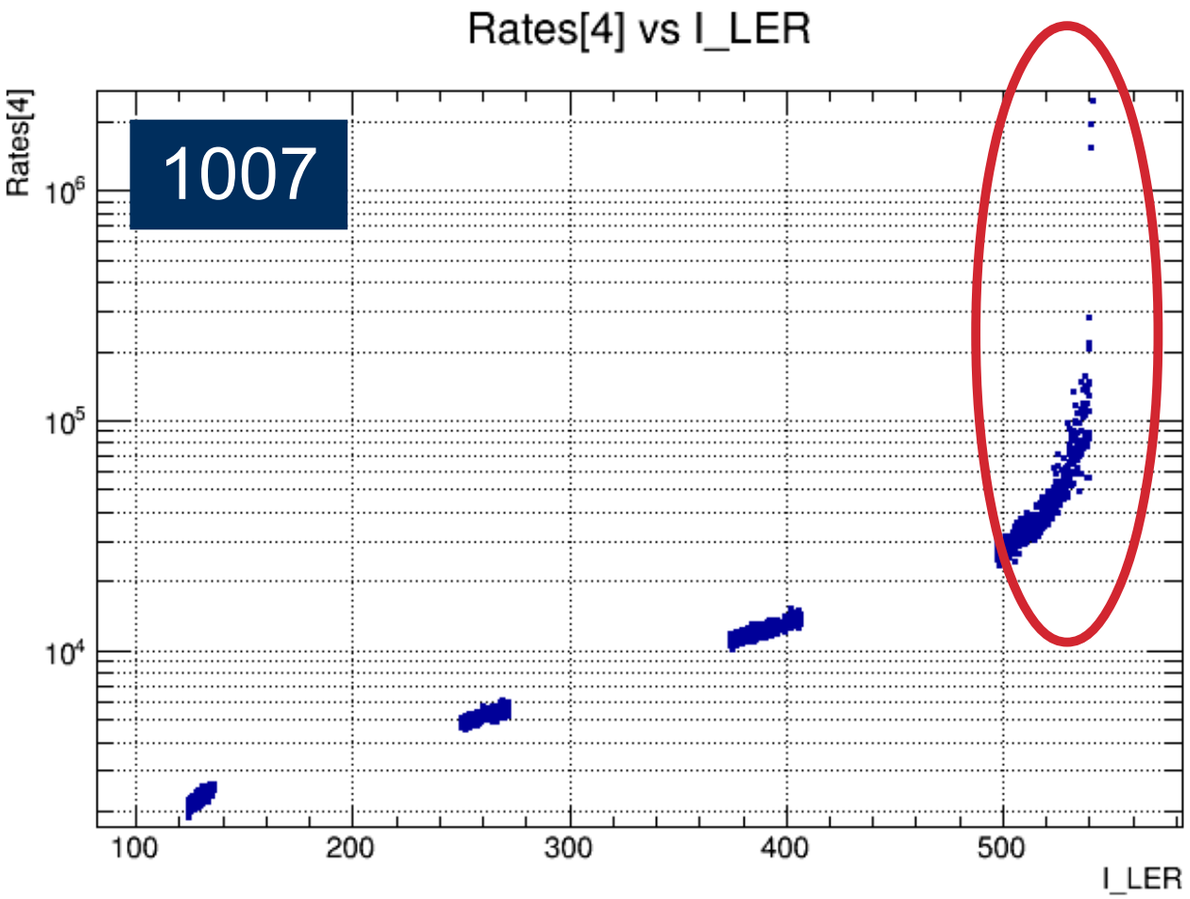


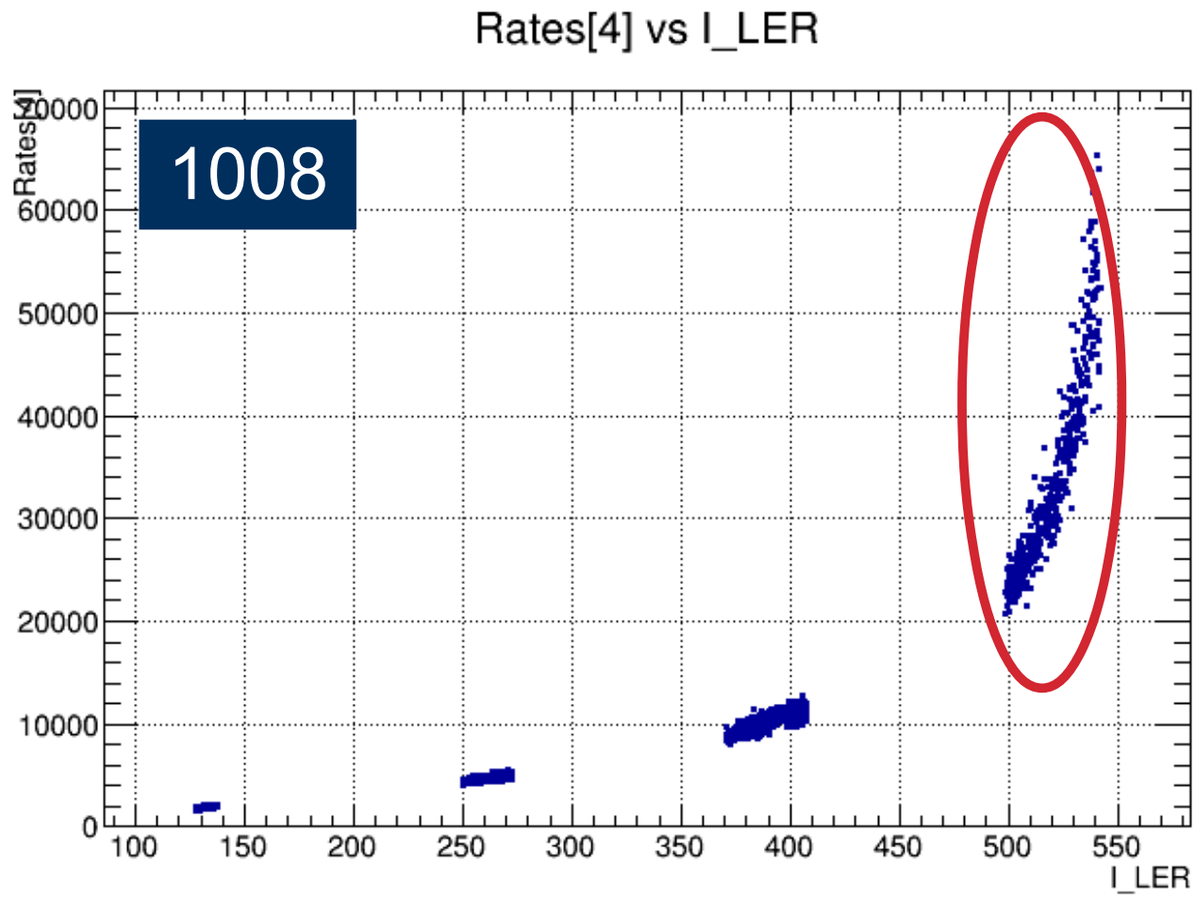


Beam gas ∝ I^2

Fit with p*I^2 , parameter p decreases with time, indication of vacuum scrubbing

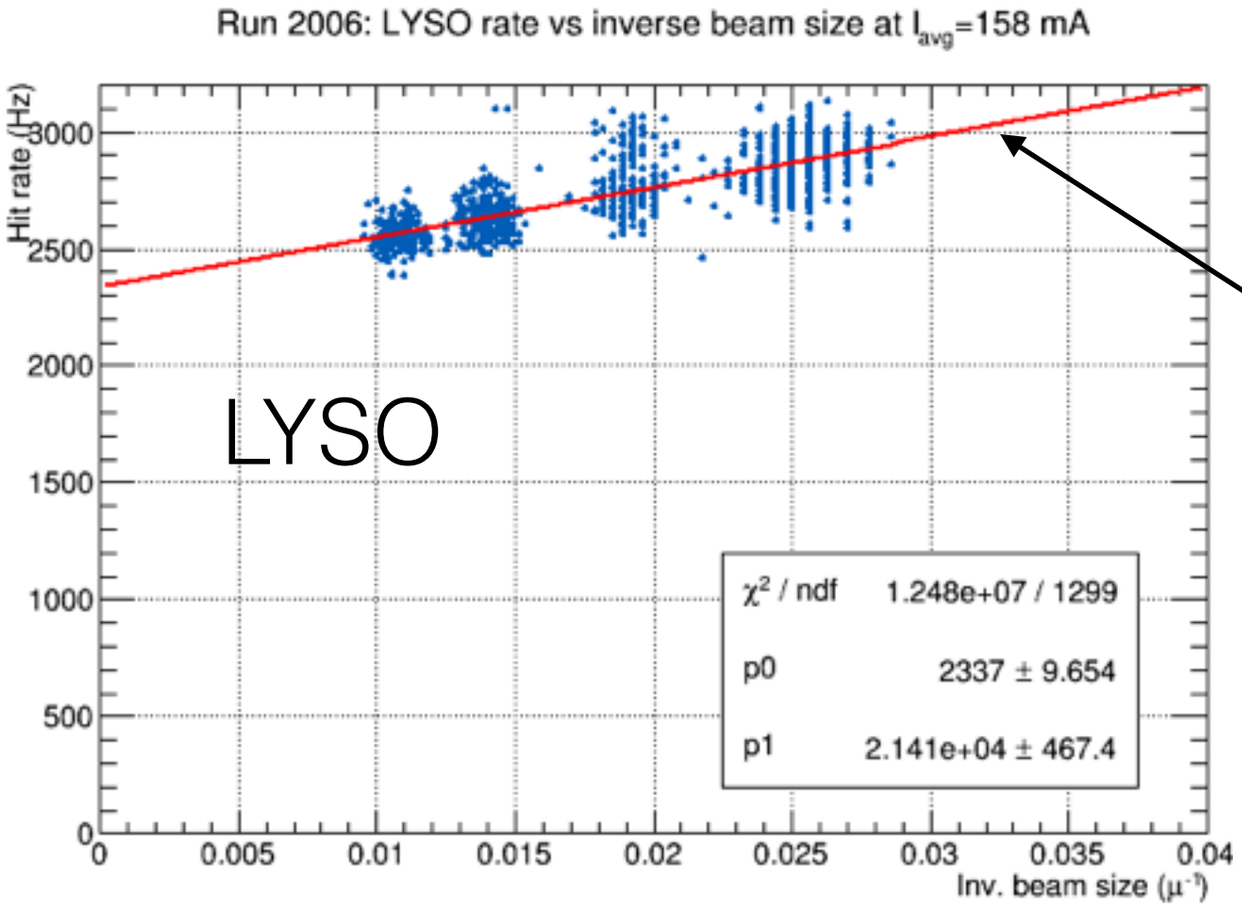
Beam Blow Up in LER





Most Likely electron cloud effect
First seen (only?) by crystals

HER Touschek Study

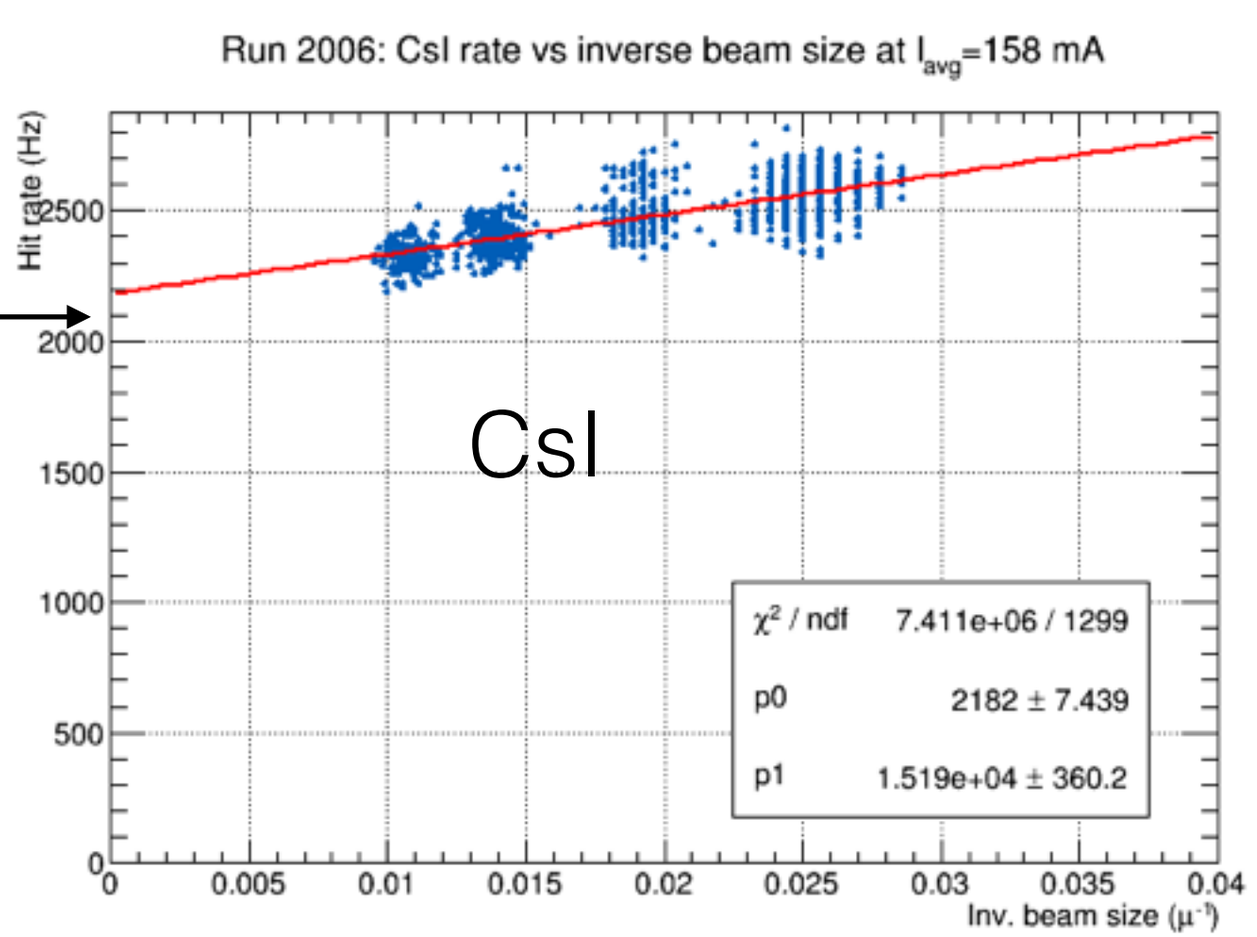


Rate vs 1/(beam size)

