Fast Luminosity Monitoring with Diamond Sensors for Belle-II/SuperKEKB

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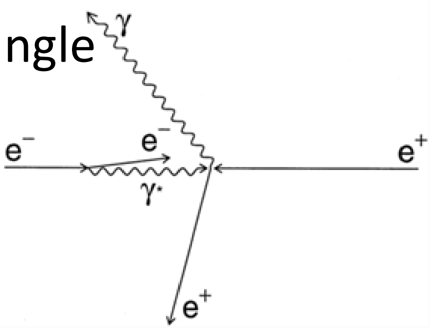
Fast Luminosity Monitoring with Diamond Sensors for Belle-II/SuperKEKB

- **Conception, development & installation of fast lumi monitor @ SuperKEKB rings for feedback in presence of dynamical imperfections, fine tuning and survey during physics runs.**

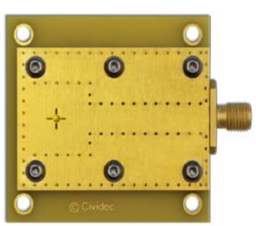
- aimed precision: $\delta\mathcal{L}/\mathcal{L}$ ~ 10^{-2} to 10^{-3} in 1 to 10ms
- Lumi monitoring for each bunch crossing: 2500 bunches, collisions every 4 ns
- Measurement: radiative Bhabha scattering at zero photon angle
  - Large cross-section: ~0.2 barn
  - Proportional to $\mathcal{L}$



- Technologies: set immediately outside beam pipe

~5x5 mm^2 diamond sensors,

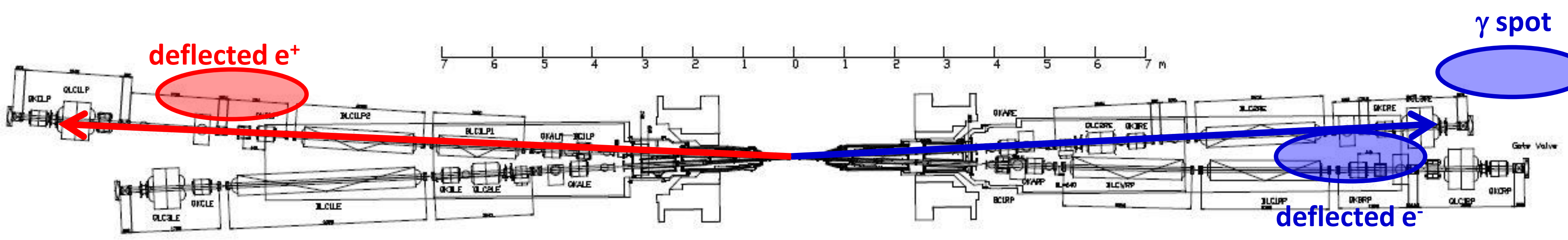
(Radiation hardness, Fast charge collection)



