RESULTS FROM BEAST

Chiara La Licata
on behalf of Univ. & INFN Trieste
JENNIFER WP2 - INFN Belle 2

Outline

- BELLE 2 and SuperKEKB

- SuperKEKB Schedule
  > BEAST phase I

  > BEAST phase II

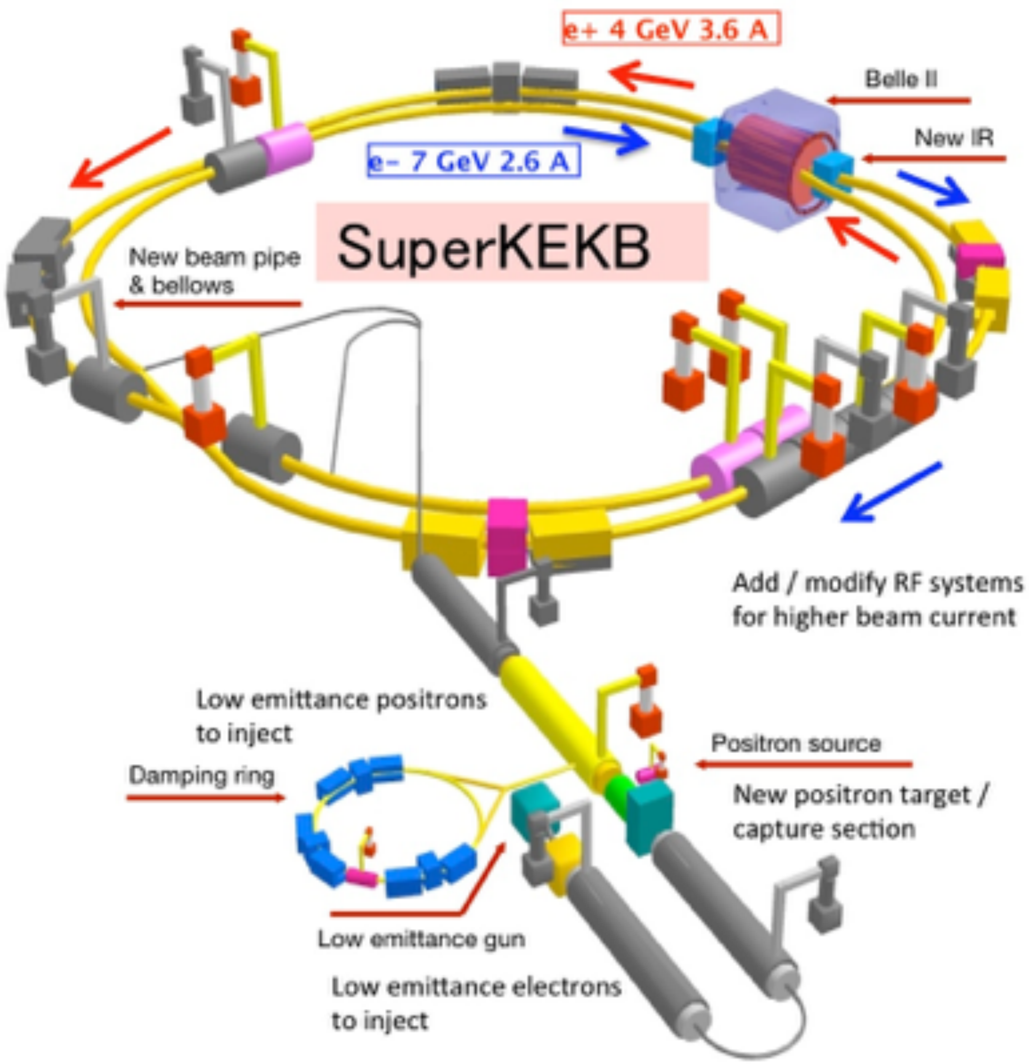
  > BEAST phase III

- Results from BEAST phase I -> background studies
  > Touschek background

  > Beam - gas background

  > injection studies

SuperKEKB & Belle II

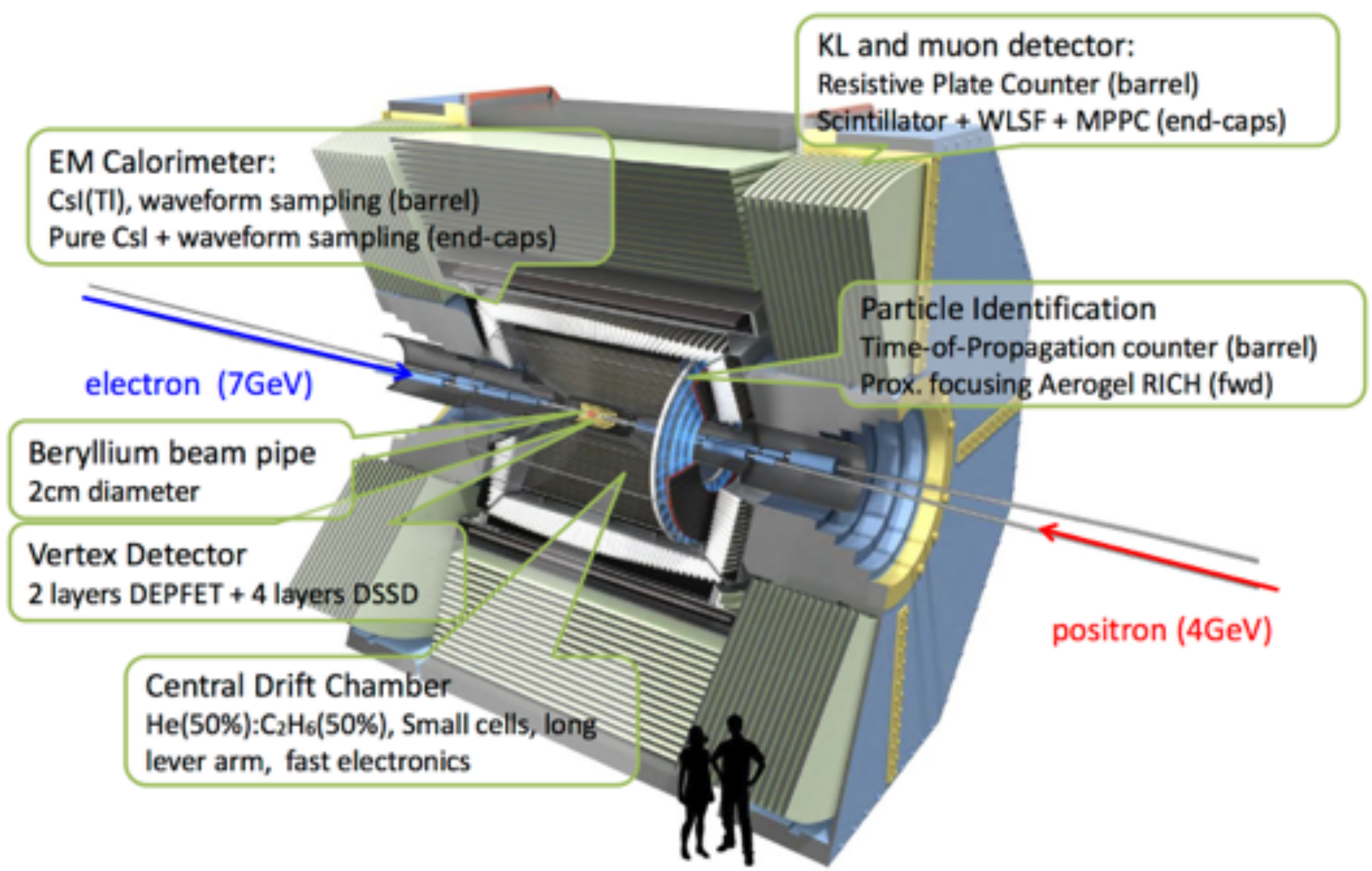


- Reduced beam spot size
- Doubled beam currents
- Larger crossing angle (2φ = 83 mrad)

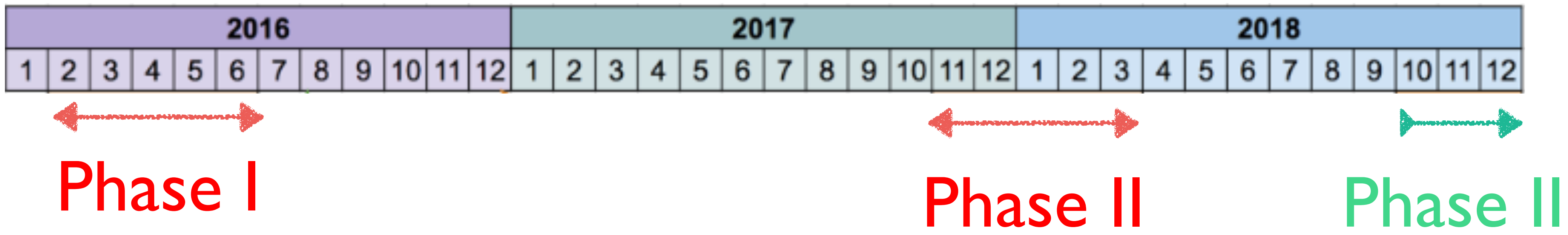
L_{peak}: 8×10^{35} $cm^{-2}s^{-1}$
L_{int}: $50 ab^{-1}$

$$L = \frac{\gamma_{\pm}}{2er_e}\left(\frac{I_{\pm}\xi_{y\pm}}{\beta^*_{y\pm}}\right)\left(\frac{R_L}{R_{\xi_y}}\right)$$