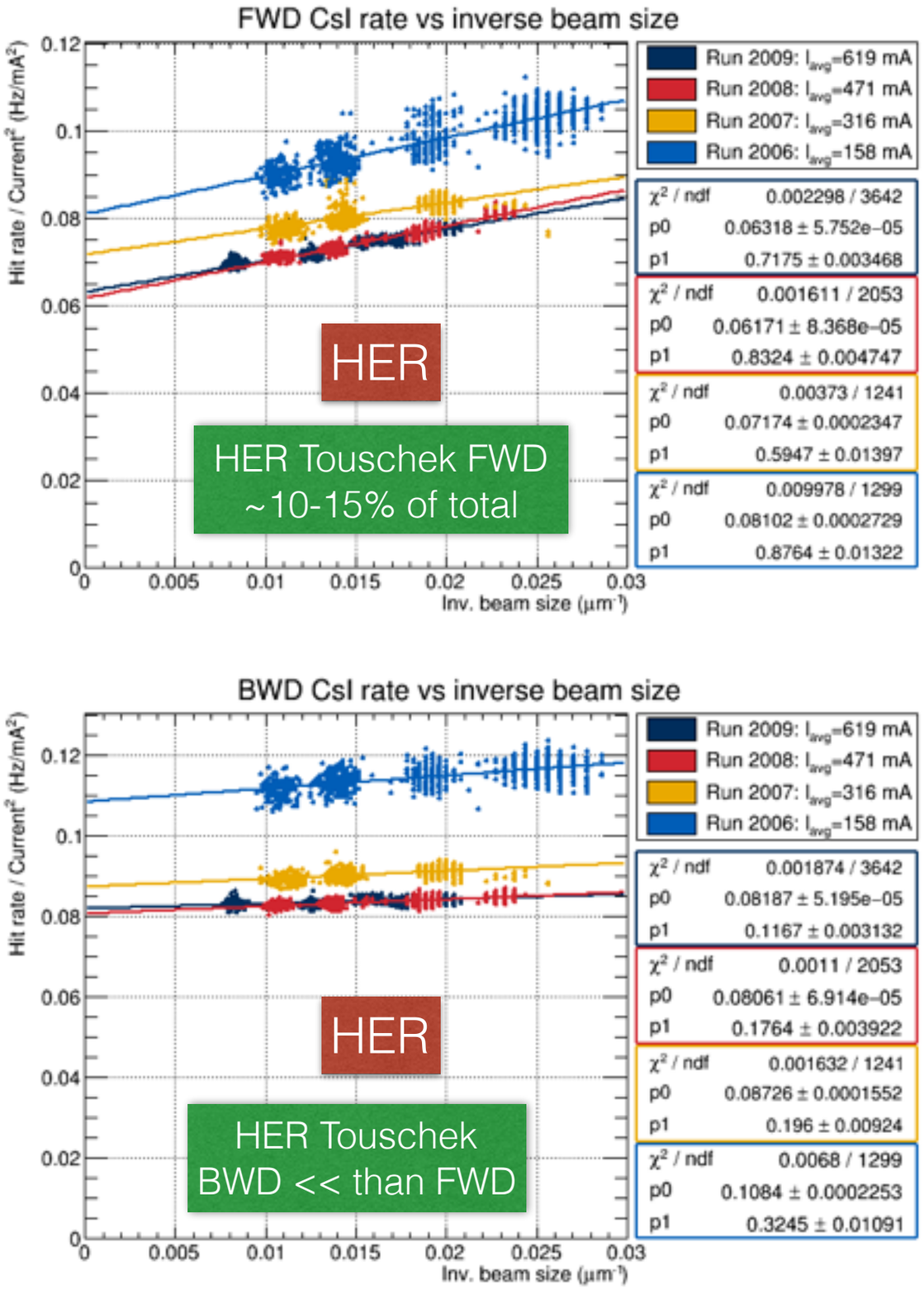
Linear term ∝ Touschek

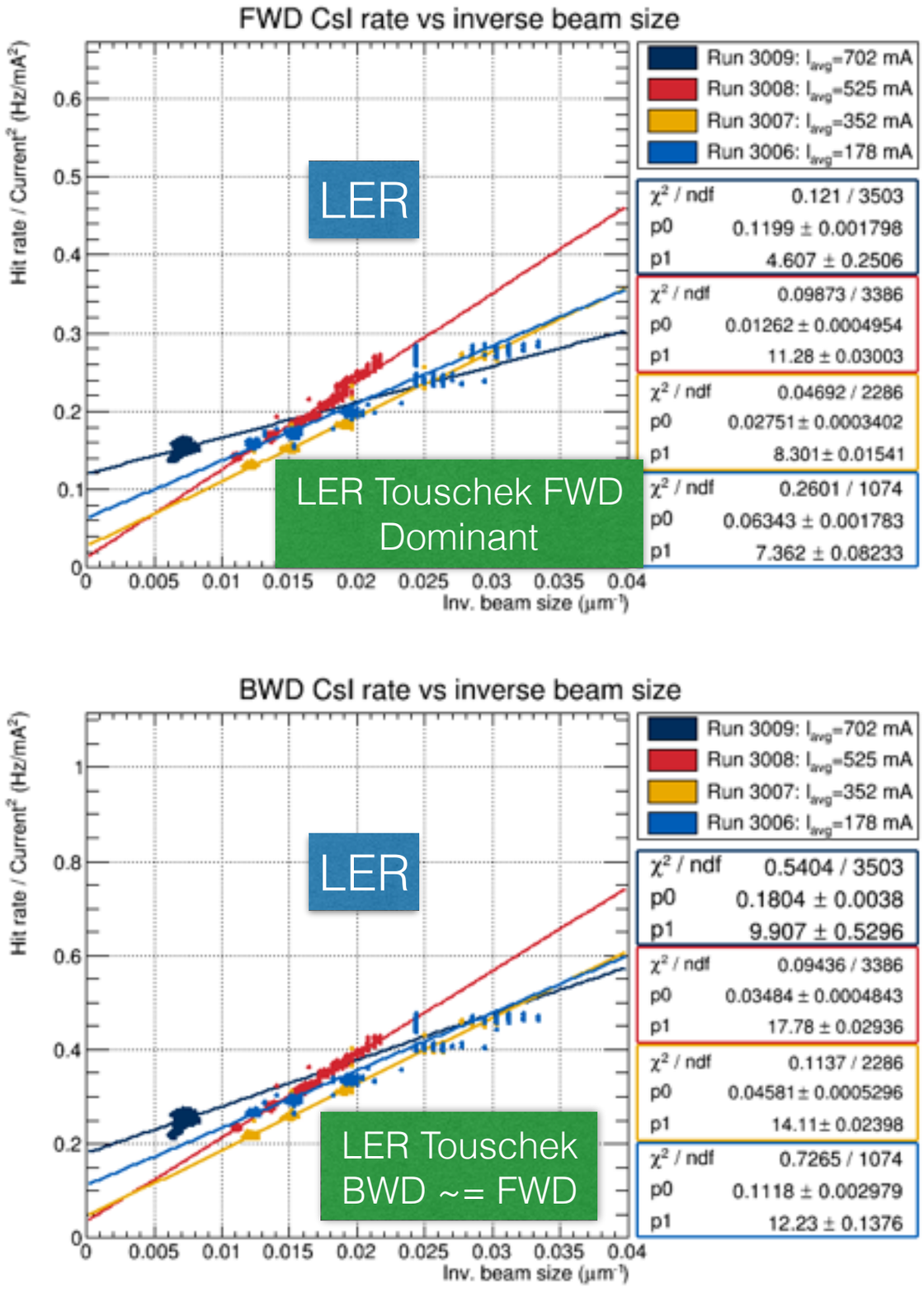
Constant term ∝ Coulomb

Touschek is:
~5% of total in CsI
~ 10% of total in LYSO



Touschek Study

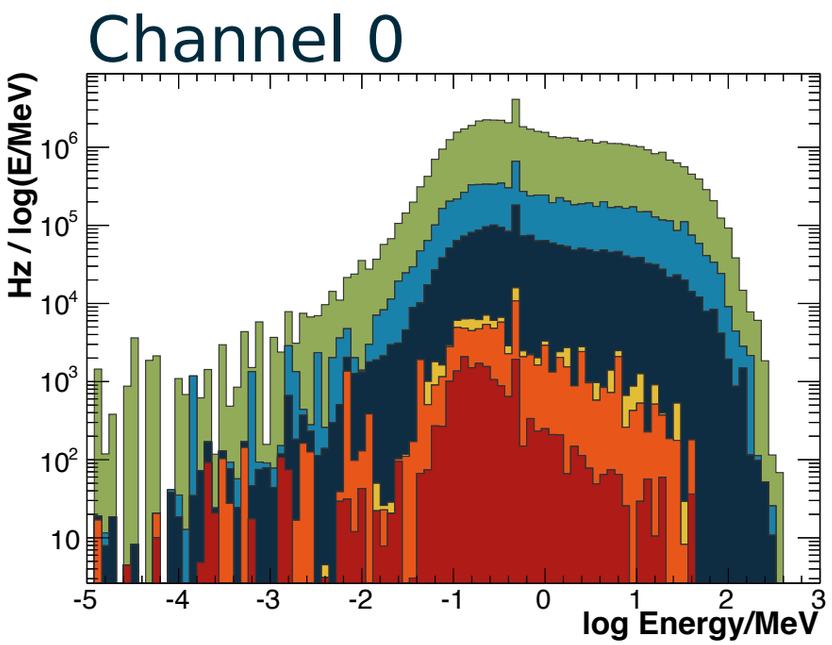


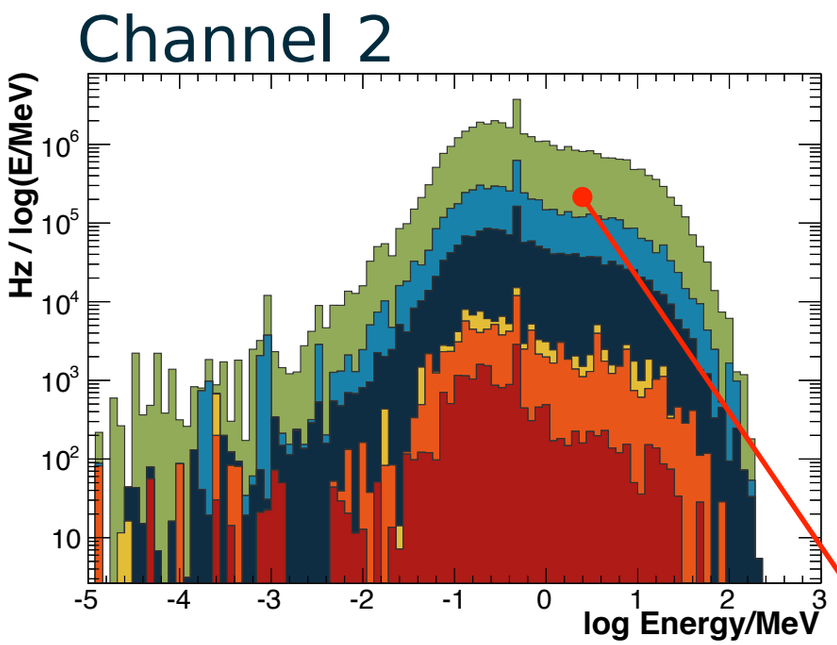


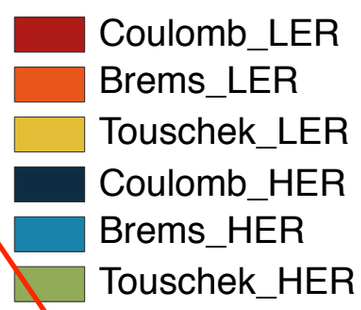
First Comparison w/MC prediction

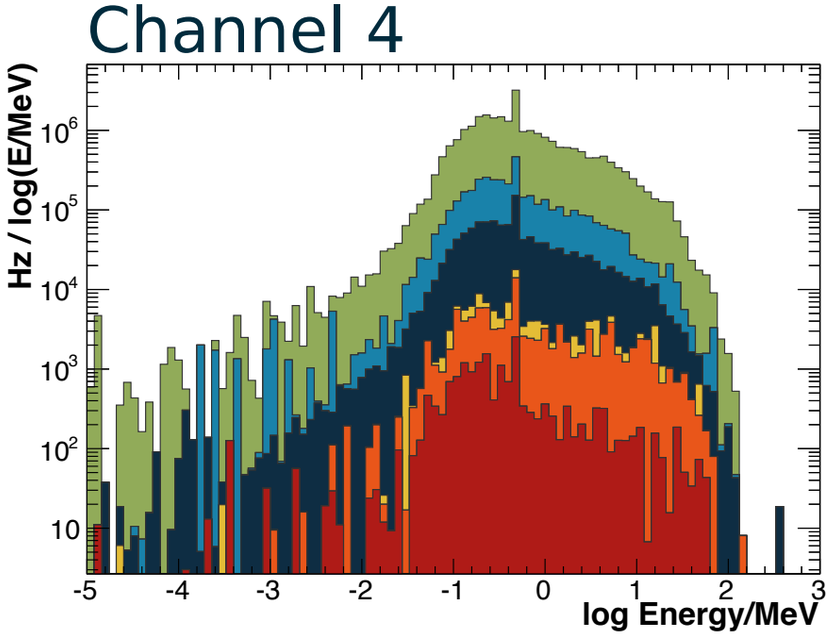
The expected background distributions II