Cerenkov detector + scintillator

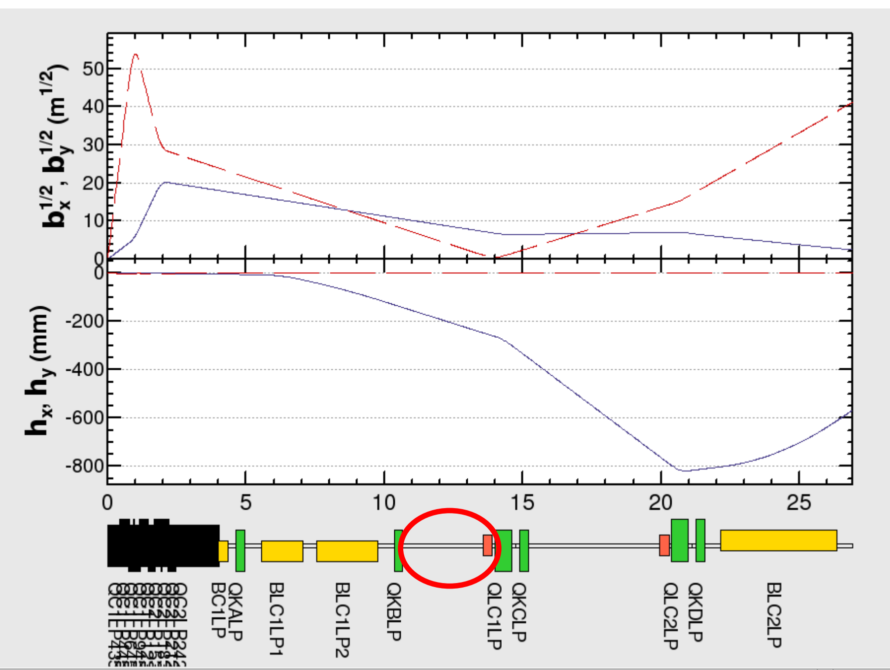
ZDLM Group

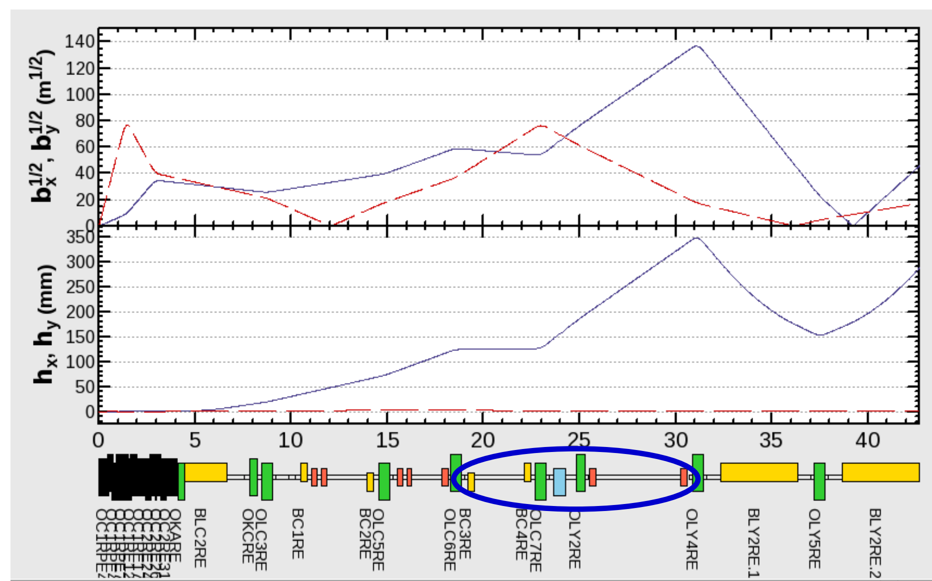
Sensor possible locations



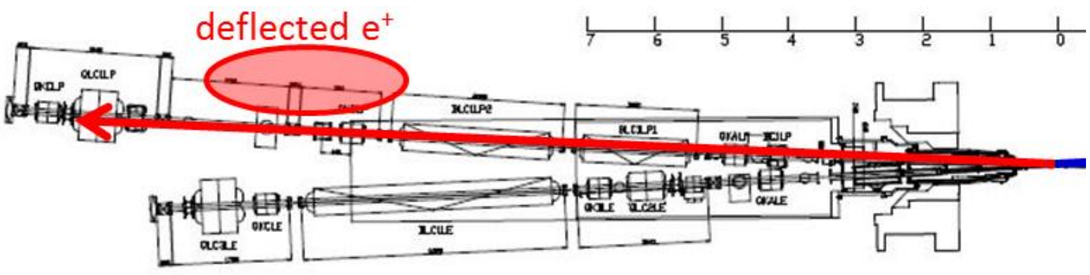
LER: low energy e^+, γ

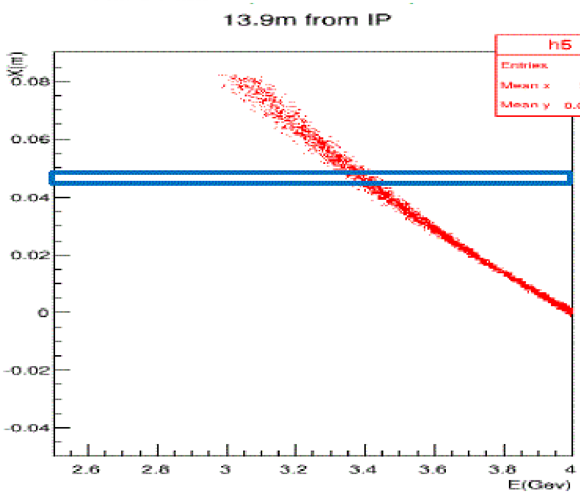
HER: low energy e^-, γ



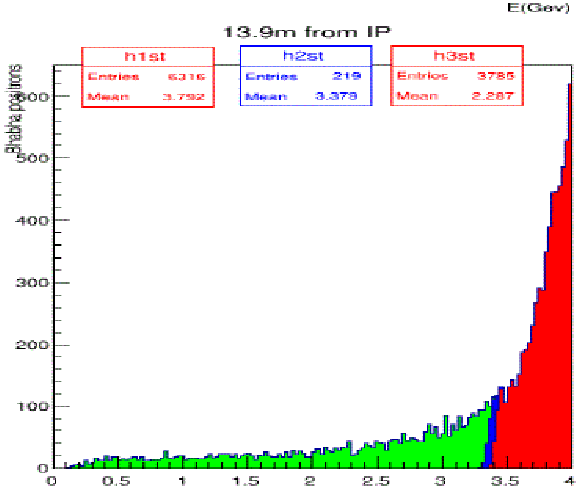