Belle II Detector



SuperKEKB commissioning schedule



Phase I

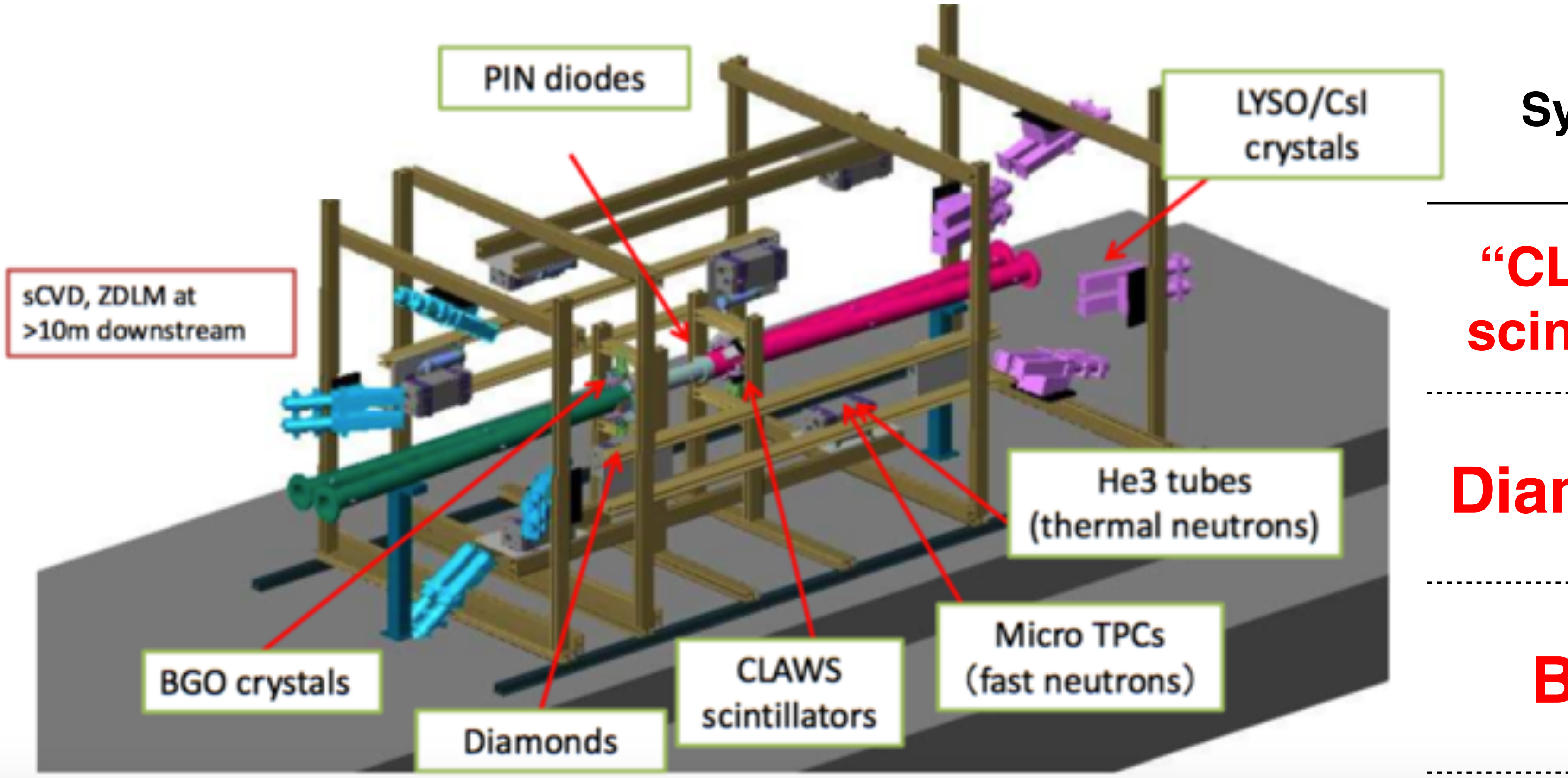
COMPLETED!

- Circulate both beam, no collision. Limited LER, HER beam currents (up to about 1 A)
- Optics study
- Vacuum scrubbing
- Beam backgrounds study

Phase II

- First collisions
- Beam abort development
- Tune accelerator optics
- other beam background studies

BEAST sensors



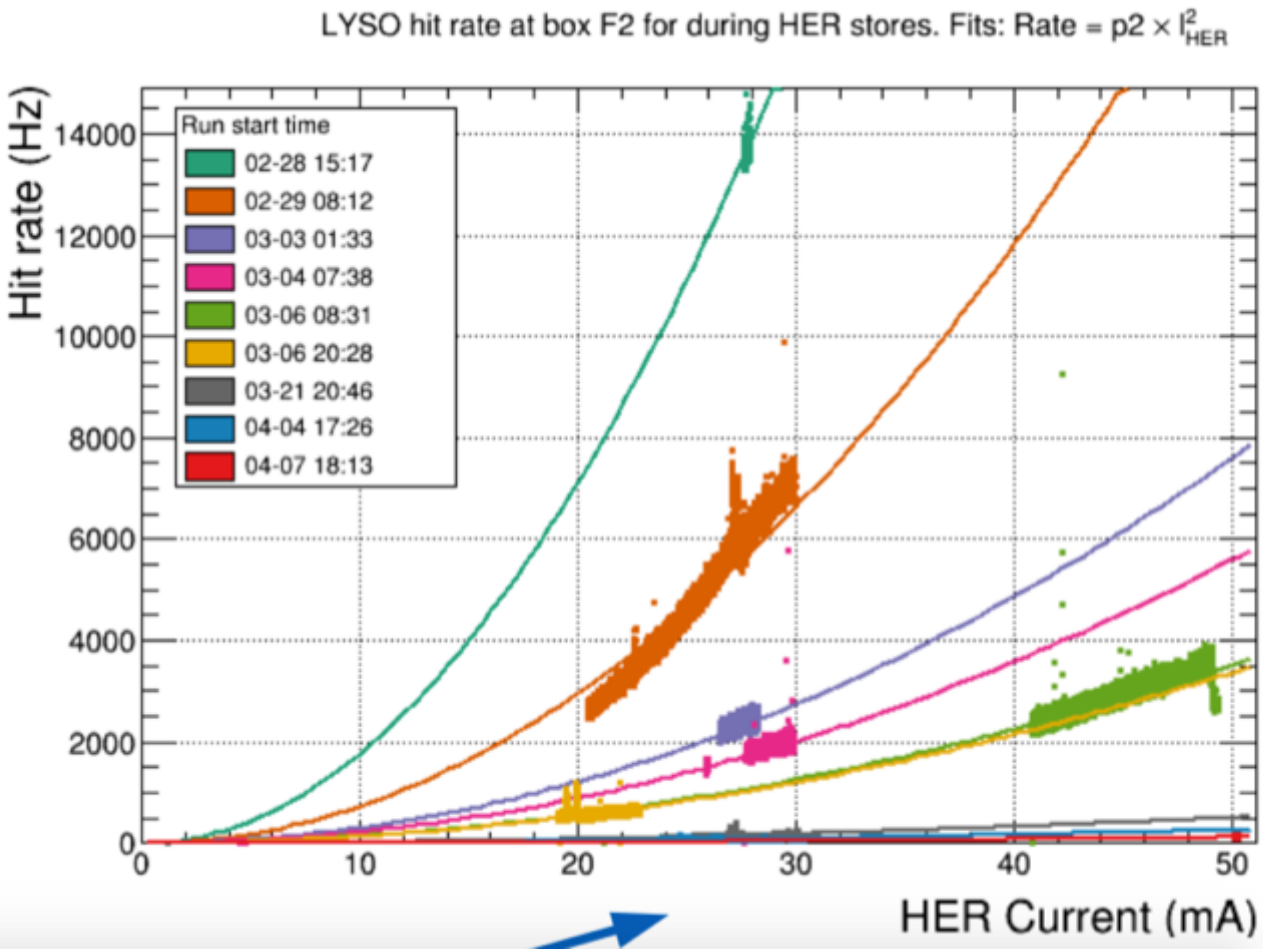
System	Detectors installed	Measurement
"CLAWS" scintillator	8	injection backgrounds
Diamonds	4	ionization dose
BGO	8	luminosity
Crystals	6 CsI(Tl) 6 CsI 6 LYSO	EM energy spectrum
He-3 tubes	4	thermal neutron flux
Micro-TPCs	2	fast neutron
PIN diodes	64	neutral vs charged radiation dose

- Since Background simulations have huge uncertainties: measurements near IP
- First measurements of SuperKEKB injection background
- Test and calibration of diamond sensors Precision (0.5 nA on the shortest 10µs time scale) OK for reliable fast and slow aborts for phase 2/3

Vacuum scrubbing

Coulomb scattering between beam particles and residual gas in beam pipe

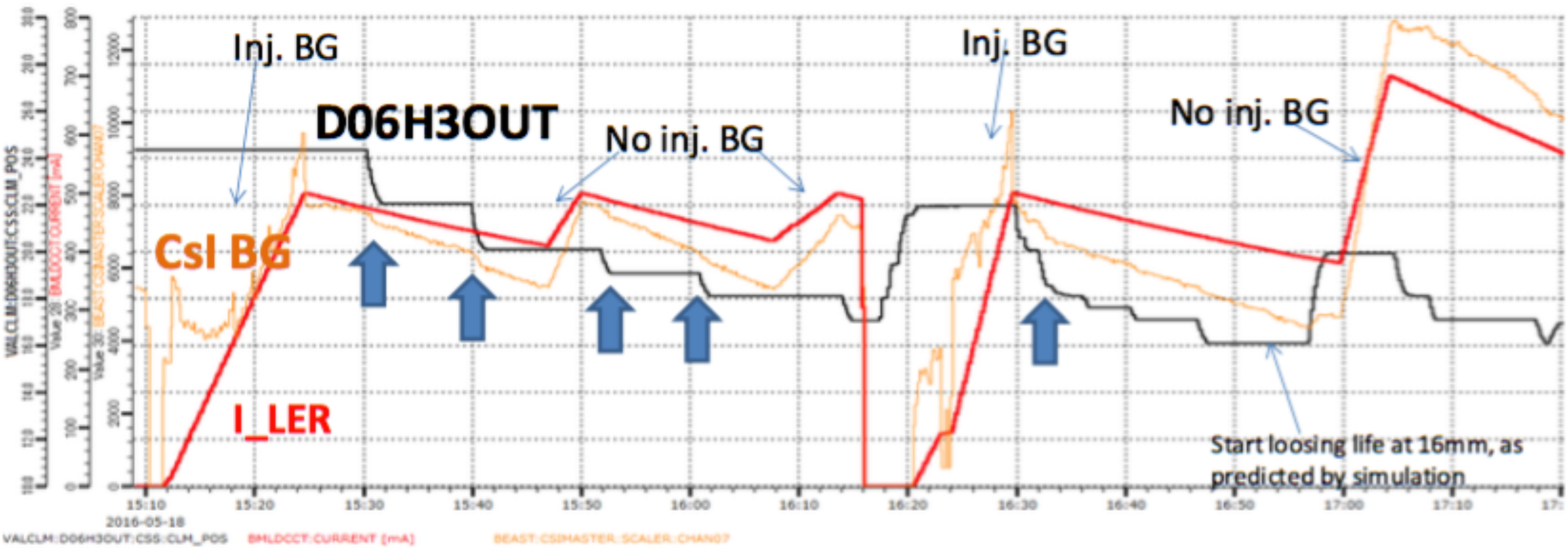
Beam background in the HER vs time



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

vacuum scrubbing to reduce beam gas background

Beam BG vs LER collimator



in this case CsI and LYSO are most sensitive BEAST detectors

- width changed from 24mm to 17mm
- narrower collimators -> decrease of the background seen by CSI