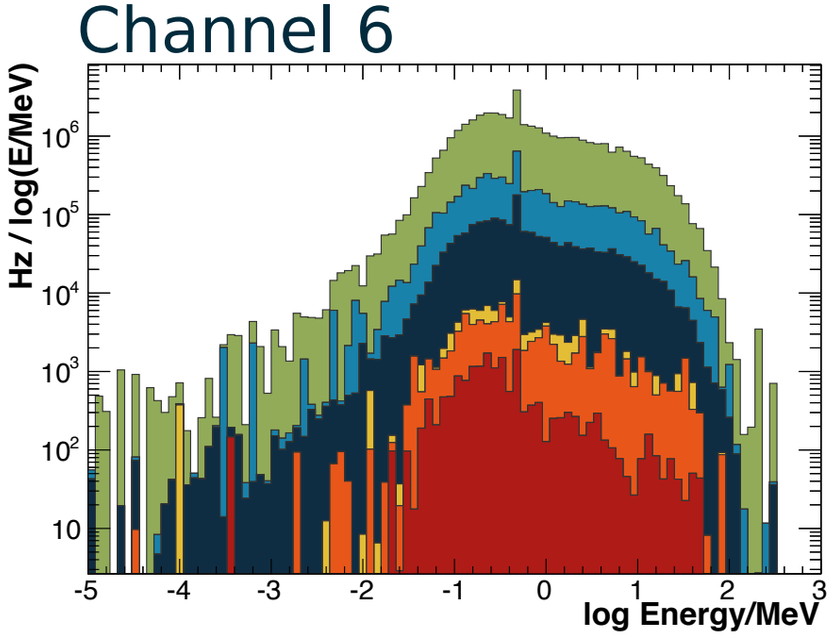
A. Beaulieu





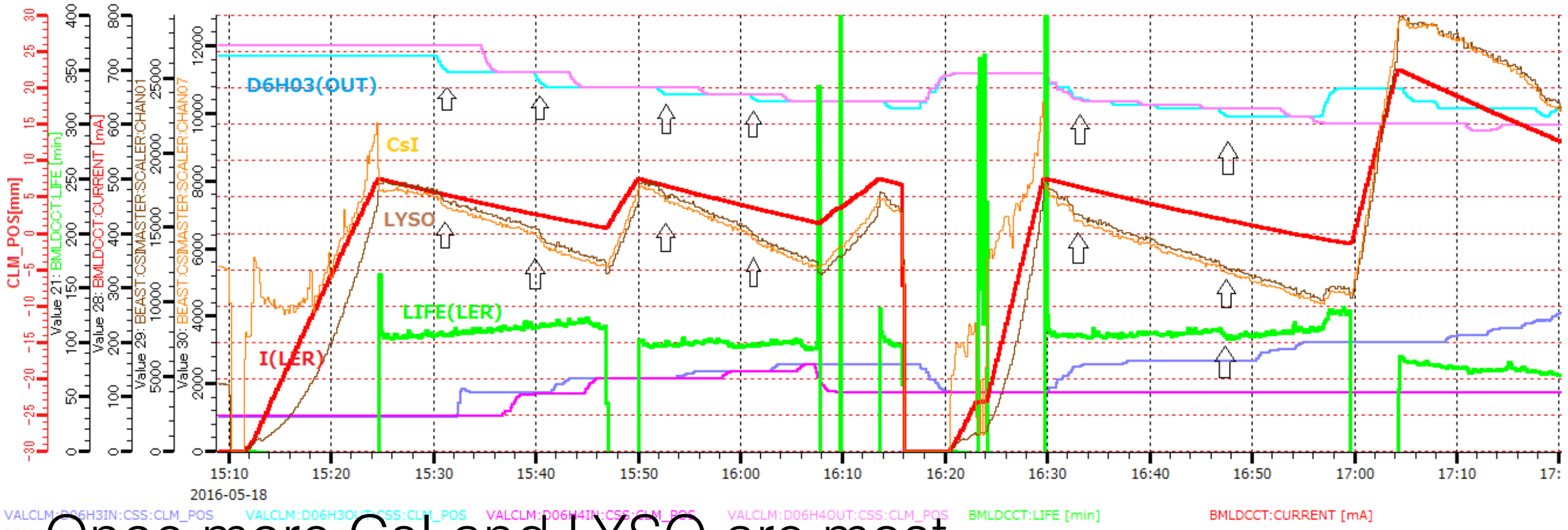






Touschek HER expected to be dominant, is ~10-15% of total in the data instead

LER Collimation Study



Once more CsI and LYSO are most sensitive BEAST detectors

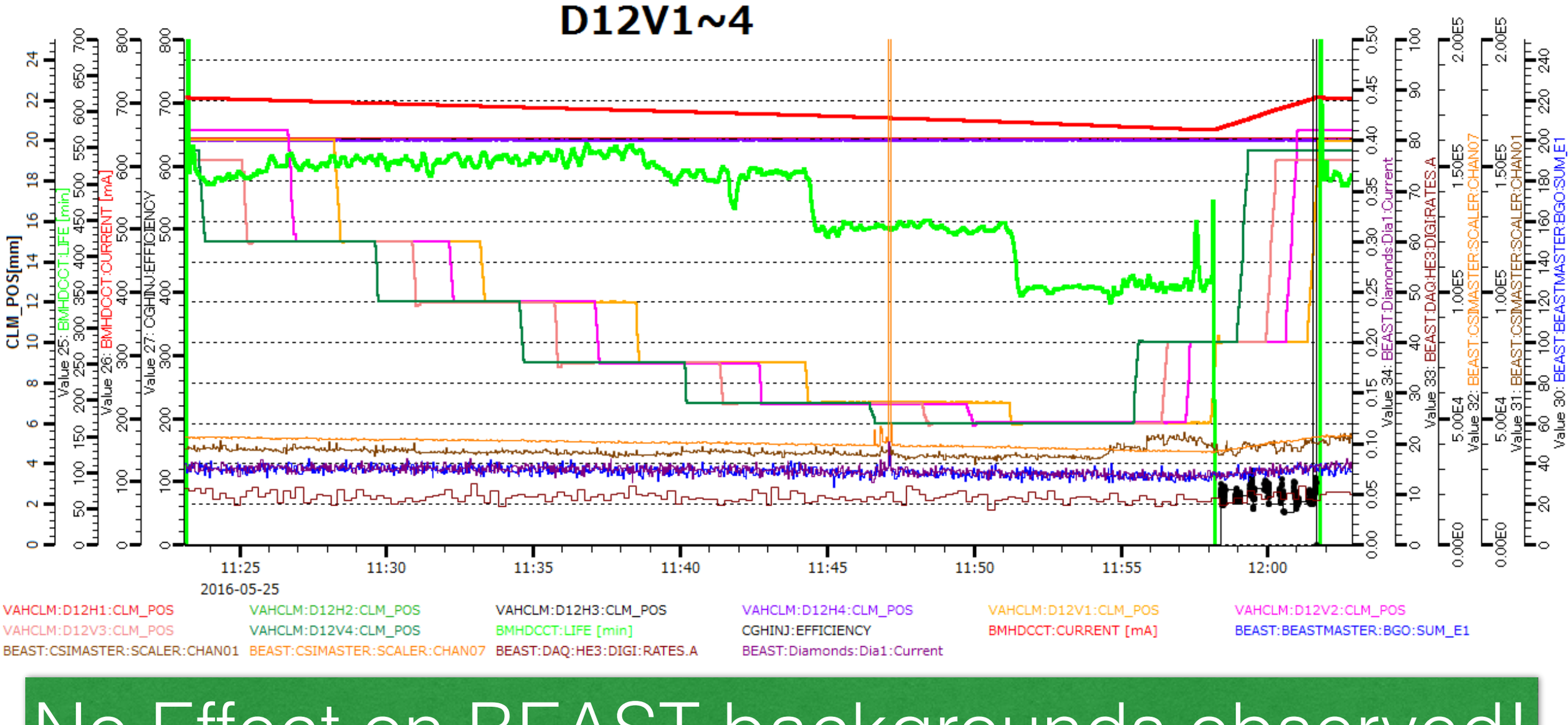
As we change D06H3OUT width from 24mm to 17mm,
LYSO/CsI BG shows step-like decrease at every time collimator get narrower.

<u>This is the clear evidence of BG suppression by the collimator!</u>

When we make it further narrower, from 17mm to 16mm at 16:48,
we observed beam life time decrease.
Which means this should be the minimum collimator width for D06H3OUT.