Sensor locations in LER

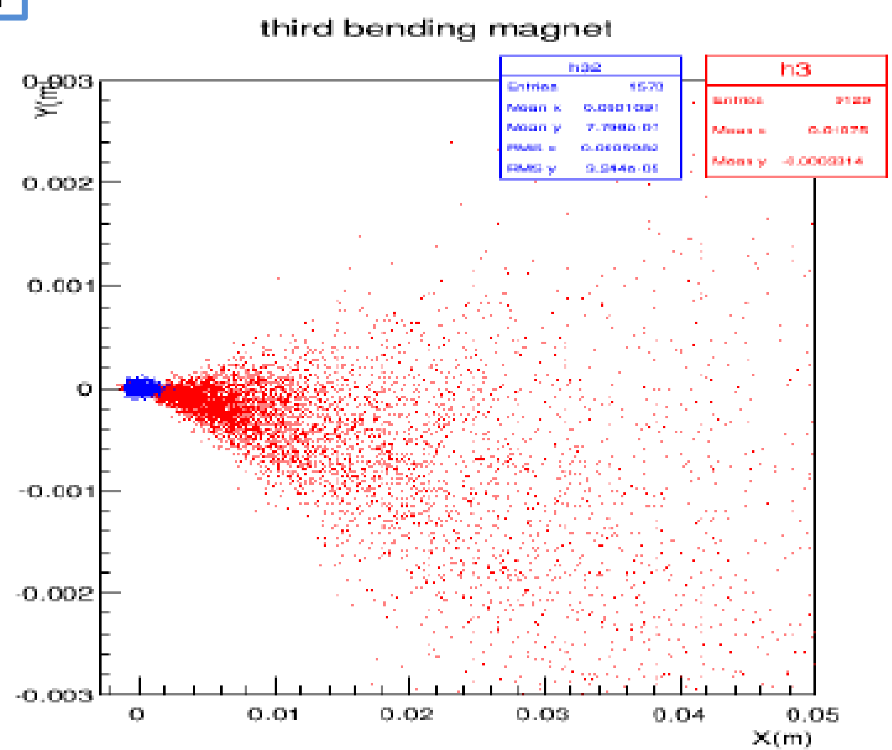




1.1% σ_{Bhabha}

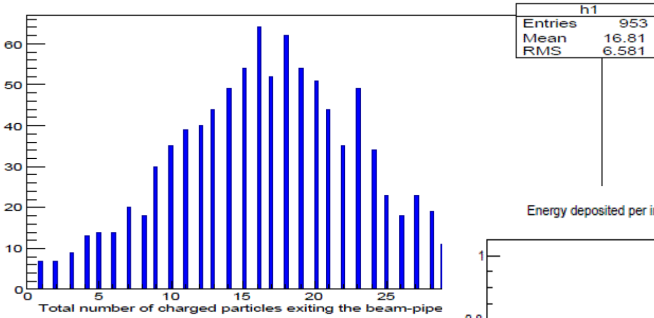


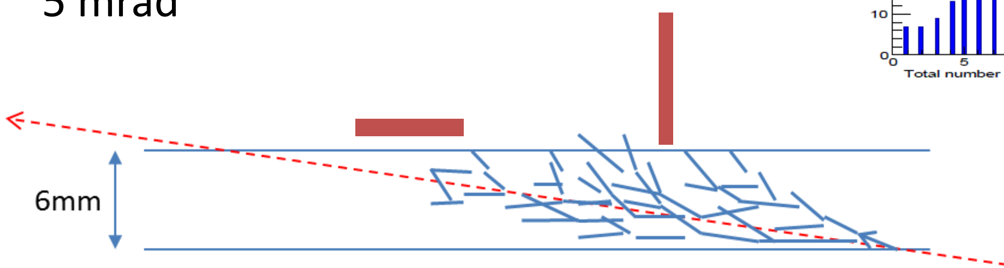
- Low energy e^+/e^- deflected downstream of the IP after bending magnets
- Study of the rate of Bhabhas exiting the beampipe (BP) with SAD tracking code (precision and space)