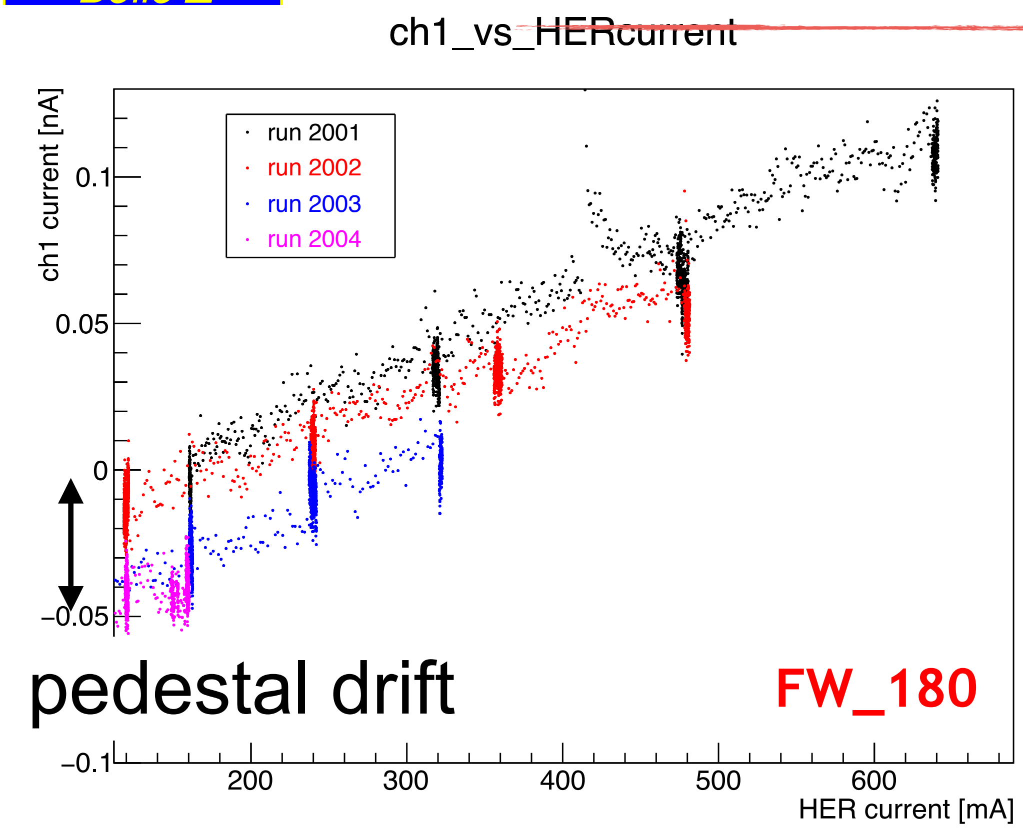
clear evidence of BG suppression by the collimator