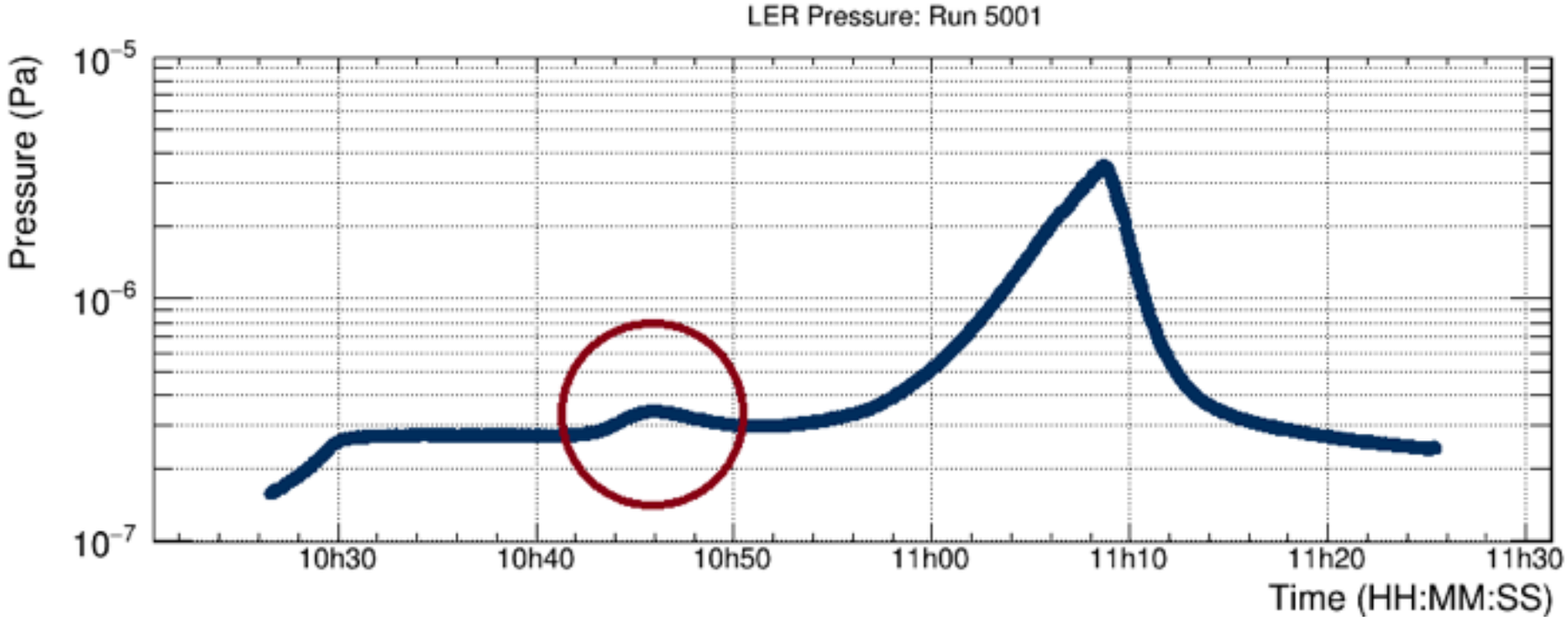
HER Collimation Study

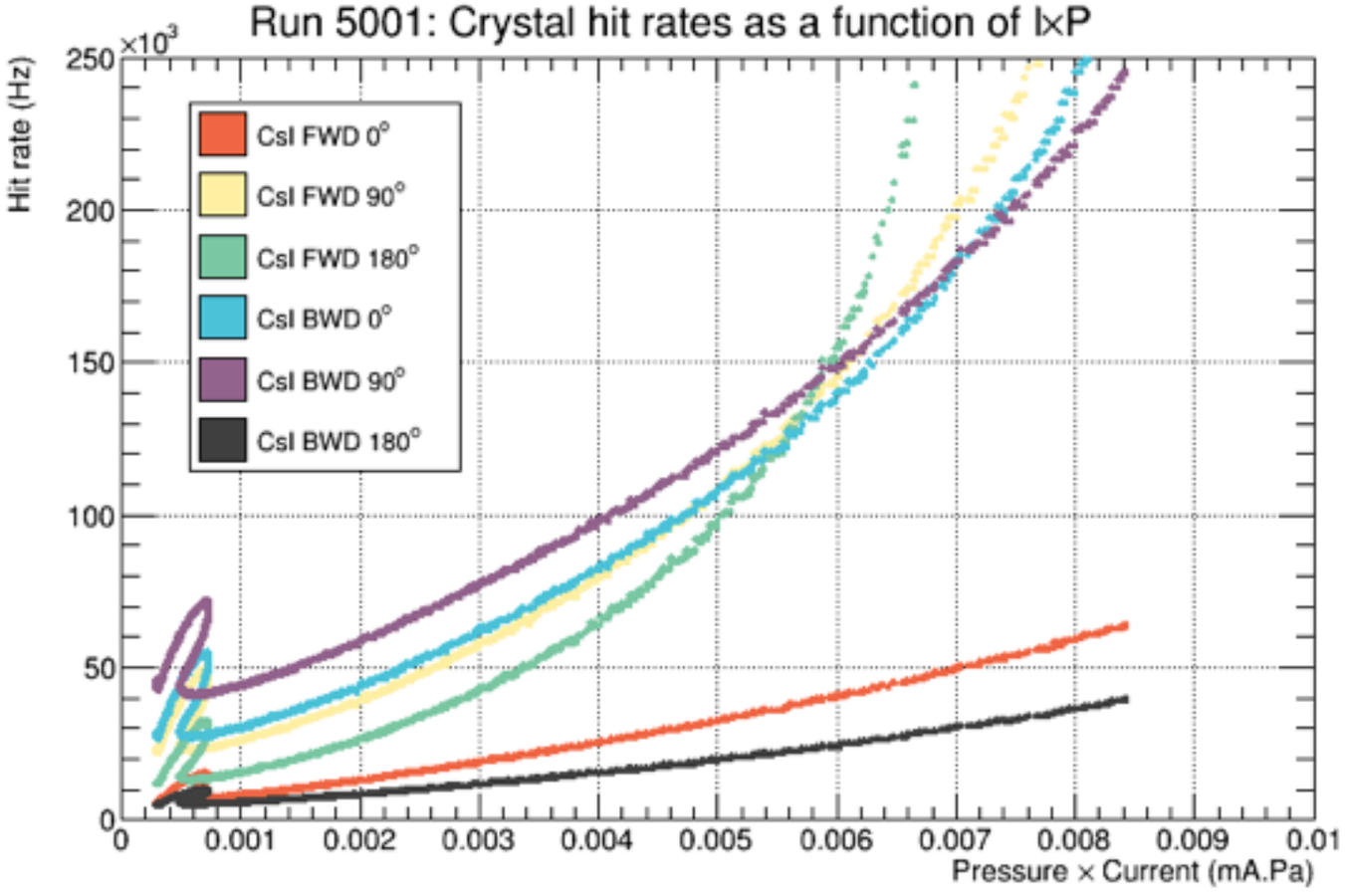
D12 Vertical



No Effect on BEAST backgrounds observed!

LER Pressure Bump

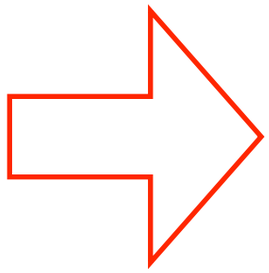




- Effect of the increase in pressure in the LER
- There is a dependence on the angle

Injection Background Study

Cosa vogliamo misurare?



9.4.4 Dead time during injection

SuperKEKB will operate with continuous injection (Ch. 2). For a brief interval after each injection pulse, the beam is excited and produces more background in the detector. Belle's DAQ copes with this by blocking triggers for about 4 ms after an injection pulse. However, at a 100-Hz injection in SuperKEKB, such a veto time would correspond to 40% dead time. To reduce this, the following veto scheme is proposed. The DAQ is blocked for $4\,\mathrm{ms} \pm 0.5\,\mu\mathrm{s}$ *for the injected bunch only,* as it is the most copious source of background. For the other bunches, the DAQ is blocked for a much shorter time of about 150 μs.
We have studied the feasibility of this scheme in Belle using a special run without the injection veto. A signal from the backward end-cap calorimeter was used to study the energy deposition during injection.

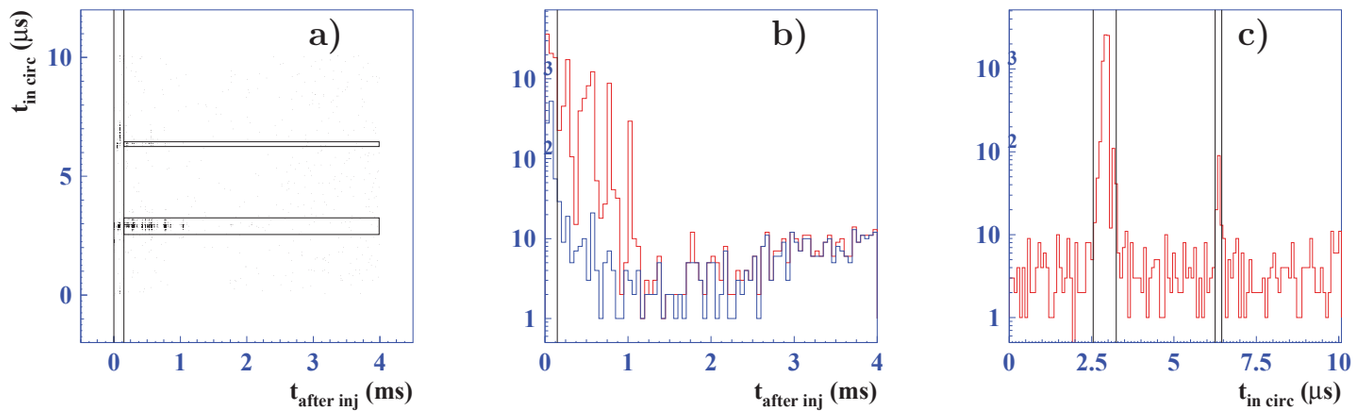


Figure 9.11: Trigger time distributions for LER injection. a) Scatter plot of time within a revolution period vs. time after injection. b) Time-after-injection distribution (red: all events; blue: excluding the two horizontal bands in (a)). c) Time-in-revolution distribution for $t_{\mathrm{after\ inj}} <$ 150 μs.

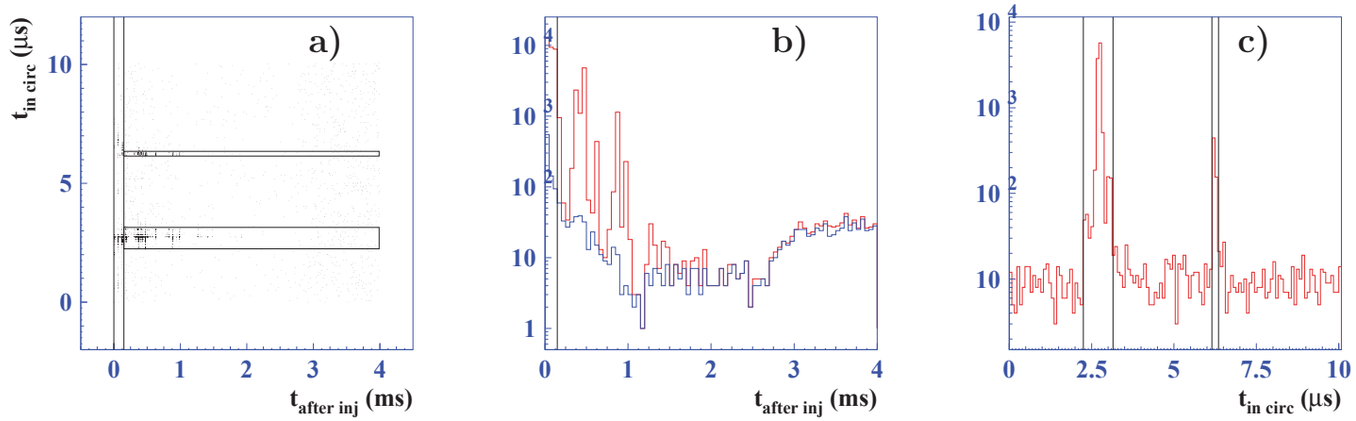


Figure 9.12: Trigger time distributions for HER injection. a) Scatter plot of time within a revolution period vs. time after injection. b) Time-after-injection distribution (red: all events; blue: excluding the two horizontal bands in (a)). c) Time-in-revolution distribution for $t_{\mathrm{after\ inj}} <$ 150 μs.

Figures 9.11 and 9.12 show the distributions of the trigger time within one revolution period

Injection Background Study with CsI and LYSO

- The DAQ was modified for this study
  - The scaler time base changed from 100 ms to 3 μs, and its acquisition has been gated for 5 ms, in synchronism with the injection signal and the acquisition of the digitisers
  - The digitisers' time window changed from 10 to 1 ms to reduce bandwidth and alleviate missing hits problem due to asynchronous acquisition
- With these modifications, the rate of hits as a function of time could be measured with the scalers (3 μs bins) for 5 ms after injection and with the digitisers at 2 ns time resolution for the first 1 ms after injection

Measurement Program

- Vary relevant injection parameters and measure backgrounds in BEAST, separately for LER and HER
  - **Injection phase shift**
    - (LER) RFLMO:PHASESHIFT_SET
    - (HER) RFHMO:PHASESHIFT_SET
  - **Vertical steering angle**
    - (LER) BTePS:VM27E:KRB, BTePS:VM28E:KRB
    - (HER) BTpPS:VM32P:KRB, 2BTpPS:VM33P:KRB
- **Septum angle** (Horizontal steering)
  - (LER) CGLNJ:SEPTUM:ANG_R
  - (HER) CGHNJ:SEPTUM:ANG_R

LER

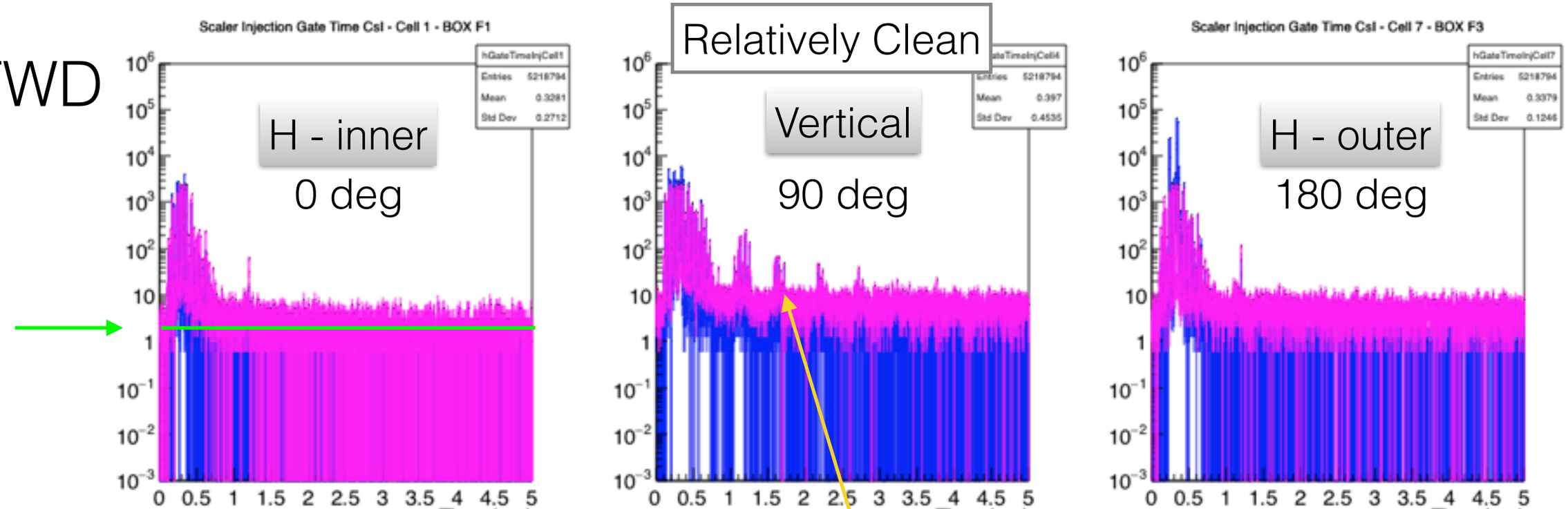
Parameter Tables LER

LER Parameter	Nominal RUN 14	RUN 3	RUN 6	RUN 17
Phase Shift	1°	**31°**	1°	1°
Vertical Steering Angle 1	-0.378 mrd	-0.378 mrd	-0.378 mrd	1°
Vertical Steering Angle 2	0.12 mrd	0.12 mrd	**0.043 mrd**	0.12 mrd
Septum Angle	5.51 mrd	5.51 mrd	5.51 mrd	**5.31 mrd**
Injection Efficiency	95%	70%	75%	60%
Current Ramp (mA)	0-400	200-500	200-500	0-200