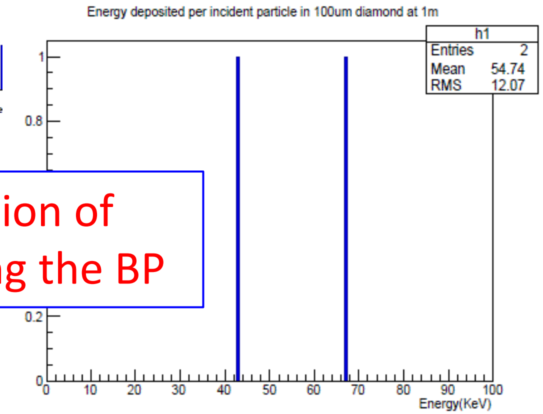


Geometry of beam pipe

- At 13.9 m dowstream the of IP, 3.35 GeV Bhabha positrons cross the BP material at 5 mrad

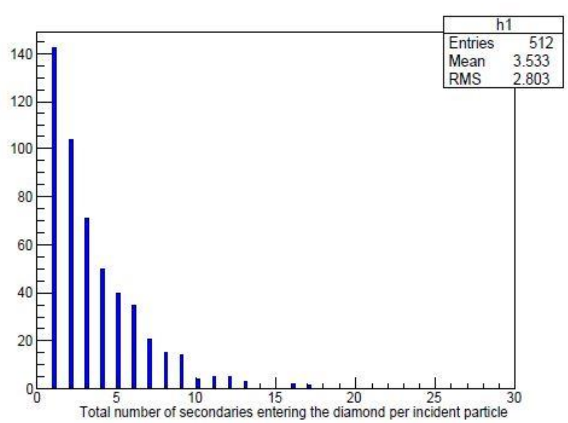




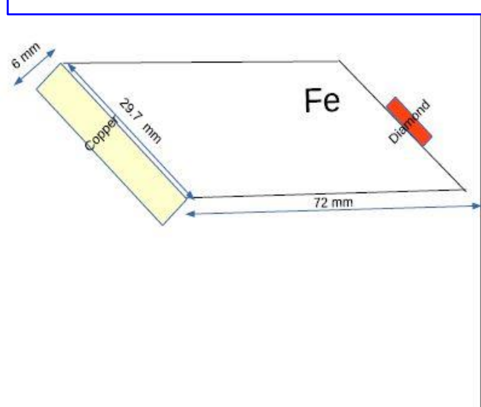


< 0.2% of fraction of Bhabhas exiting the BP

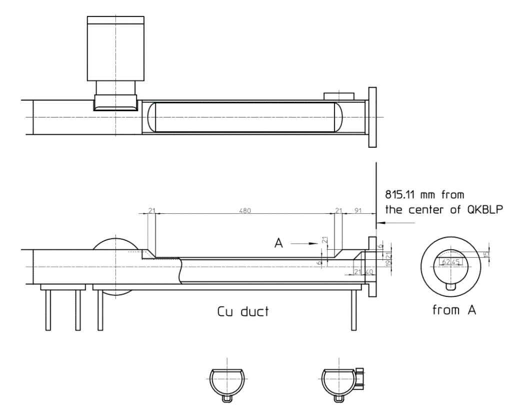
- A modification of the vacuum chamber may be required (window + radiator)



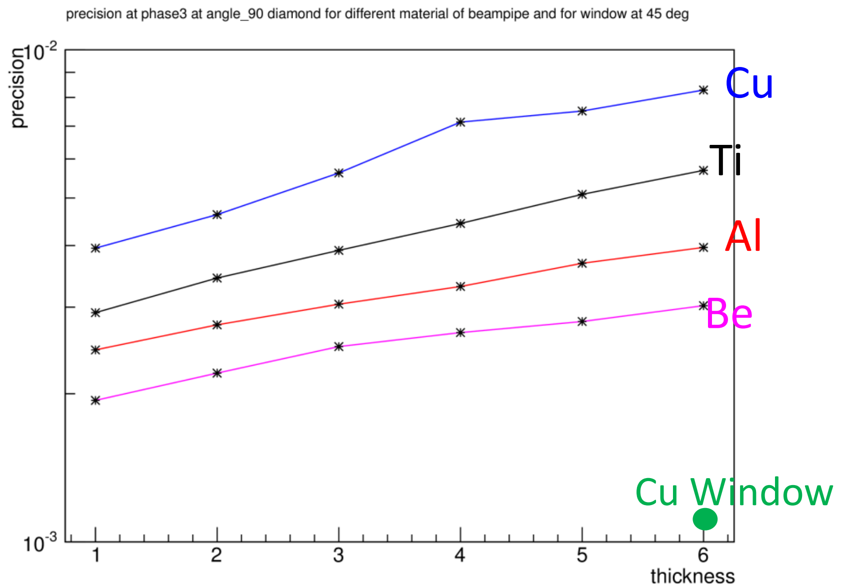
~50% of fraction of Bhabhas exiting the BP