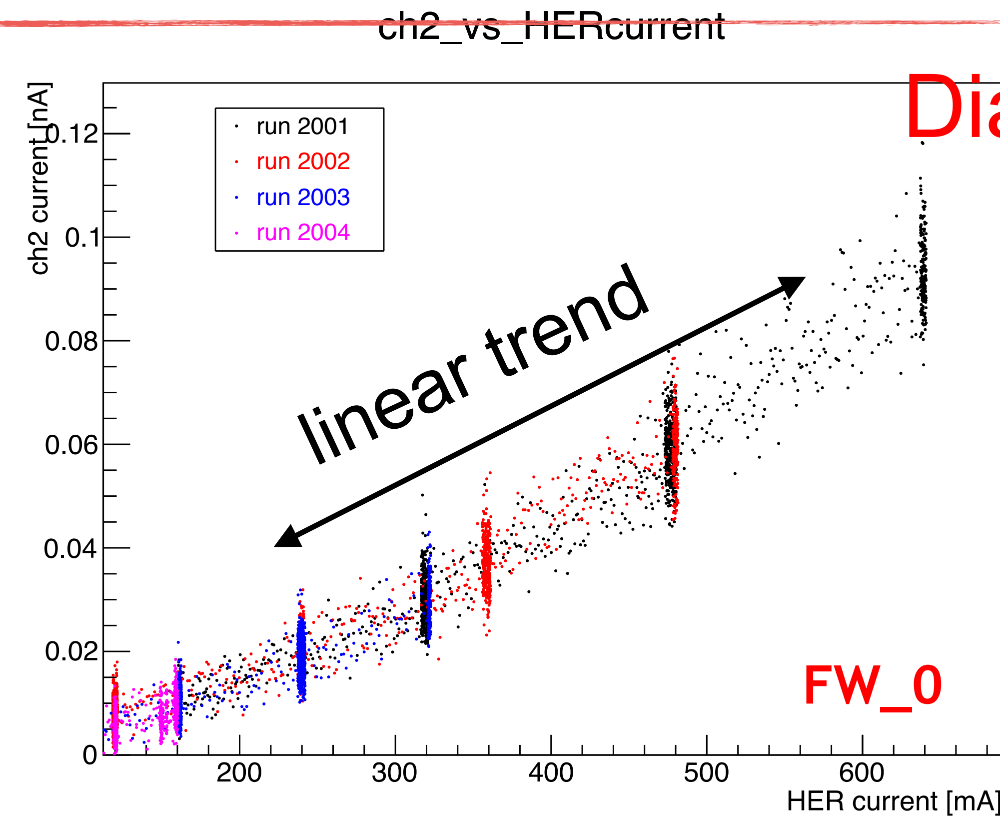
2016-05-16

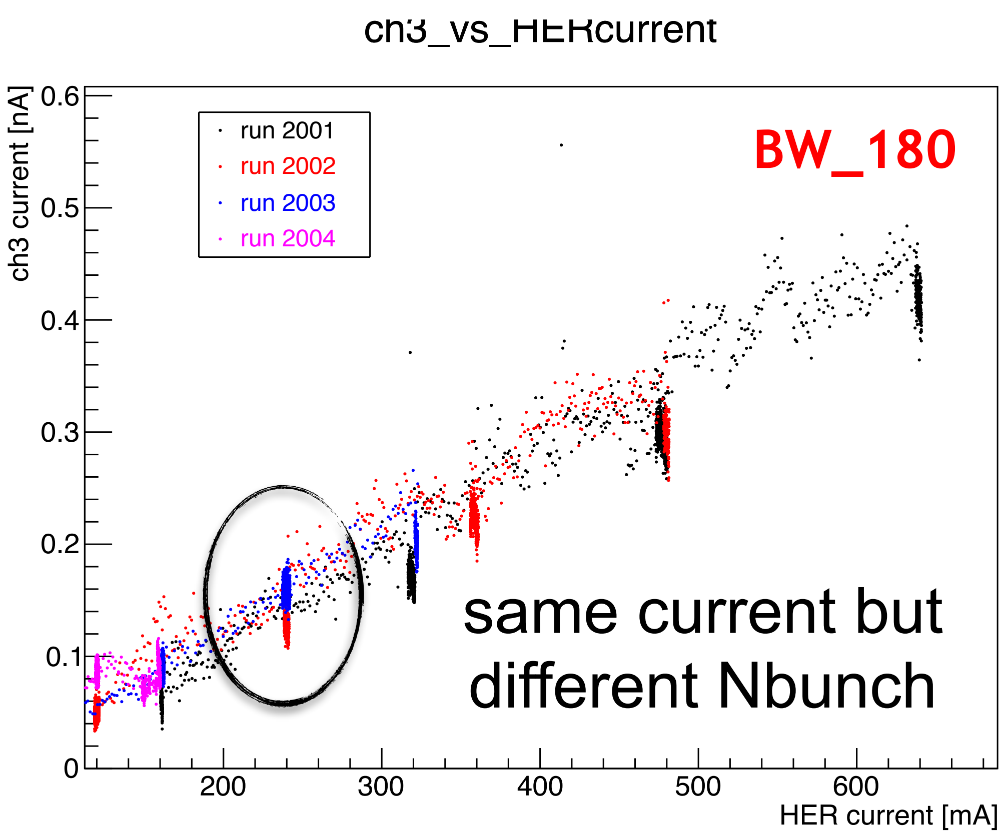
HER current scan

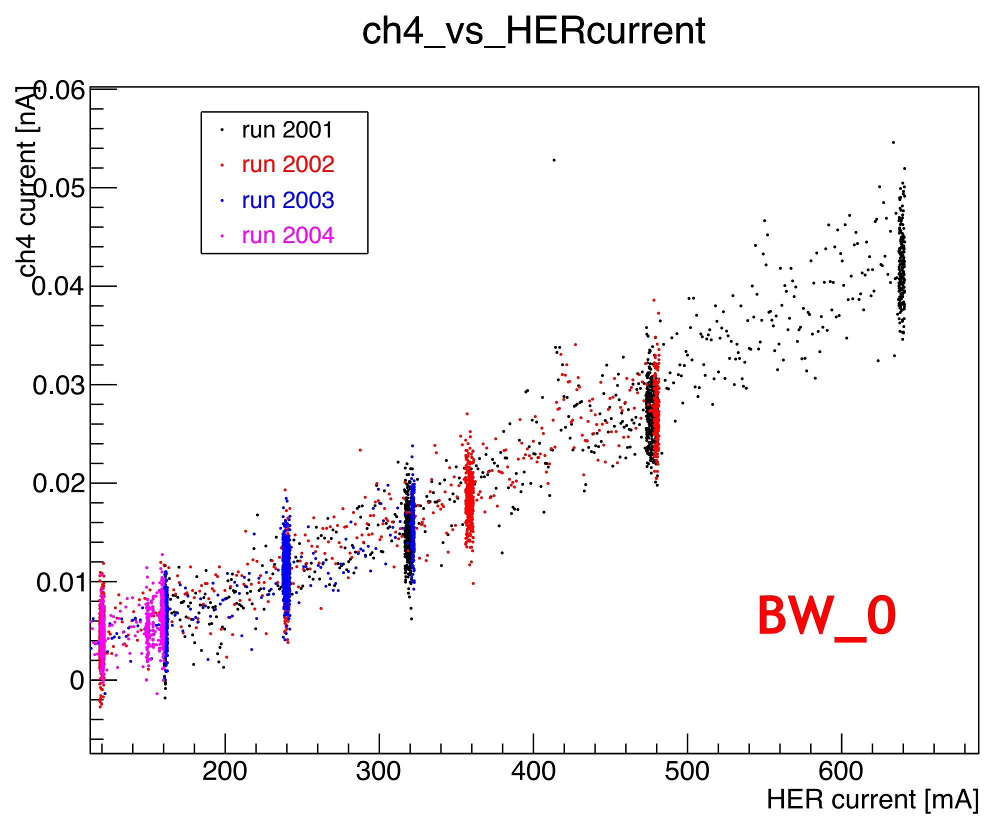
HER on
LER off

Diamond sensors





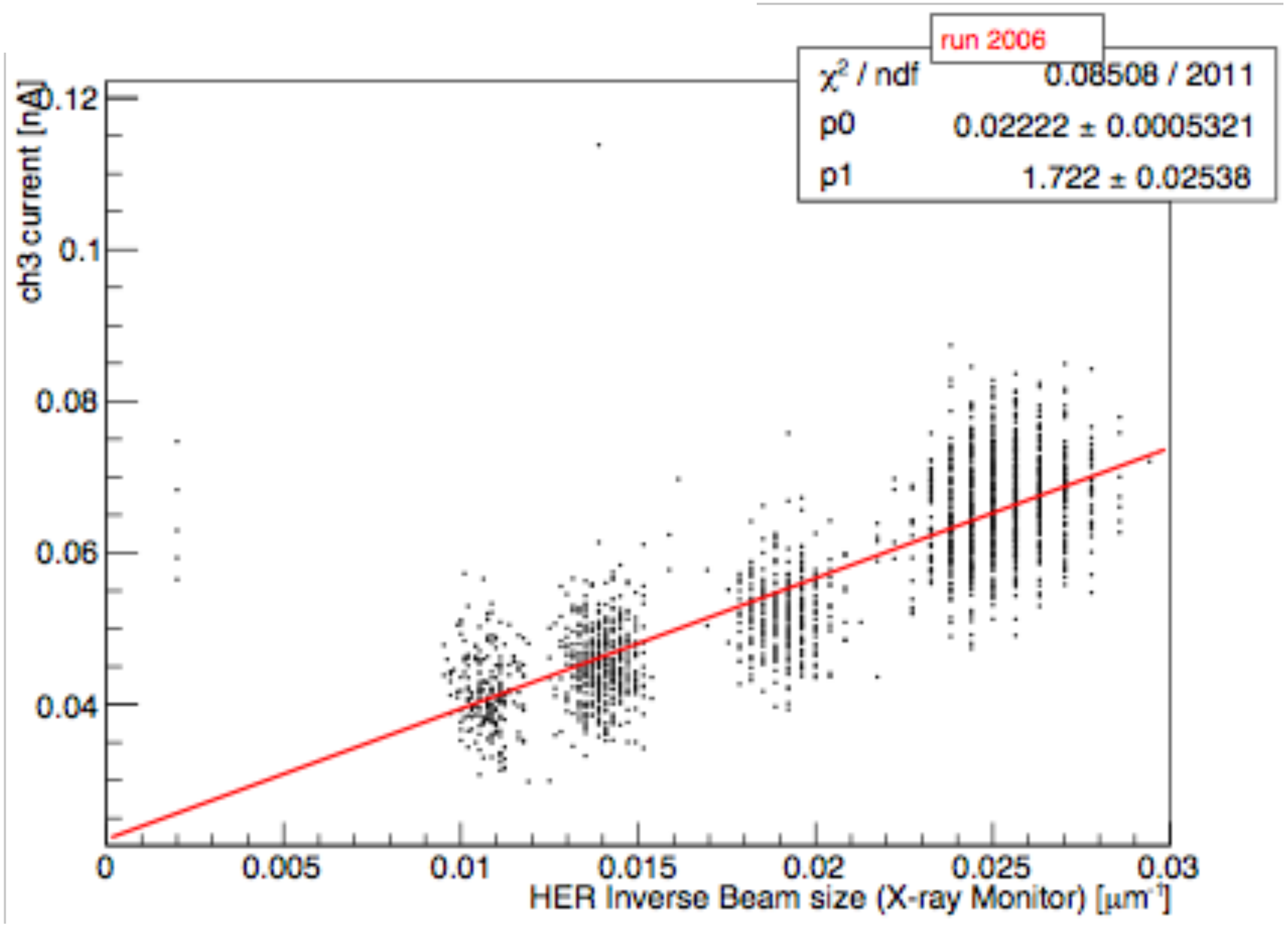




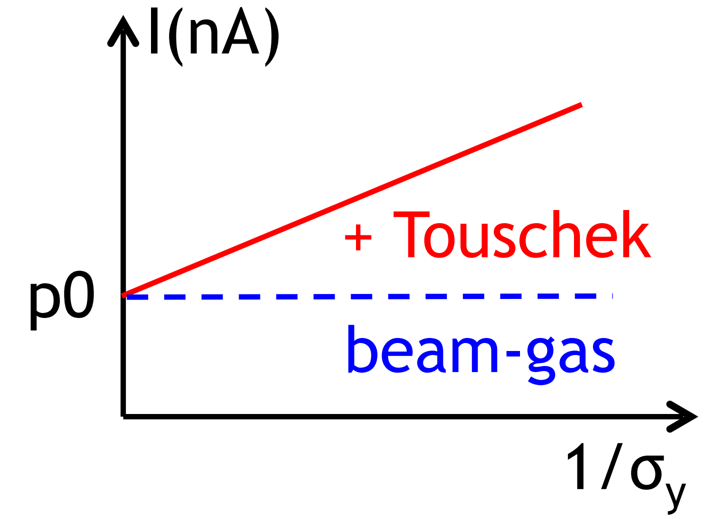
- run #2001: 100% Nbunch
- run #2002: 75% Nbunch
- run #2003: 50% Nbunch
- run #2003: 25% Nbunch

Touschek study (intra beam effects)

Coulomb scattering between two particles in the same bunch



Diamond current vs inverse beam size: Linear fit, intercept p0 = (0.0222 ± 0.0005) nA extrapolation to pure beam-gas contribution



Just one example for HER and diamond BW_180:
beam vertical size = {90 um, 75um, 51um, 46um, 42 um}
I HER = 160 mA

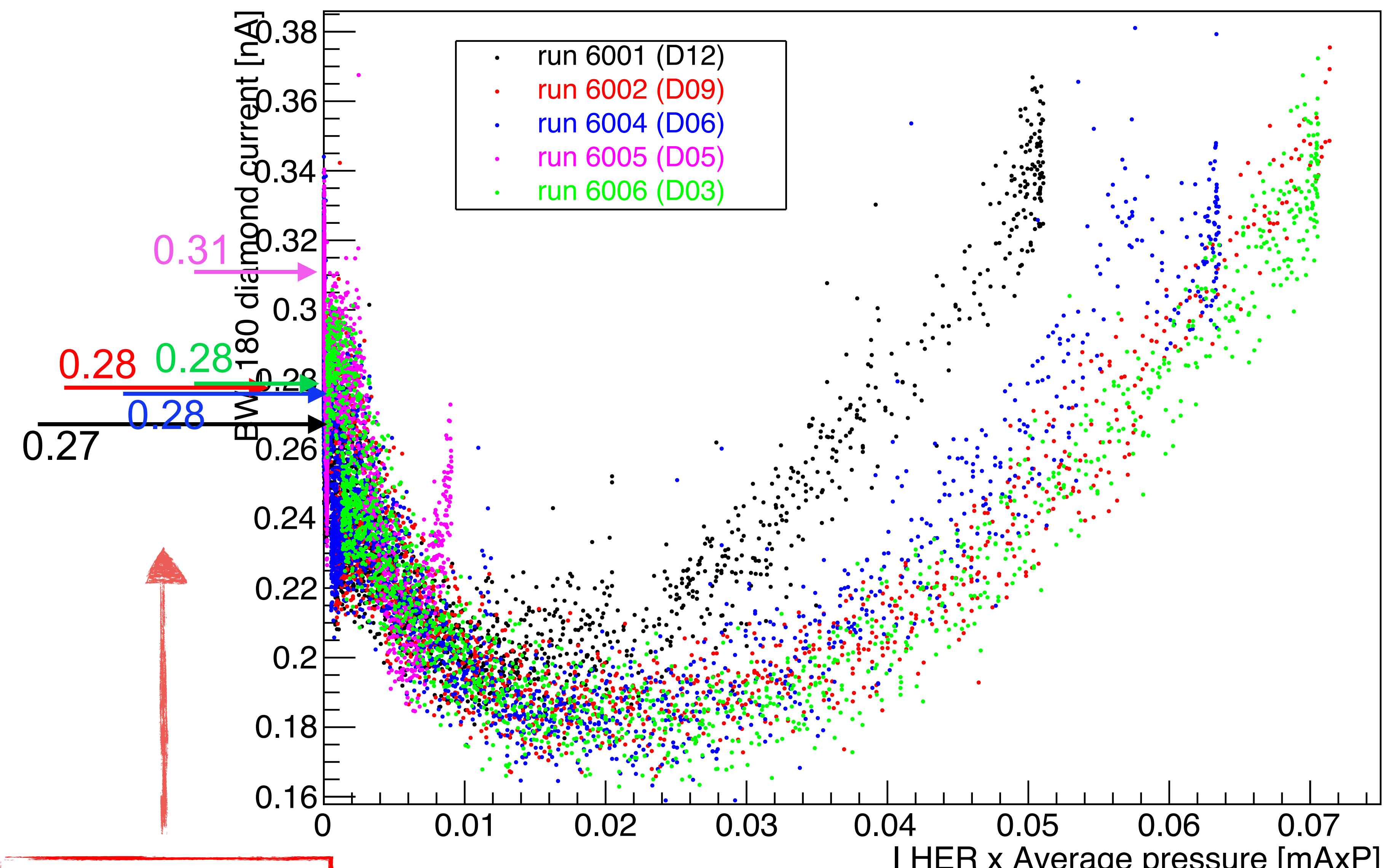
Evidence for Touschek BG contribution !