Magenta= LYSO
Blue = CsI

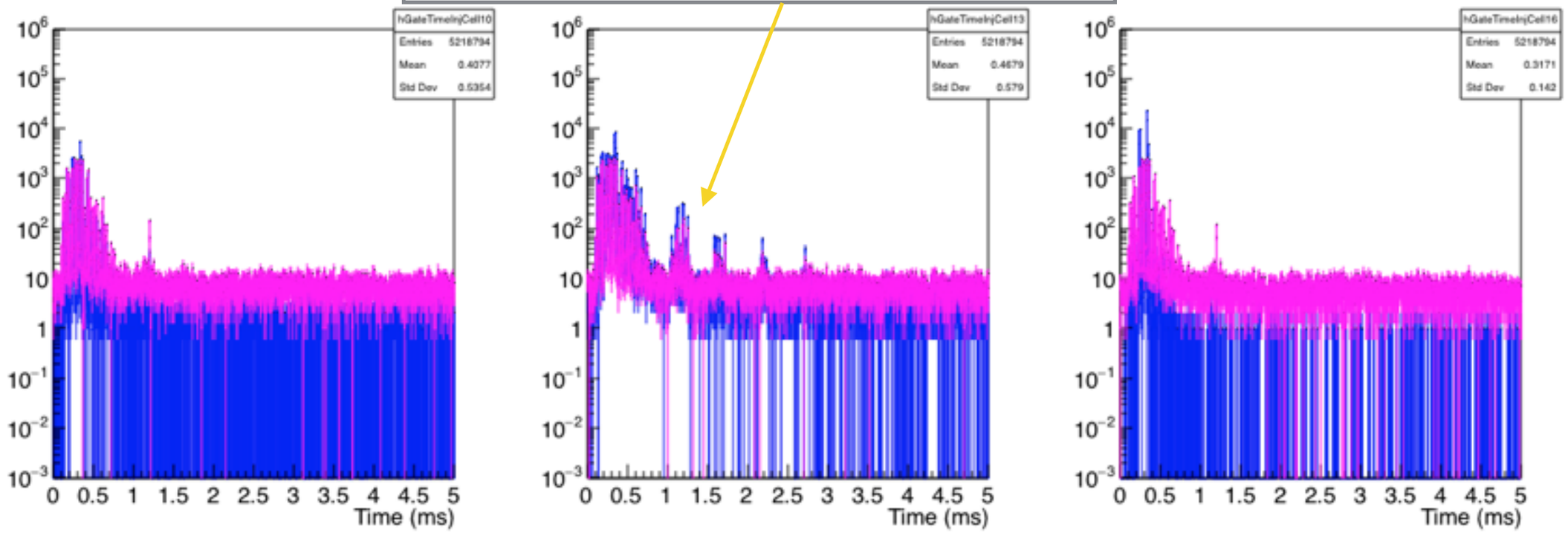
RUN 14 - Reference 95% Inj Eff.

FWD



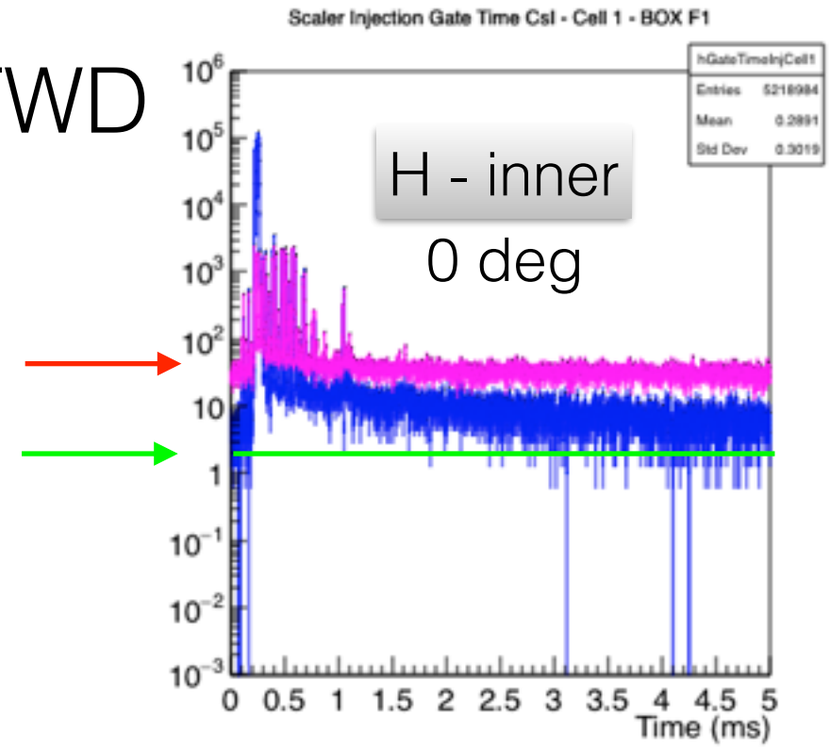
Synchrotron oscillations are visible

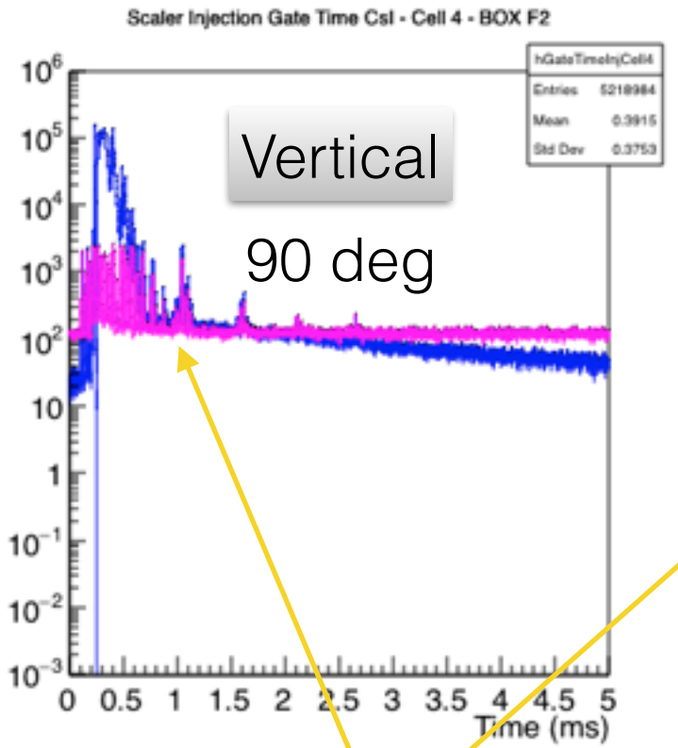
BWD

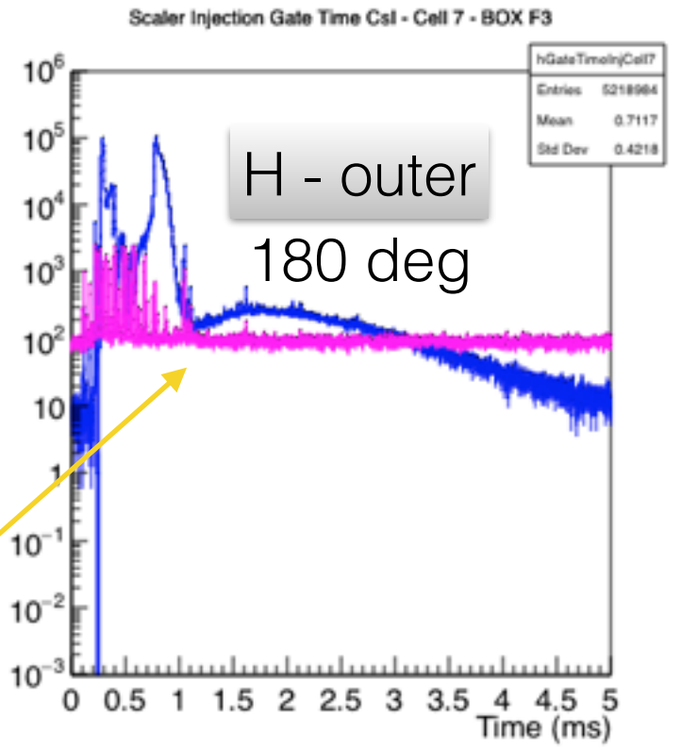


RUN 3 - Phase Shift 31deg - ~70% Inj Eff.

FWD

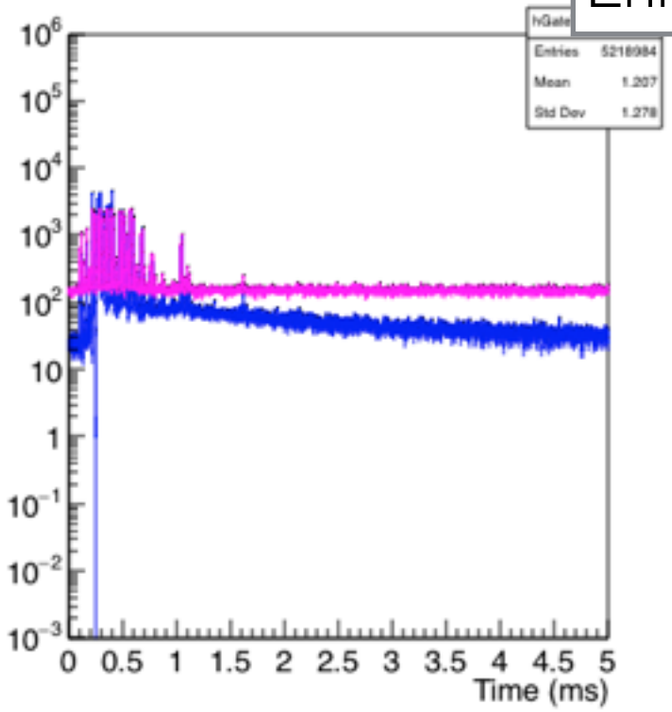


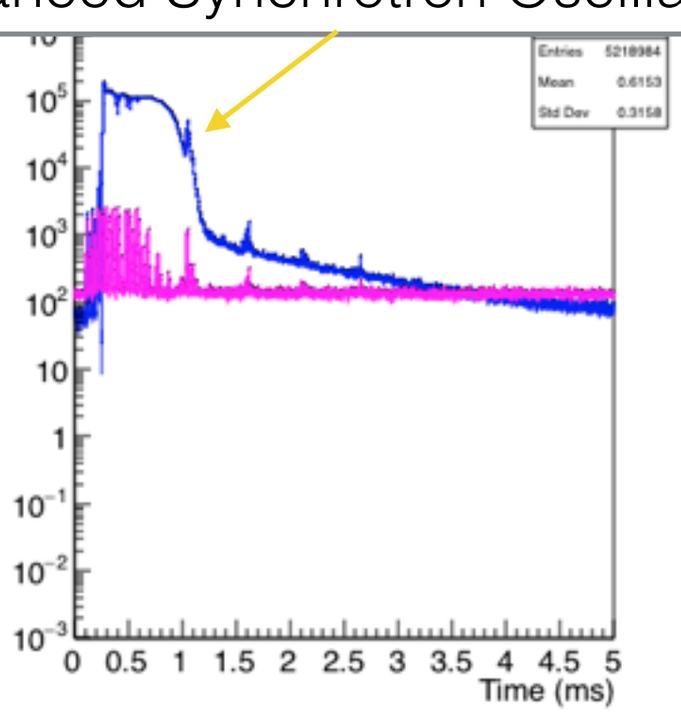


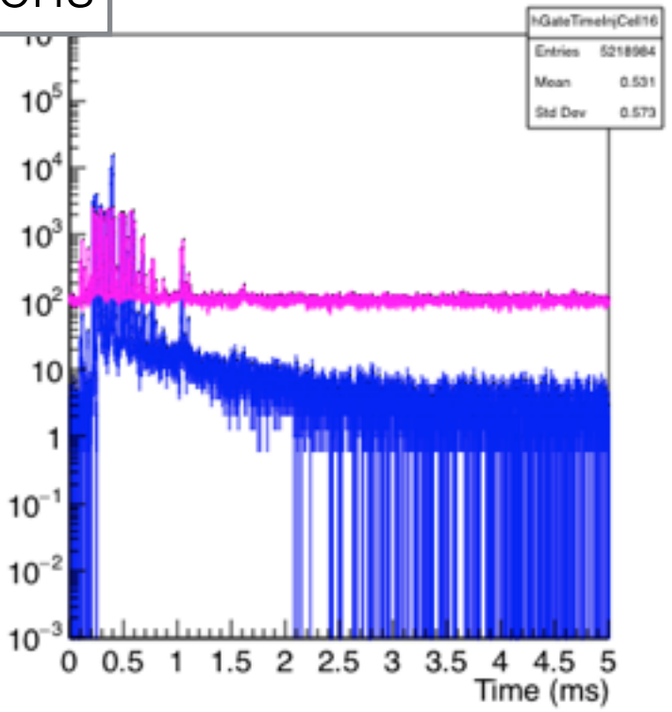


Enhanced Synchrotron Oscillations

BWD

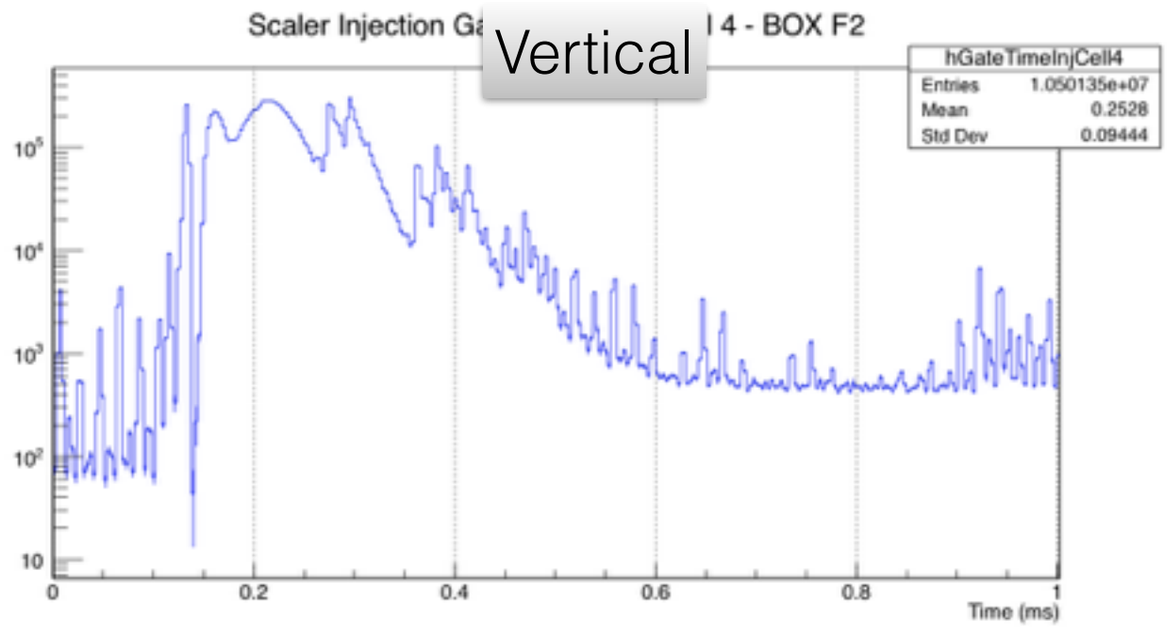




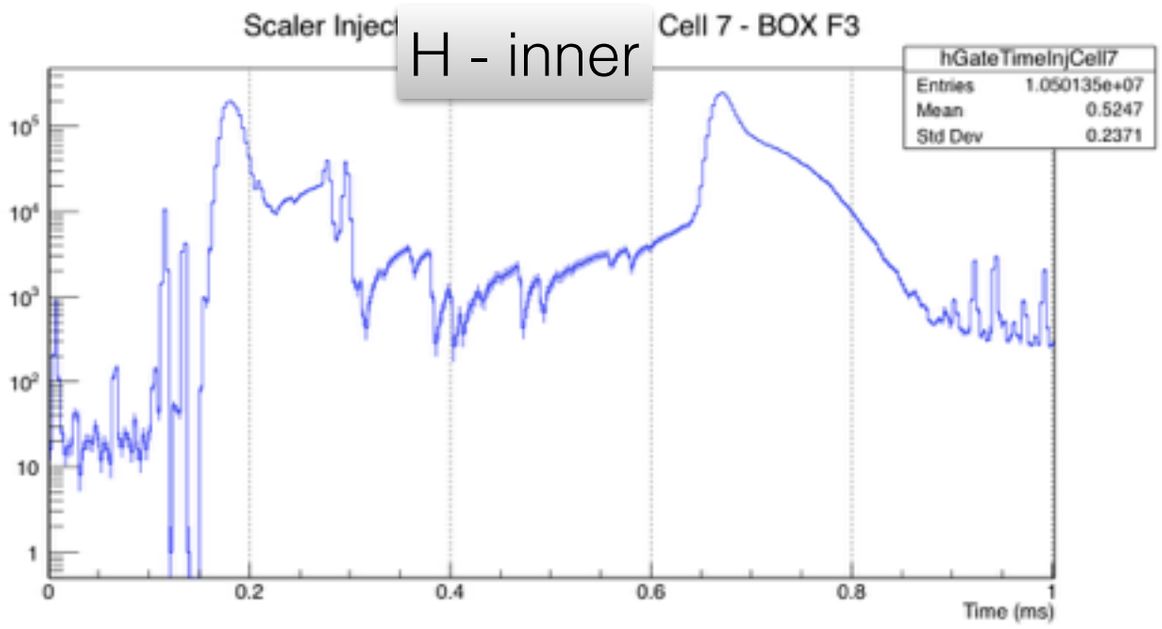


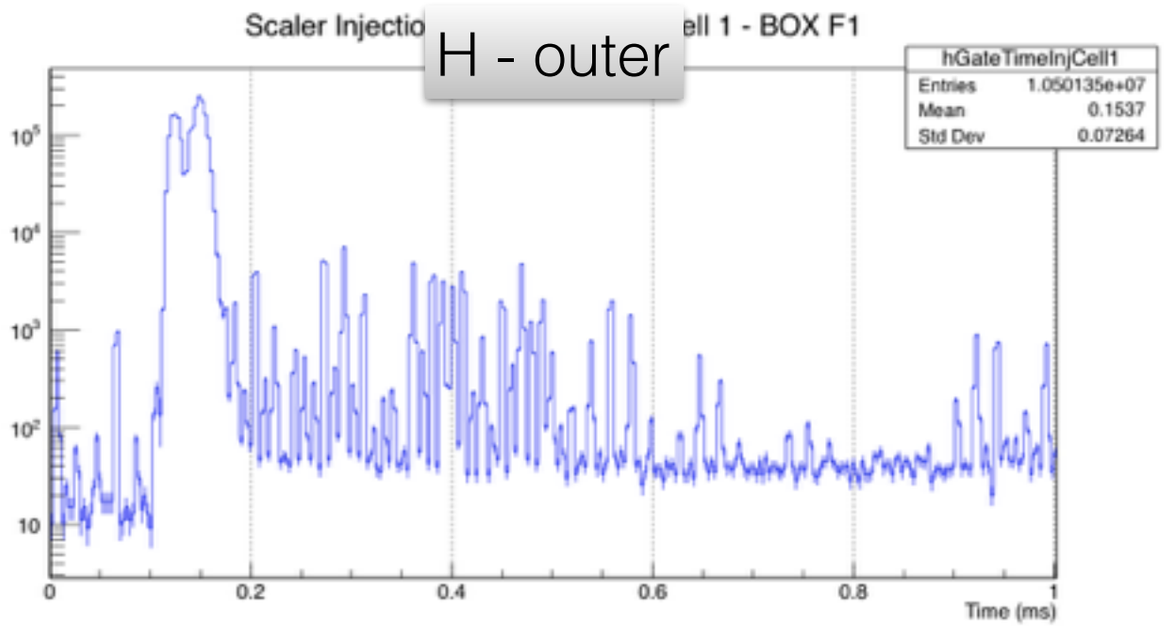
RUN 3 - Phase Shift 31deg - ~70% Inj Eff.

Zoom
0-1ms



Forward





Big activity within the first ms

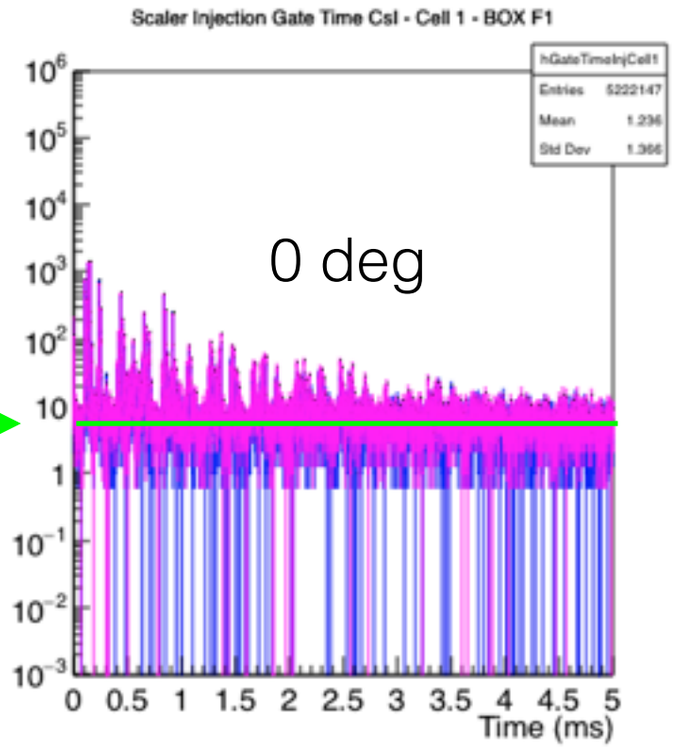
HER

Parameter Tables HER

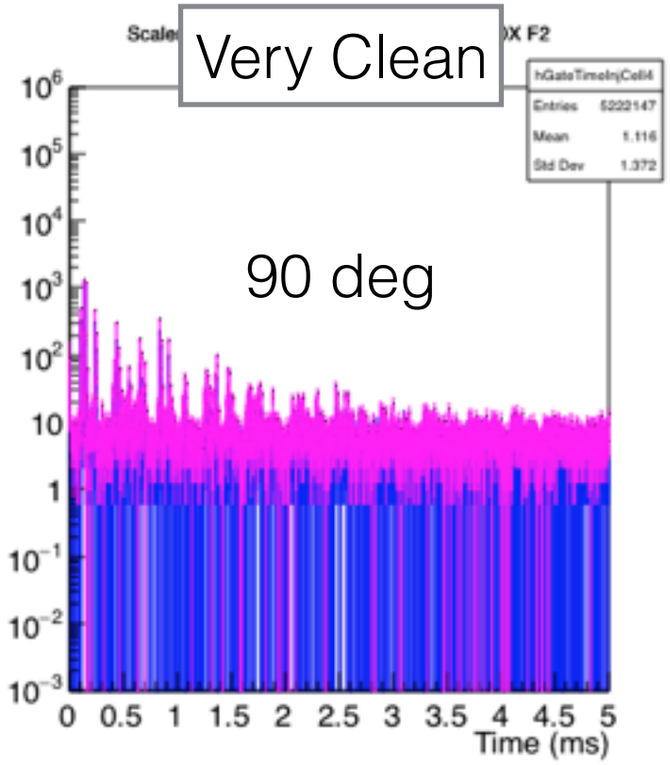
HER Parameter	Nominal RUN 10	RUN 9	RUN 12	RUN 13
Phase Shift (degrees)	258°	**305°**	258°	258°
Vertical Steering Angle 1 (mr)	-0.385	-0.385	**-0.465**	**-0.435**
Vertical Steering Angle 2 (mr)	0.08	0.08	0.08 mrd	0.08 mrd
Septum Angle (mr)	2.35	2.35	2.35 mrd	2.35 mrd
Injection Efficiency	95%	50%	25%	50%
Current Ramp (mA)	0-150	150-400	200-300	300-450

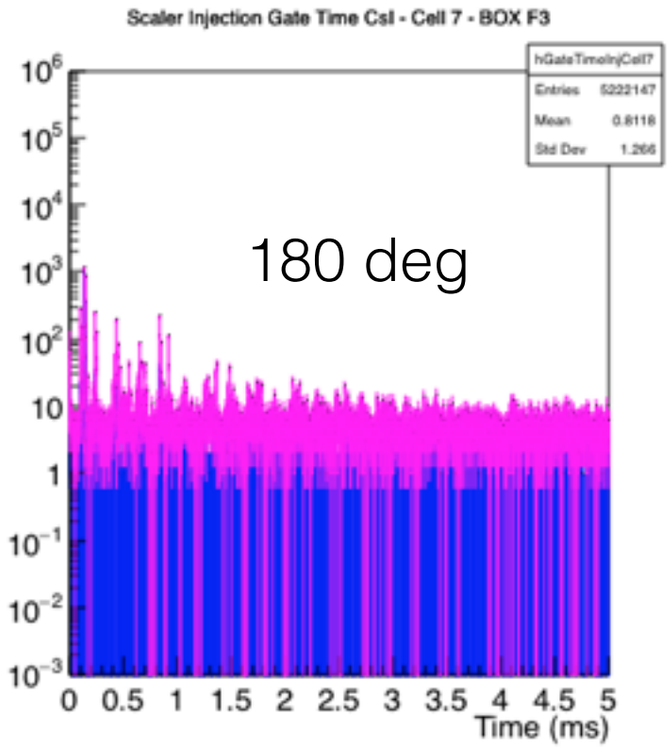
Run 10 - Reference - 95% Inj Eff.