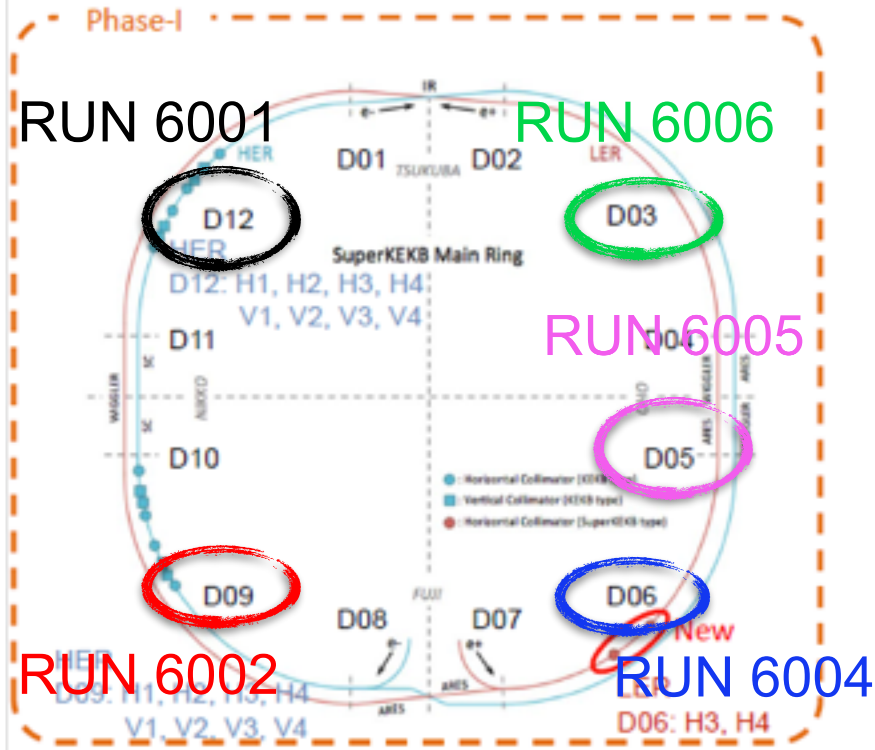
HER Vacuum study

Coulomb scattering between beam particles and gas in beam pipe

Diamond BW_180

Diamond current vs I HER x Pressure



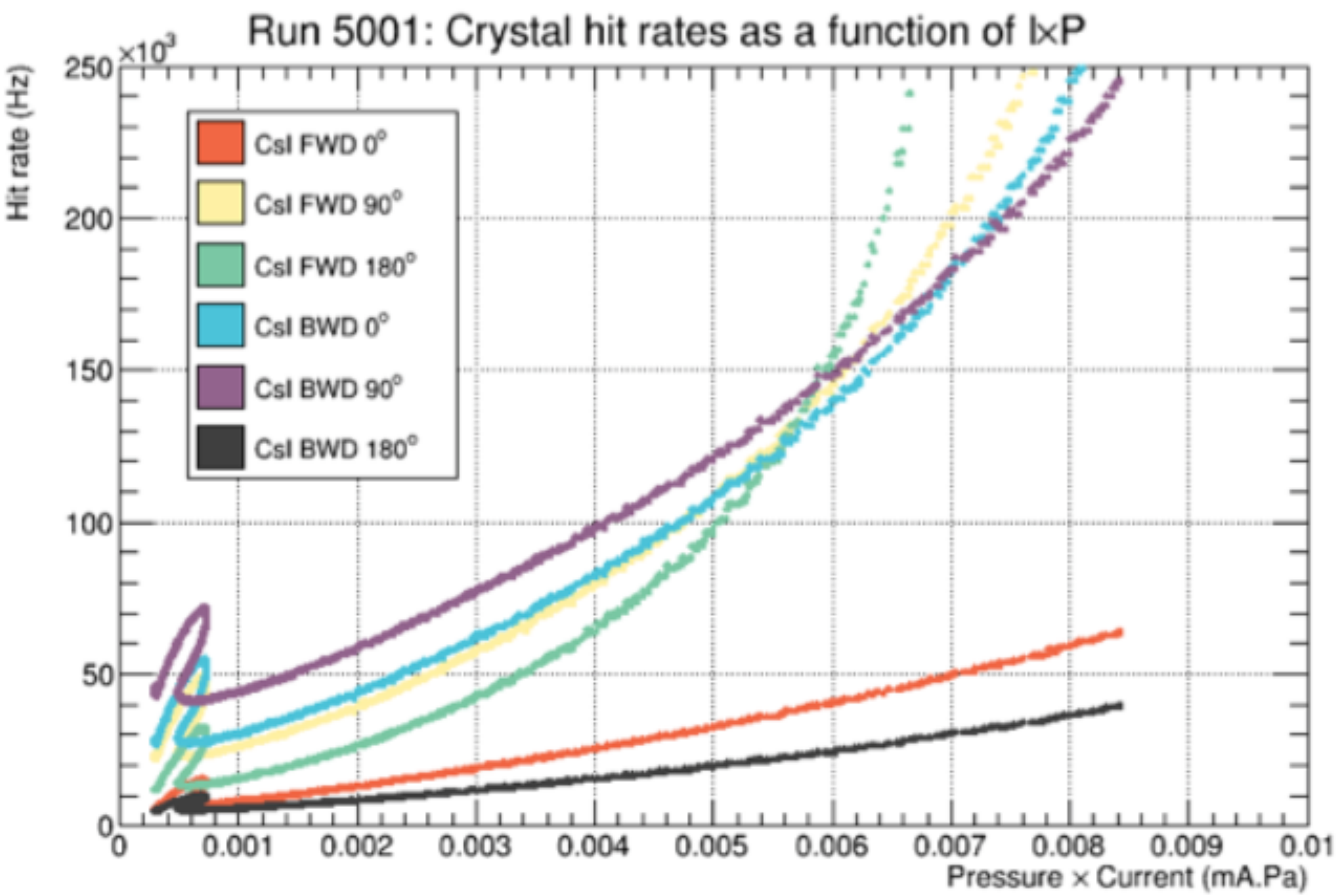


starting point for each run

HER:Vacuum bump in all position have impact on BEAST BG

LER Vacuum study

Coulomb scattering between beam particles and gas in beam pipe



Just an example: CsI

Effect of the increase in pressure in the LER

There is a dependence of the angle

LER: Vacuum bump near interaction region sections has impact on BEAST BG but other position did not

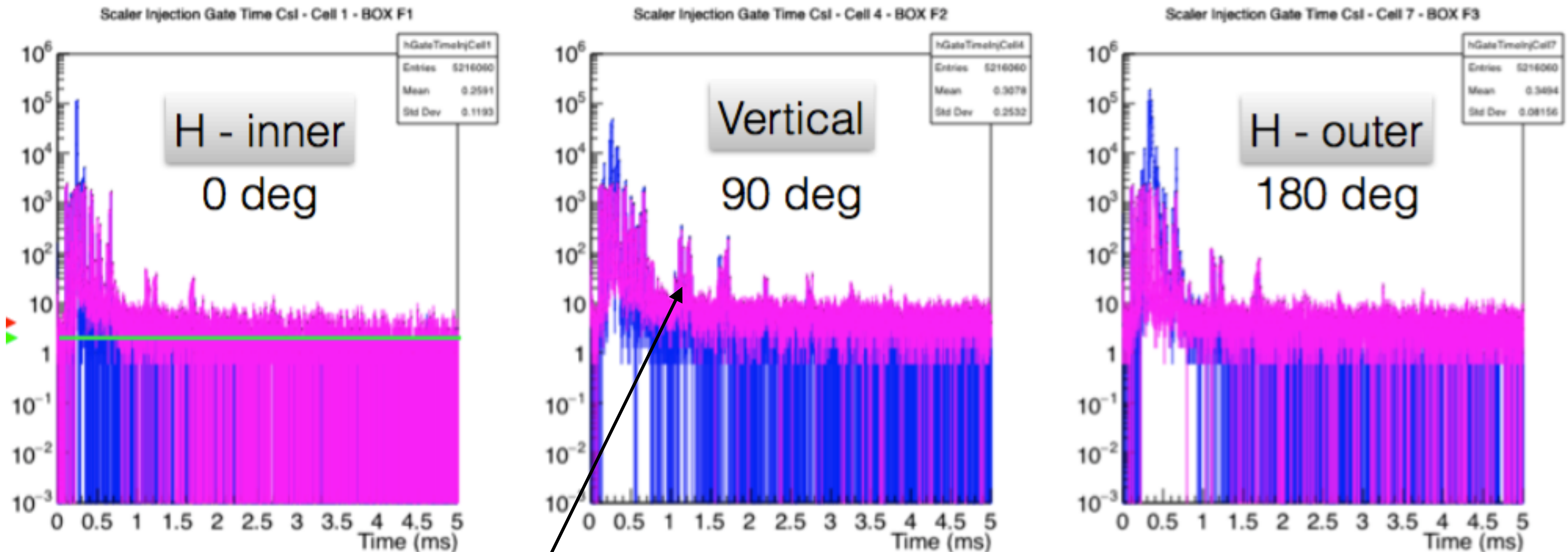
Injection study

- SuperKEKB will operate with continuous injection
- after injection pulse more background in the detector
- blocking triggers for 4 ms
- To reduce dead time the DAQ is blocked for 4 ms only for the injected bunch only

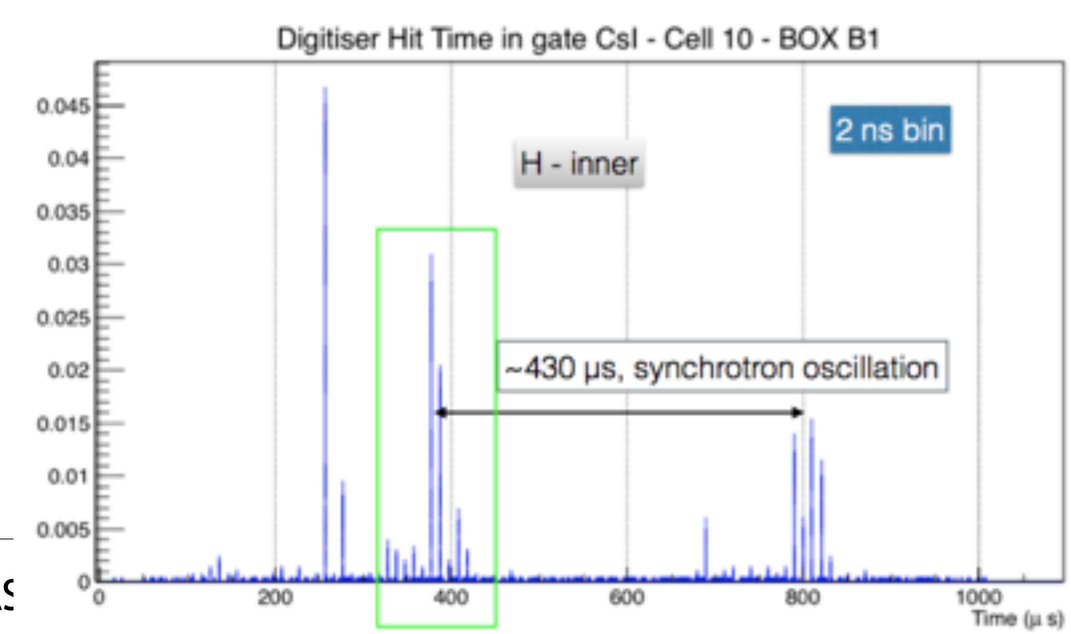
-> Important phase: injection studies

Injection study

CsI crystal/CLAWS scintillator observed interesting time structure



Spikes at every ~0.5ms can be explained by synchrotron oscillation (~2kHz)