FWD

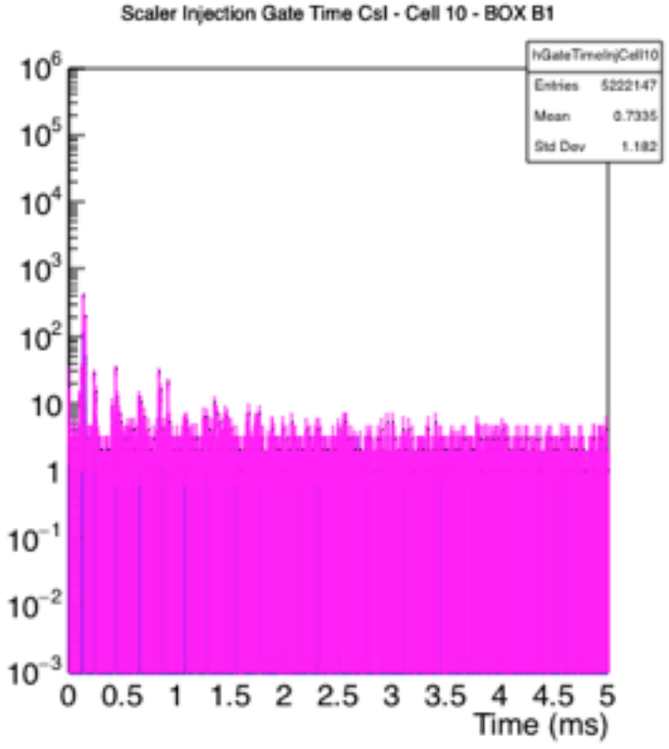


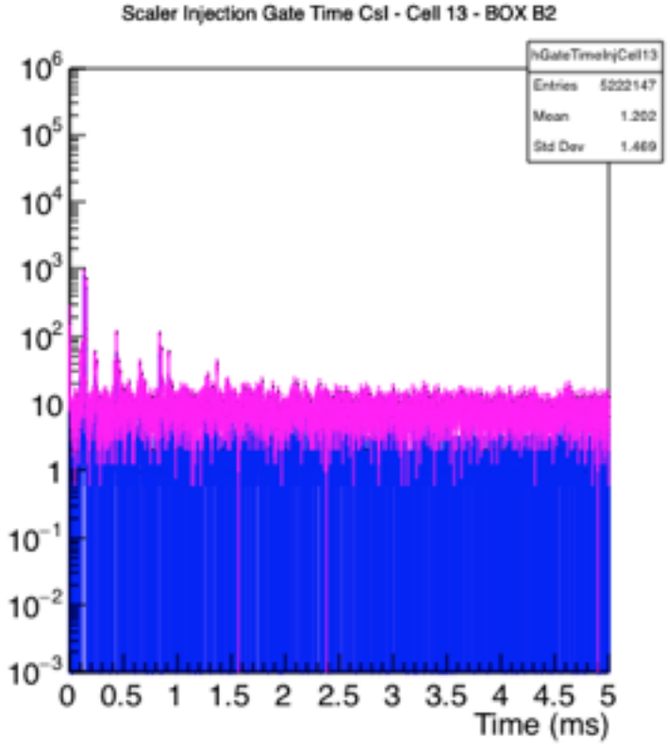
Very Clean

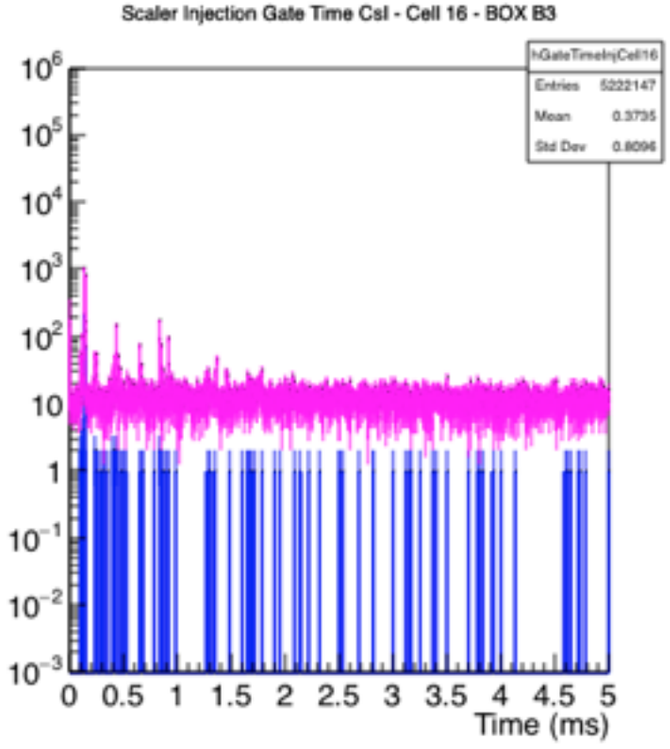




BWD



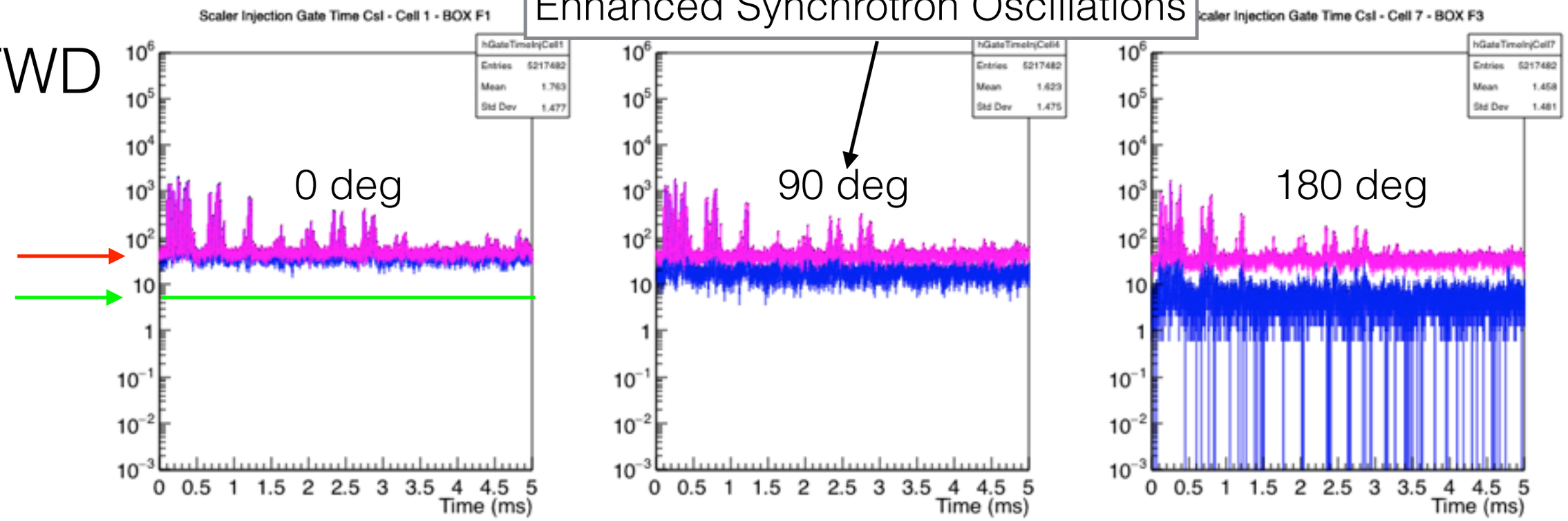




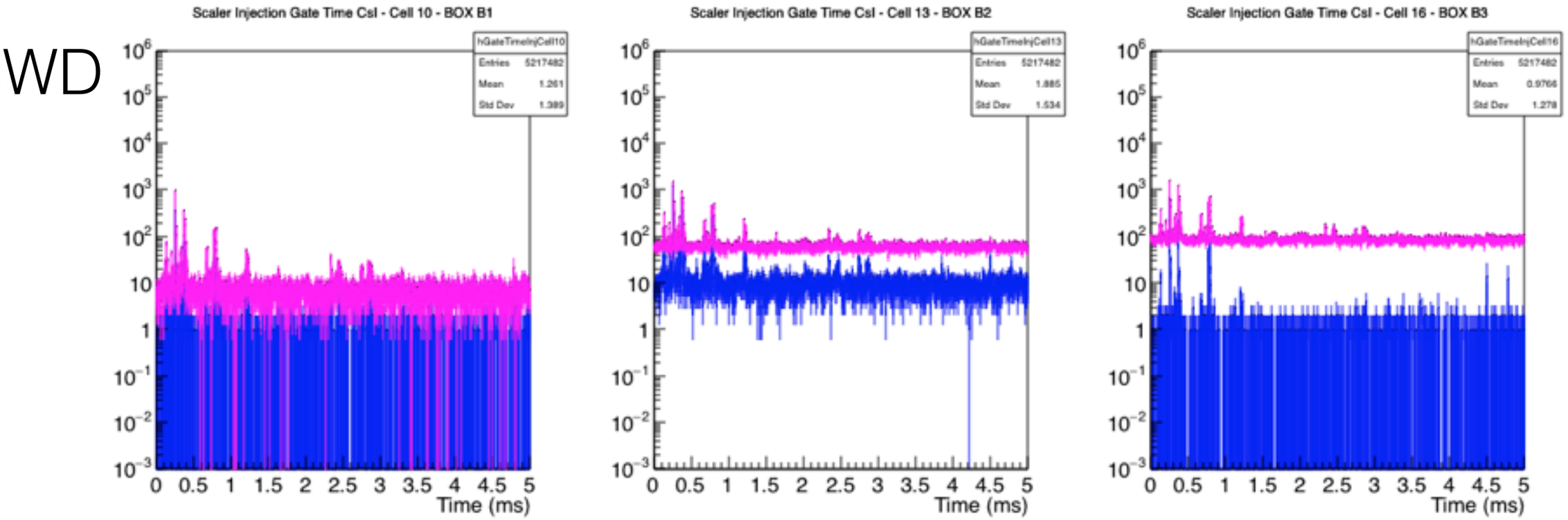
RUN 9 - Phase Shift 305 deg - 50% Inj Eff.