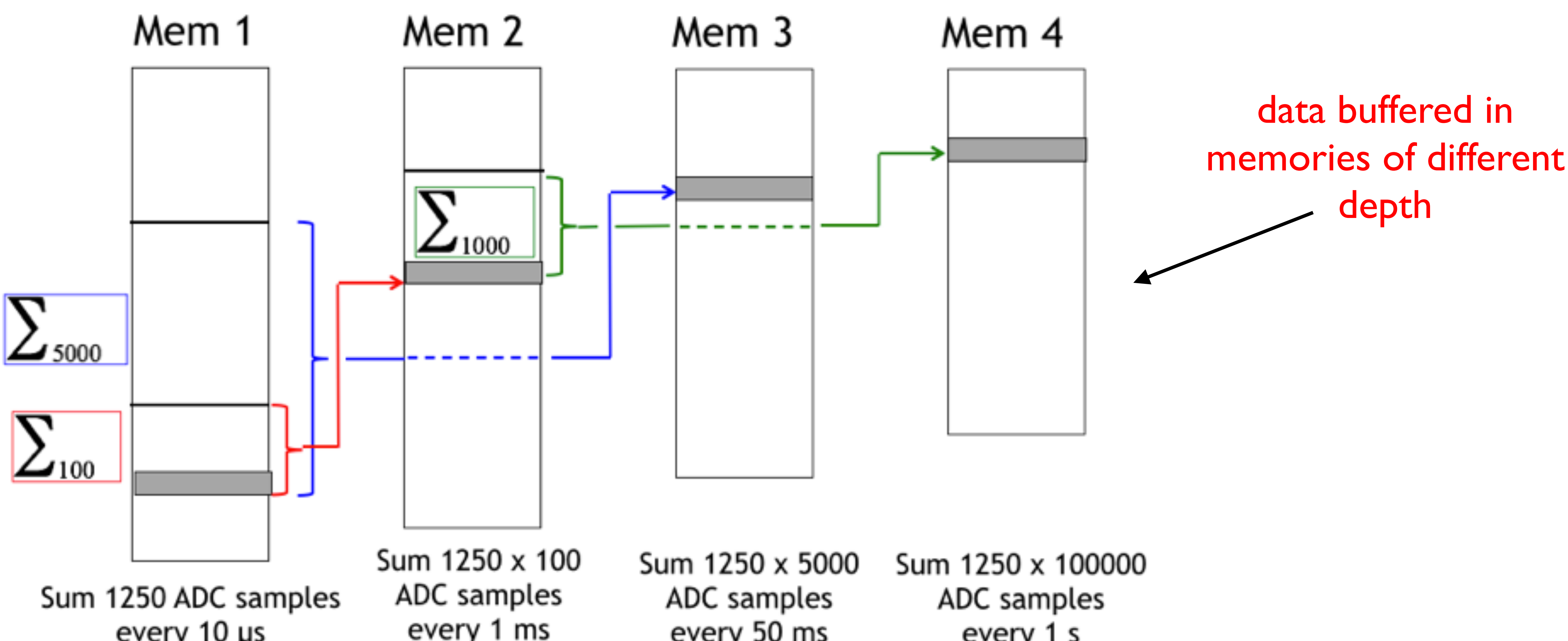
Beam abort thresholds (1/2)

Preliminary study from diamond sensors

Diamonds: Abort Buffer Memories

- diamond current will be sampled and digitized at 100kHz
- several levels of running averages are computed providing an effective digital filter

Present configuration of revolving Abort Buffer Memories
to be improved with really "running sums"



Beam abort thresholds (2/2)

Buffer memories: snapshot example

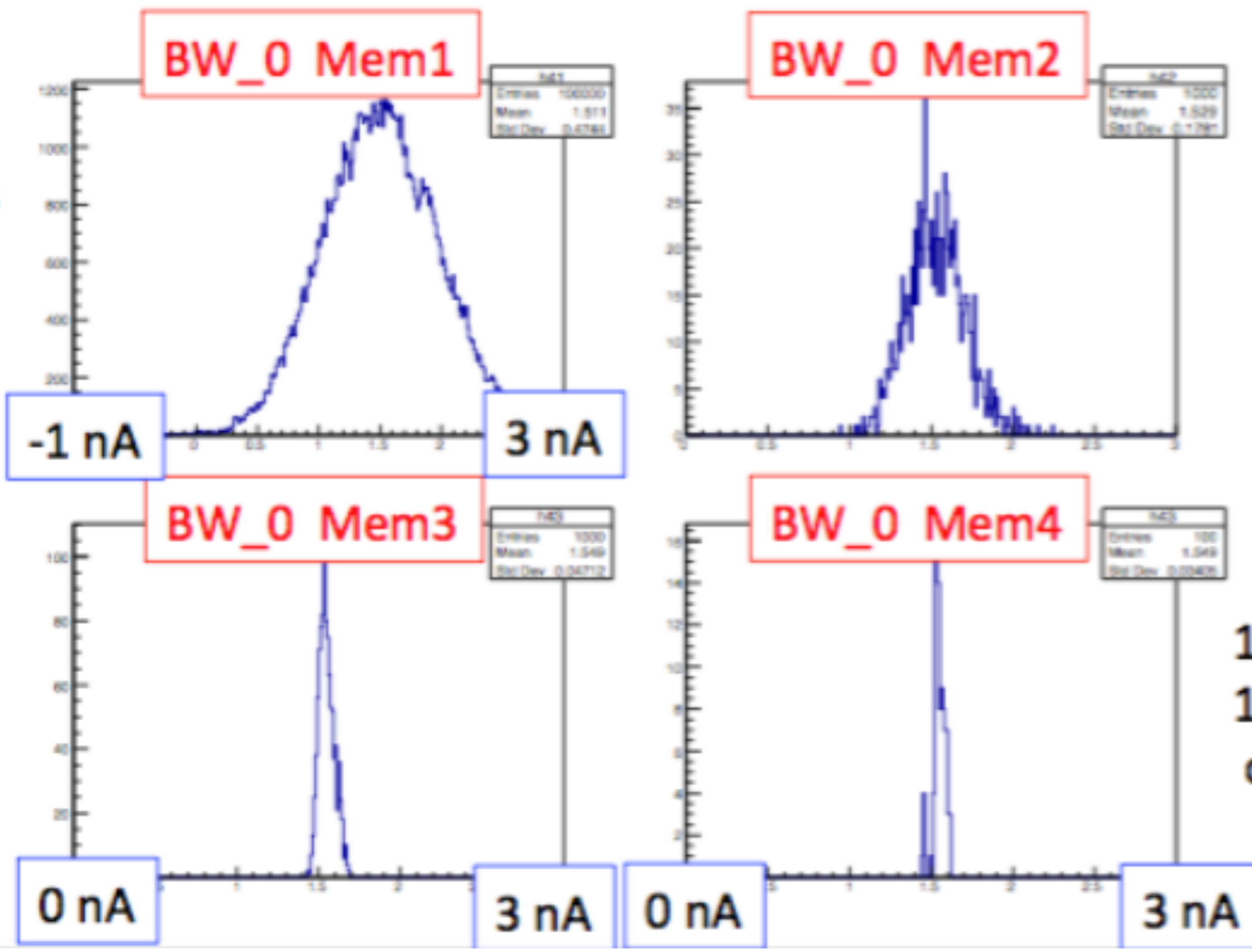
Example of snapshot of Buffer Memories (Mem1 to Mem4) for Dia3 = BW_0 in stable beam conditions, with average I(BW_0) = 1.5 nA

Noise decreases with increased averaging, from about 0.47 nA to < 0.04 nA

OK both for fast (10 μs) and slow (> 1 s) beam aborts with appropriate thresholds

100000 entries
1 s history
σ = 0.47 nA

1000 entries
1 s history
σ = 0.18 nA



1000 entries
50 s history
σ = 0.047 nA

100 entries
100 s history
σ = 0.034 nA

Conclusions

> BEAST phase I concluded

> Background level measurements:

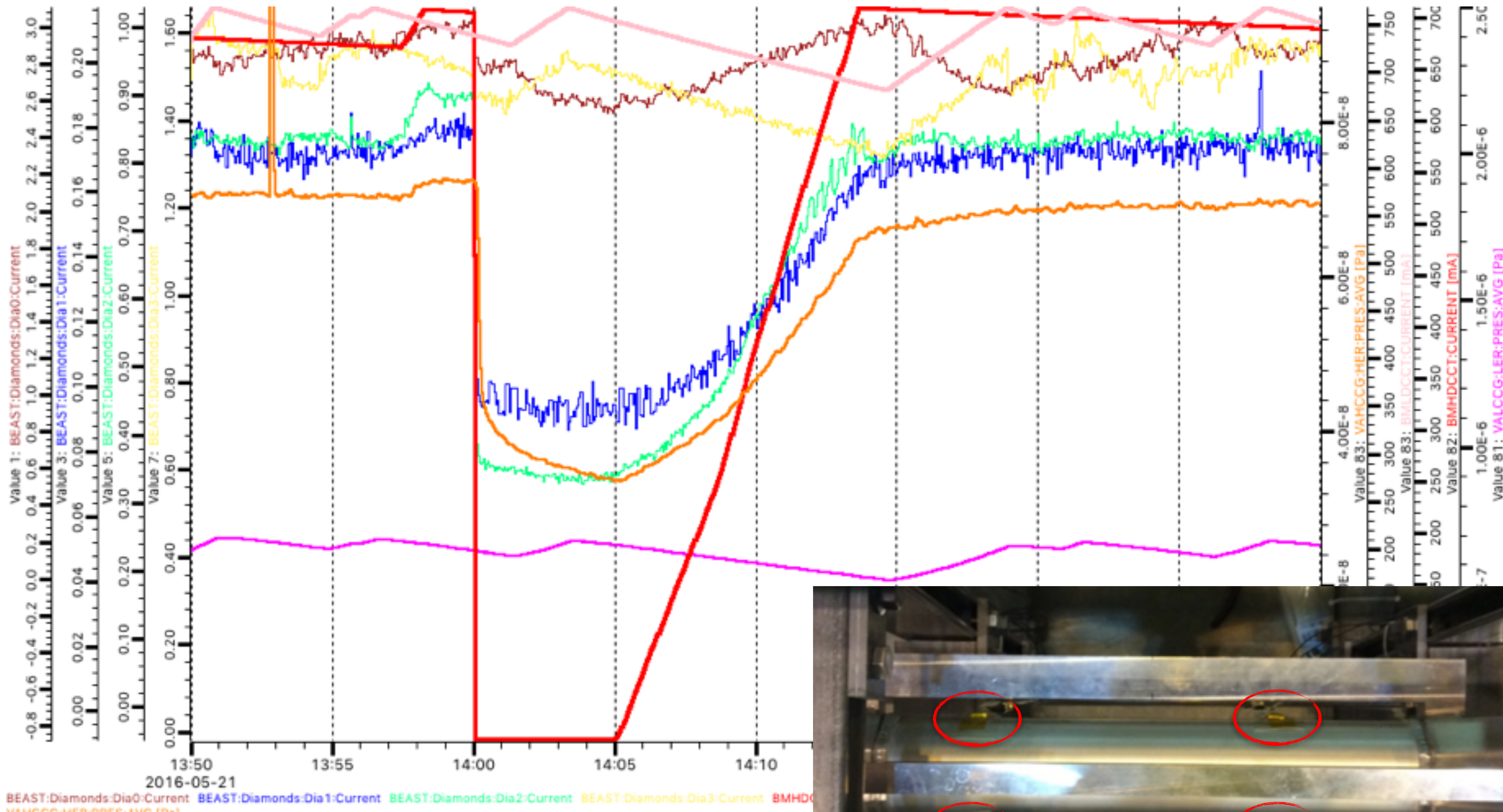
- Touschek background
- Vacuum bump study
- Injection background

> Other studies performed:

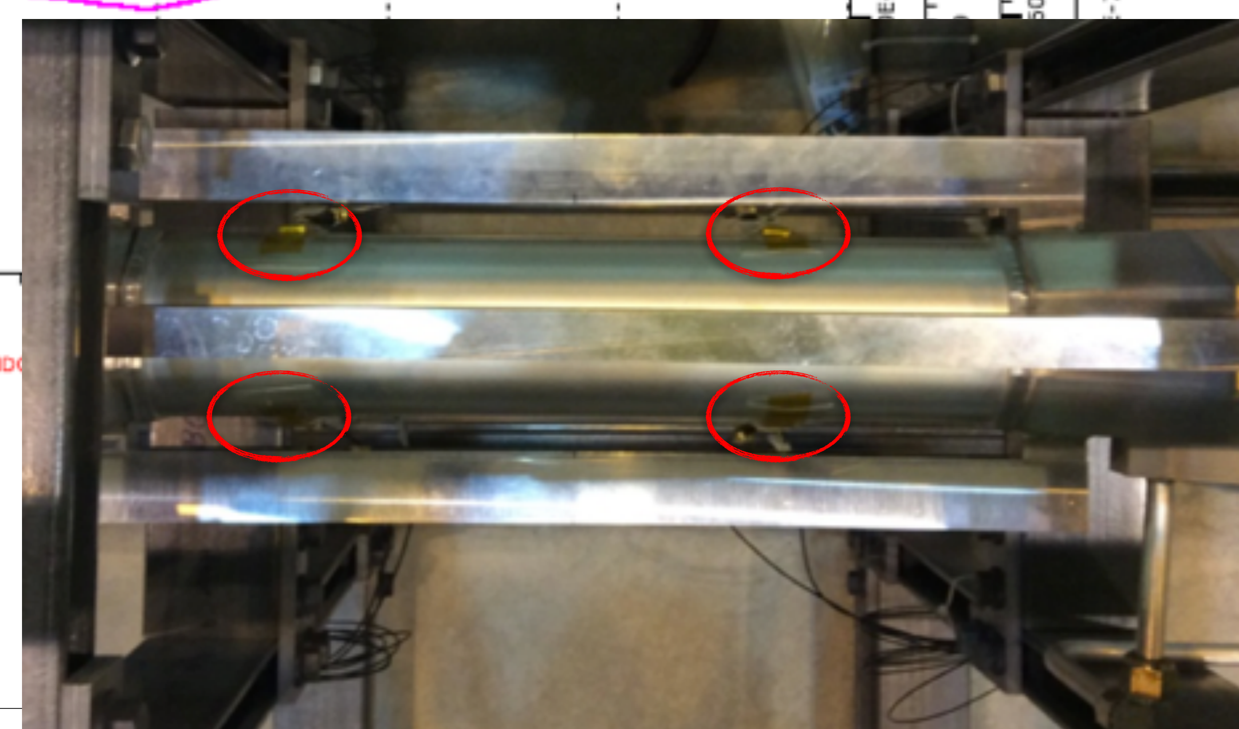
- Collimator
- beam abort thresholds (preliminary study for diamond sensors)

Backup

Diamond sensor response



Volume:
(4.5 x 4.5 x 0.5) mm^3



Diamond Sensors in BEAST phase1

LER only: 2.5 nA
HER only: 0.1 nA
LER+HER: 2.6 nA

FW_180 (PV Dia0)
DM7 Z = +10 cm

LER only: 0.3 nA
HER only: 0.4 nA
LER+HER: 0.7 nA

BW_180 (PV Dia2)
DM5 Z = -12 cm

some uncertainties on the position dominated by (0,0,0) position

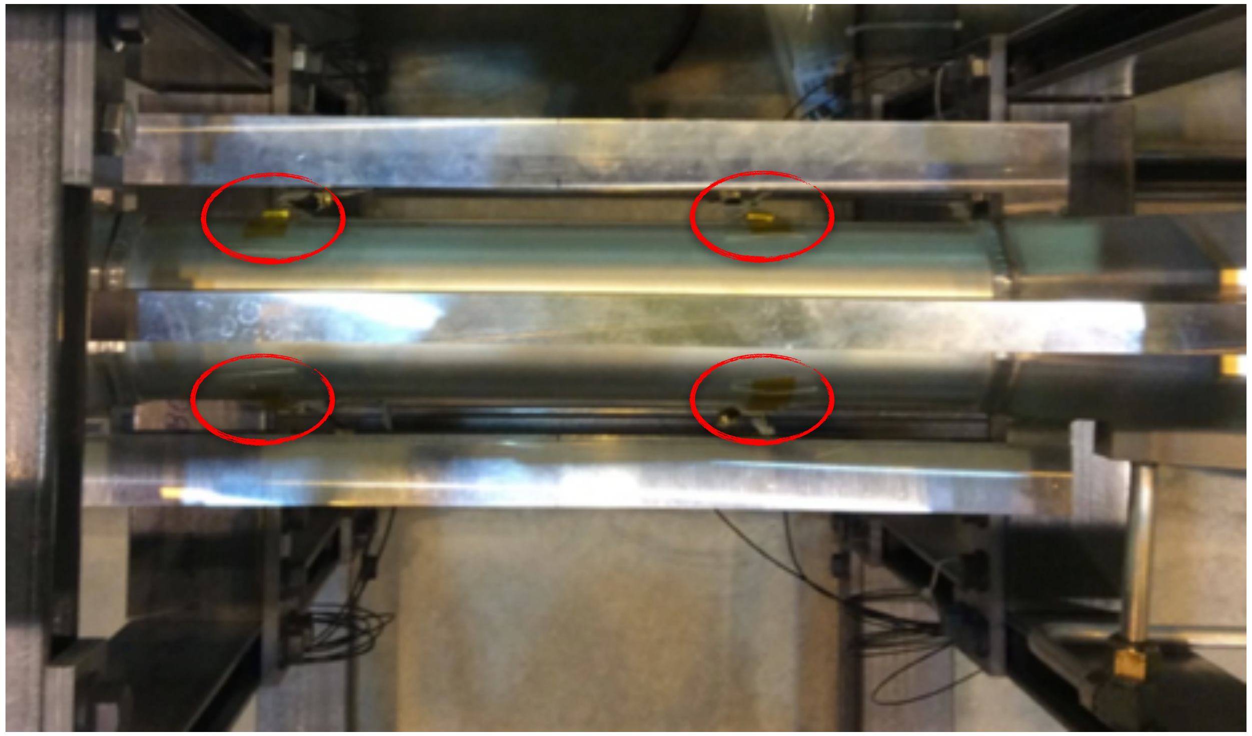
Δz = +/- 2 cm

Δy = +/- 1 cm

LER

HER

z



HER

LER

- DC3: *sCVD*, CIVIDEC metallization (Ti + Pt + Au)
- DM4, DM5: *sCVD*, Micron metallization (Al)
- DM7: *pCVD*, Micron metallization (Al)

FW_0 (PV Dia1)
DC3 Z = +10 cm

LER only: 0.08 nA
HER only: 0.08 nA
LER+HER: 0.16 nA

BW_0 (PV Dia3)
DM4 Z = -12 cm

LER only: 1.2 nA
HER only: 0.1 nA
LER+HER: 1.3 nA

1 nA -> 2 - 8 mrad/s

Volume: (4.5 x 4.5 x 0.5) mm^3

CVD sensors: tests and calibrations

- Sensor characterization

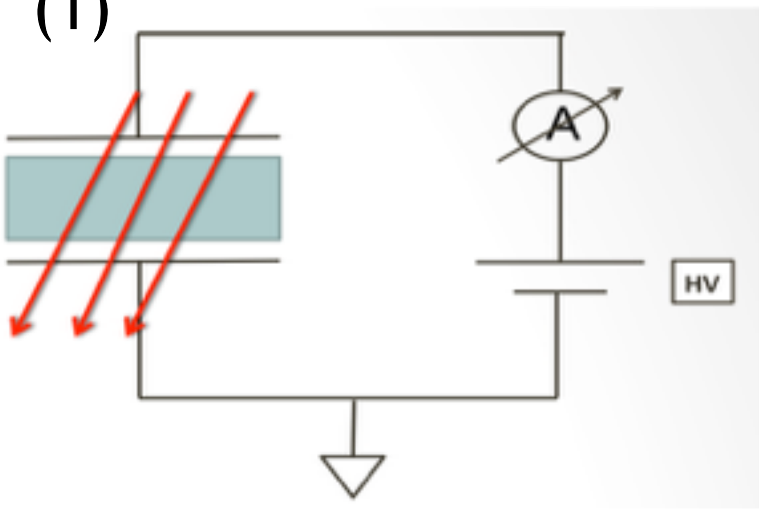
(0) Preliminary test: dark I-V characteristic

(1) I-V with β ^{90}Sr source at different distances (fluence)

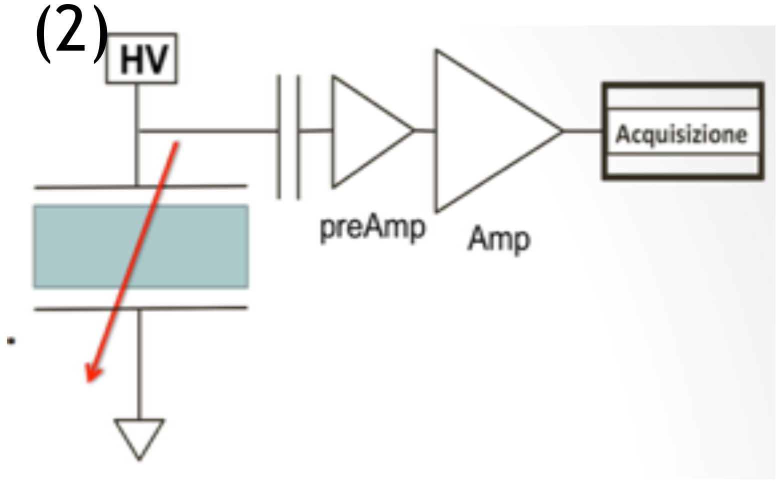
(2) Measurement with single electron (1-2 MeV, source ^{90}Sr + magnet): Charge Collection Efficiency