Enhanced Synchrotron Oscillations

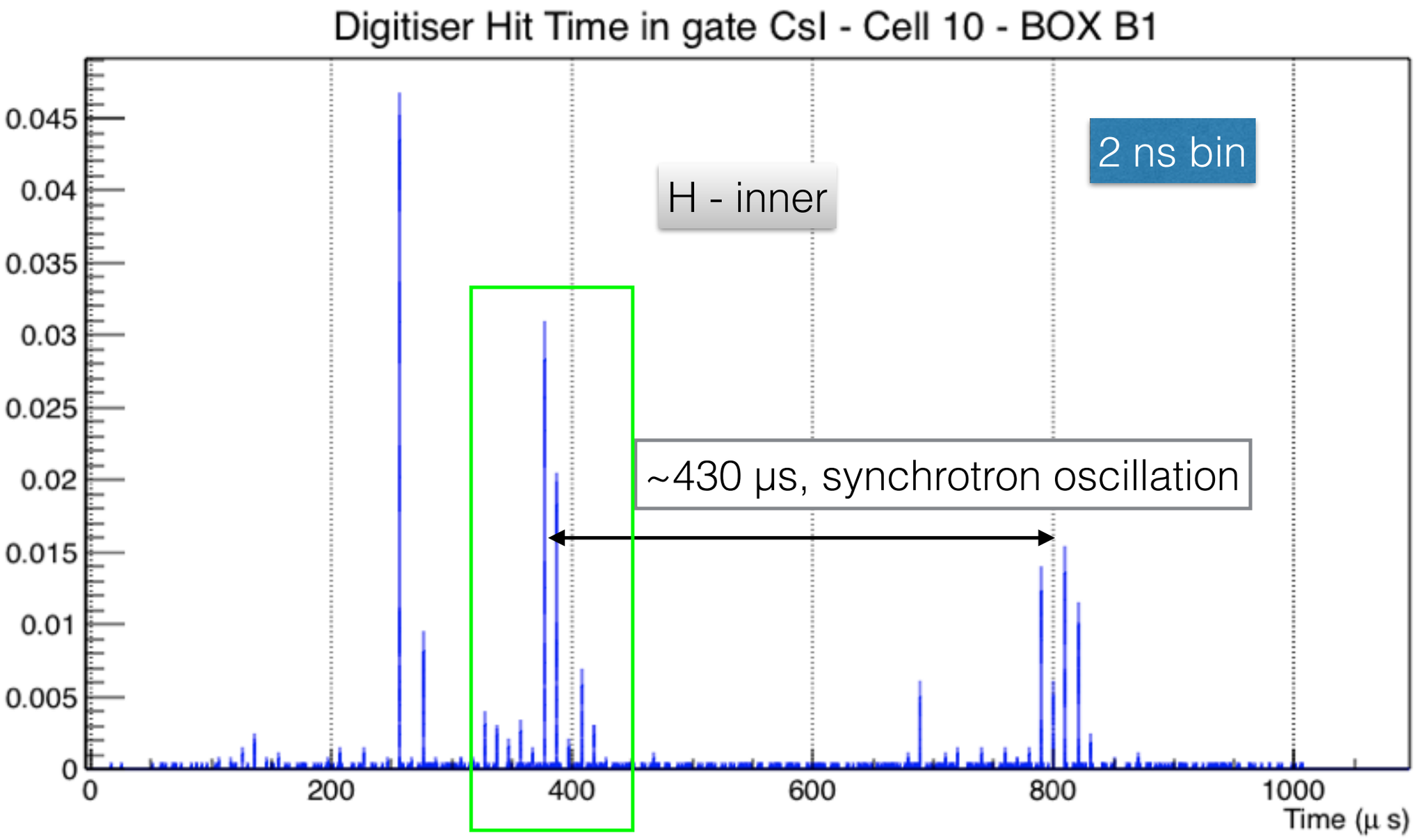
FWD



BWD

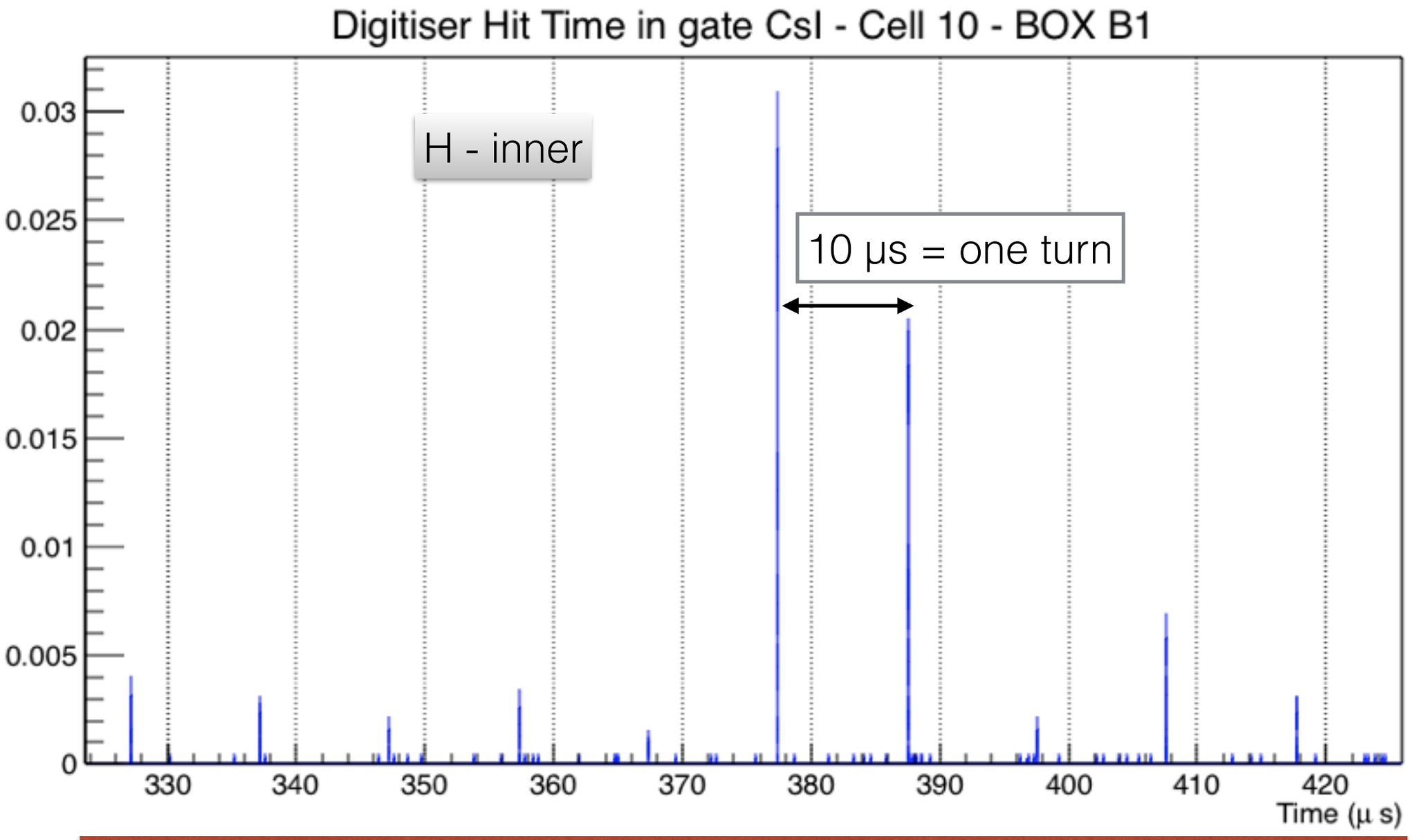


RUN 9 - Digitiser HER Data



Exploit digitiser data taken with 2 ns resolution
Zoom in!

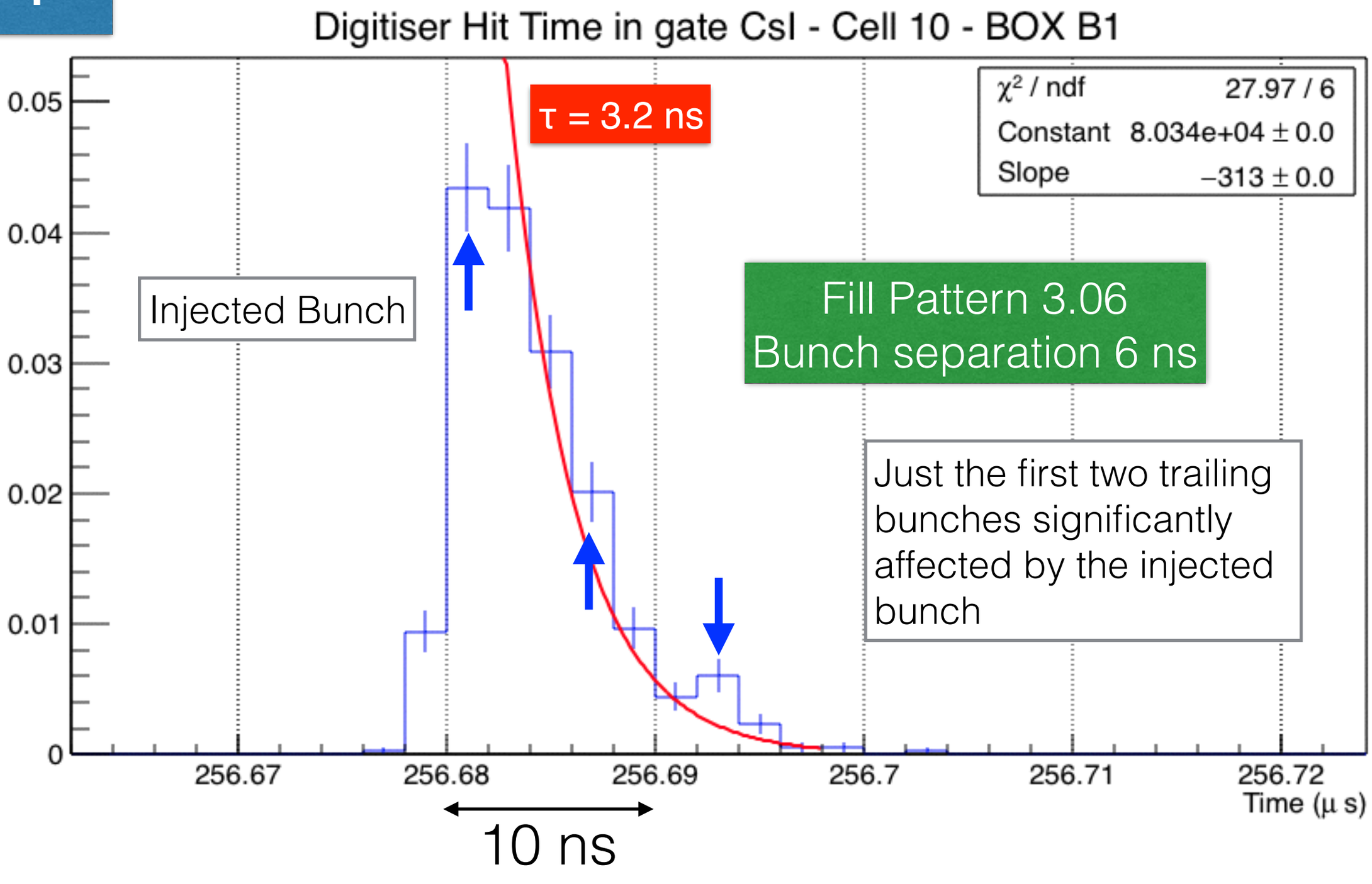
RUN 9 - Digitiser HER Data



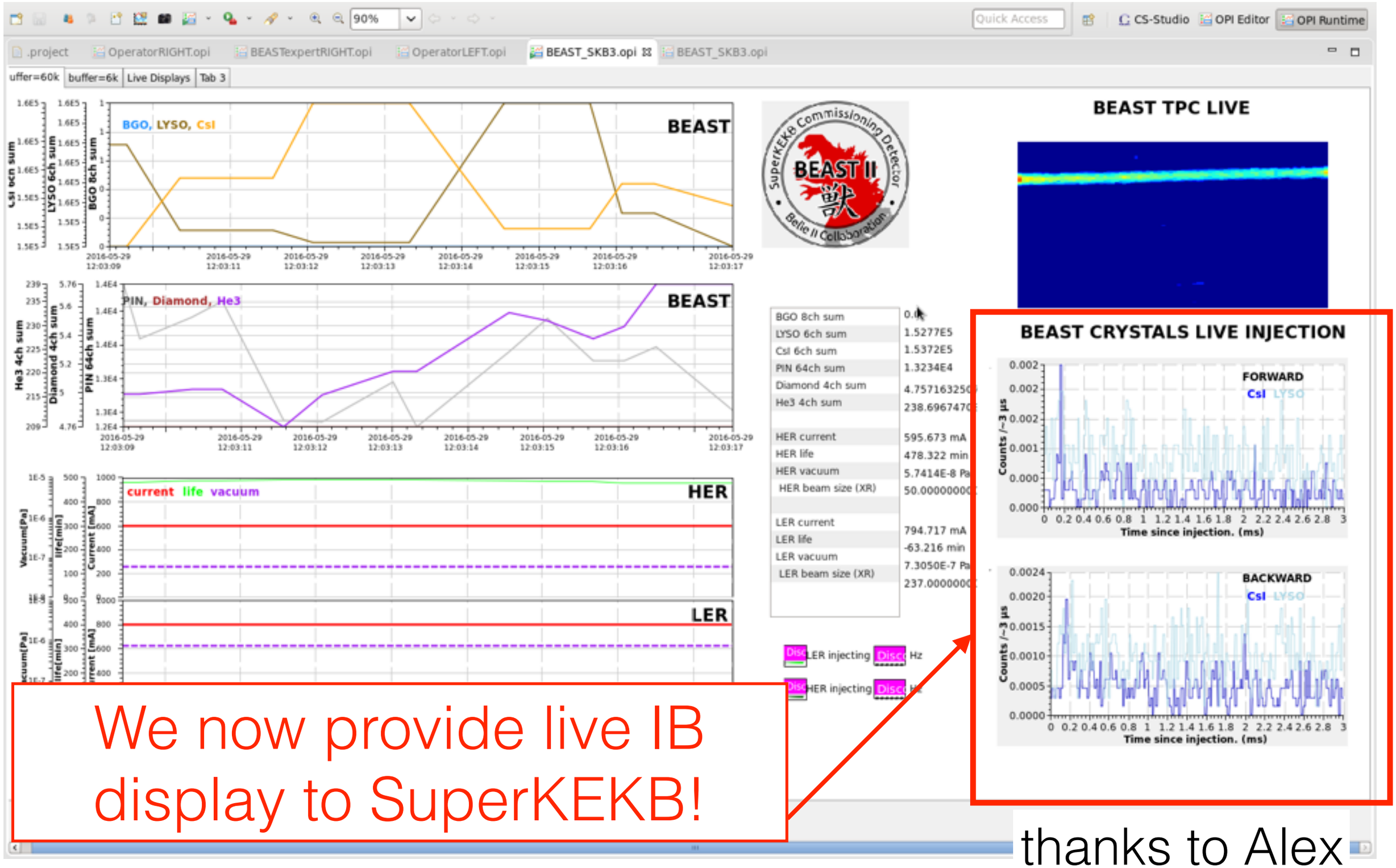
Exploit digitiser data taken with 2 ns resolution
Zoom to single bunch!

RUN 9 - Zoom in to Single Bunch

1



Last but not least…



We now provide live IB display to SuperKEKB!

thanks to Alex

Summary

- The CsI crystal system is performing well
- Background measurements have been performed
  - Coulomb
  - Touschek
- Several studies have been carried out
  - Collimation
  - Vacuum bumps
  - Number of bunches
- Injection backgrounds have been measured in great details and unique measurement of injection performances provided to the SKB control room