(3) TCT measurement with α source: uniformity of the material and mobility (e, h)

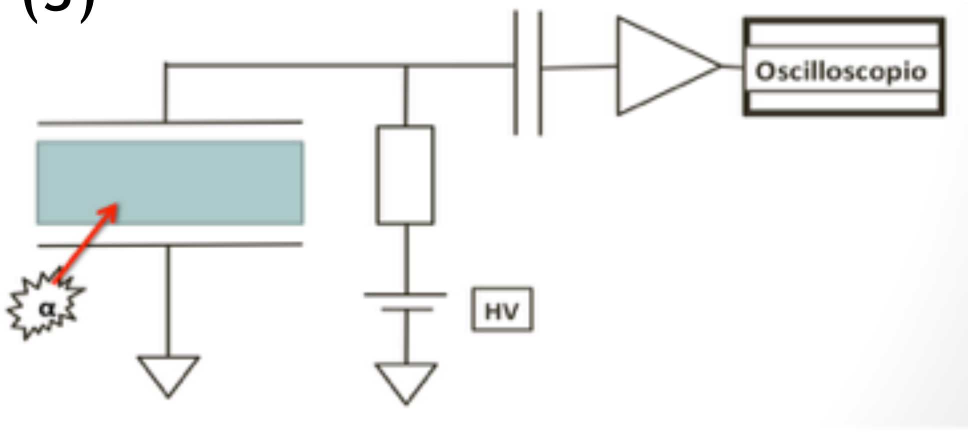
(1)



(2)

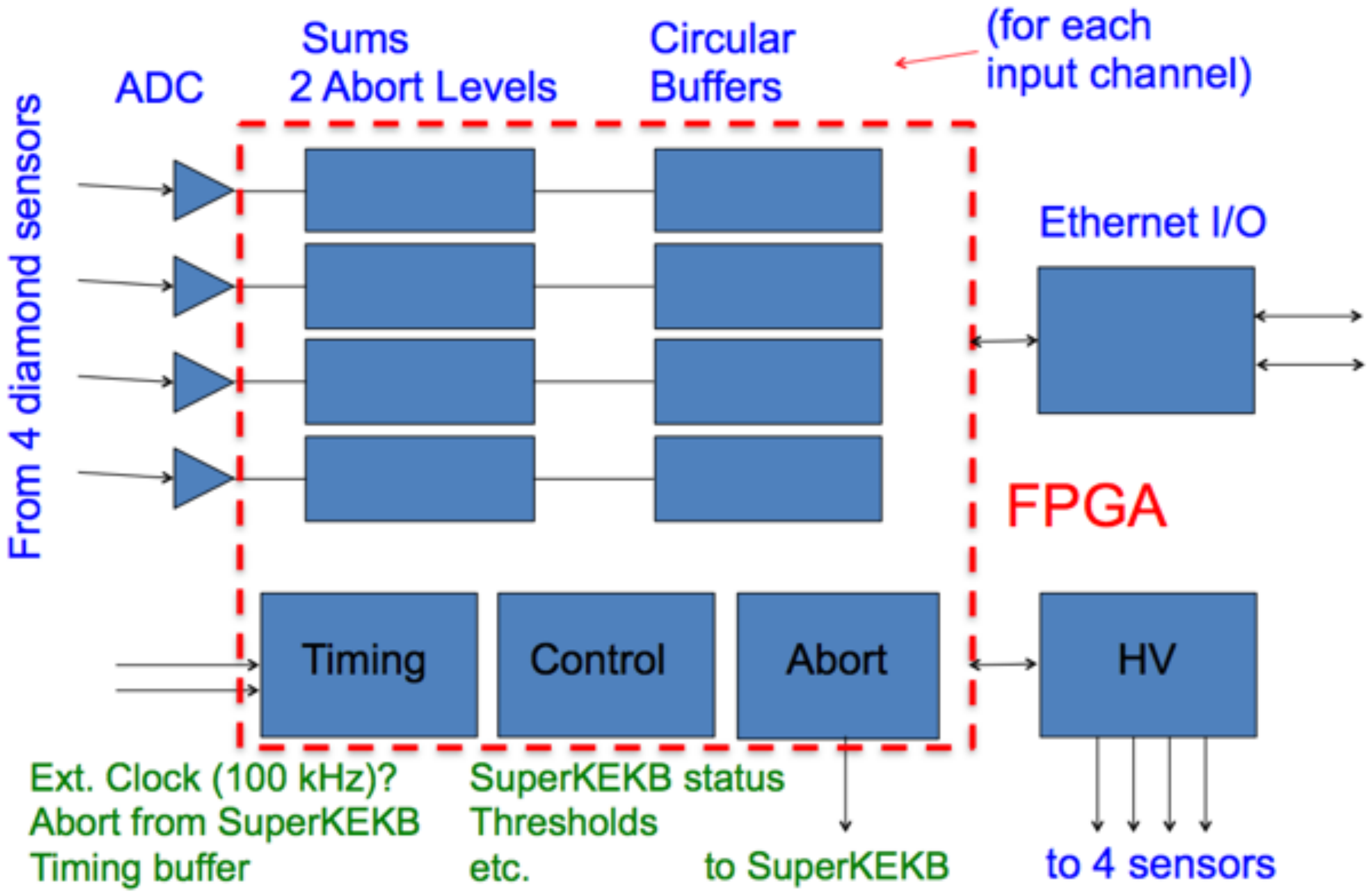


(3)



Diamond Electronics in BEAST1

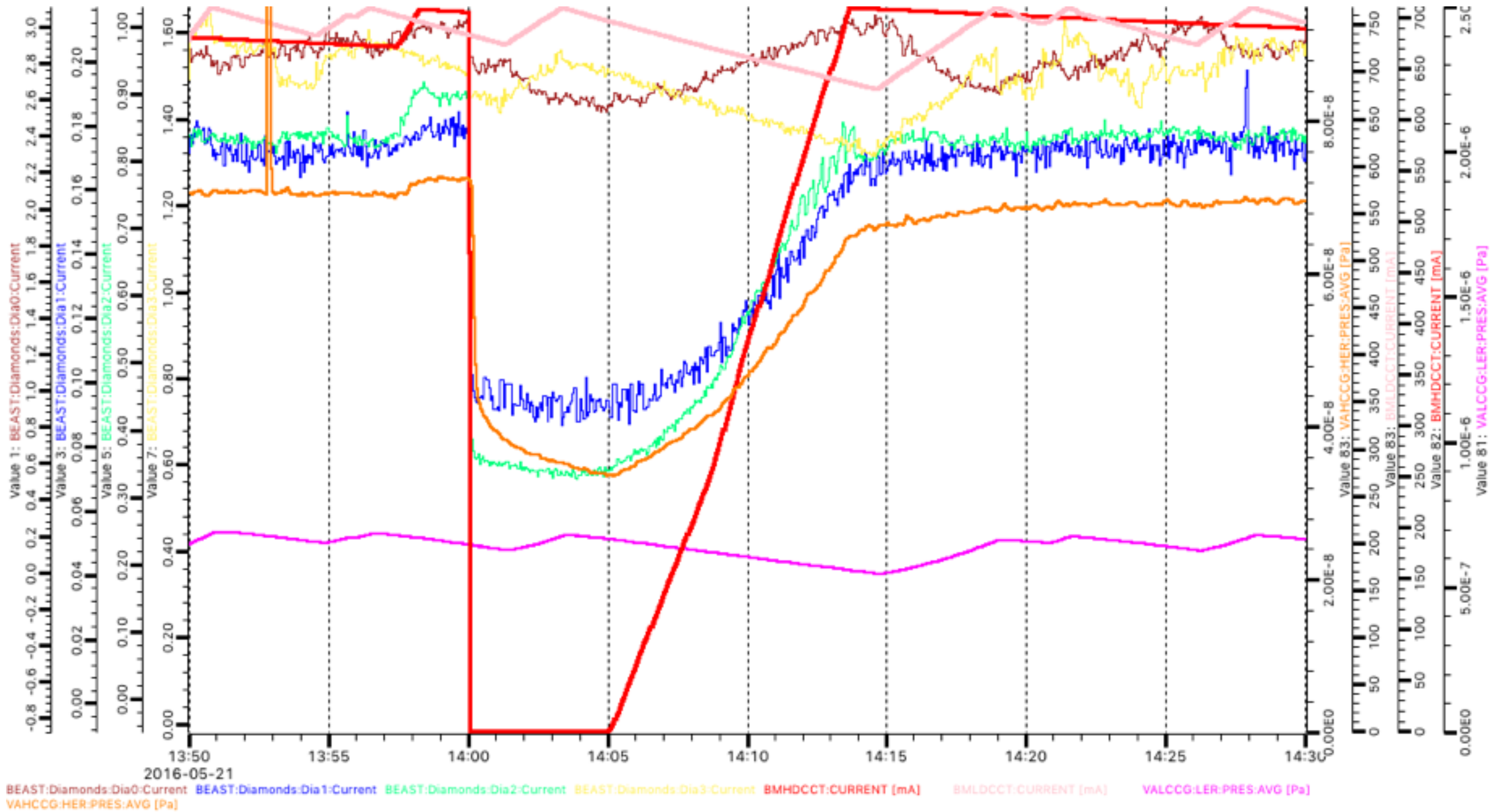
- Analog front-end picoammeters
  - transimpedance amplifiers
  - 16-bit ADCs, 130 MHz oversampling
  - 2 selectable current ranges
- Digital section: Stratix III FPGA
  - Running averages (4 levels)
  - Programmable abort thresholds, depending on machine status
  - Timing & Control
- External RAM, Ethernet
- DAC for HV module control



LabVIEW program
Monitoring readout at 10 Hz
Connected to EPICS, archived at 1 Hz

Abort buffer memories read out on request on a separate channel

Diamond sensor response



diamonds **FW_180** and **BW_0** are more sensitive to LER beam conditions and have a limited sensitivity to HER

Comments on Rad. Mon. & Beam Abort

- In Phase 1: limited LER, HER beam currents (up to about 1 A)
  - The 5 nA range for diamond currents was mostly used
  - Monitoring at 10 Hz: 0.1 s average: sensitivity of a few pA !
  - Clear correlations with beam currents and vacuum conditions
  - Participation in all background studies (see examples in back-up slides)
  - Precision (0.5 nA on the shortest 10μs time scale) OK for reliable fast and slow aborts
  - Off-line analysis of correlations with machine-initiated aborts is ongoing

- Larger beam currents in Phase 2 and 3
  - The larger diamonds current range (5-10 μA) will be used
  - Some pilot data taken in Phase 1, under study
  - After some optimizations, a reliable Beam Abort can be set up, already with the existing prototype electronics