Window design proposed by Prof. Kanasawa-san

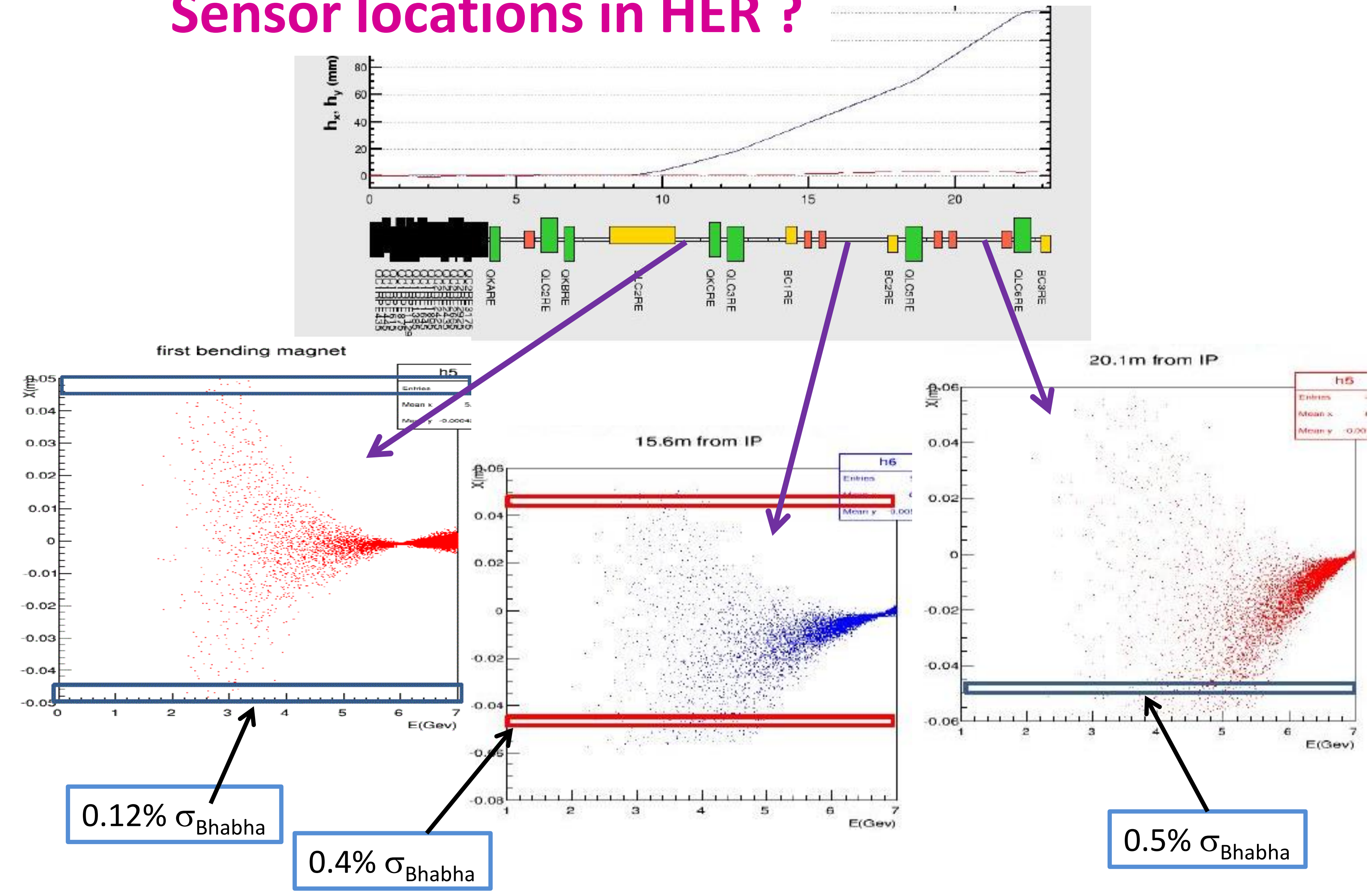


Beam pipe material & thickness studies



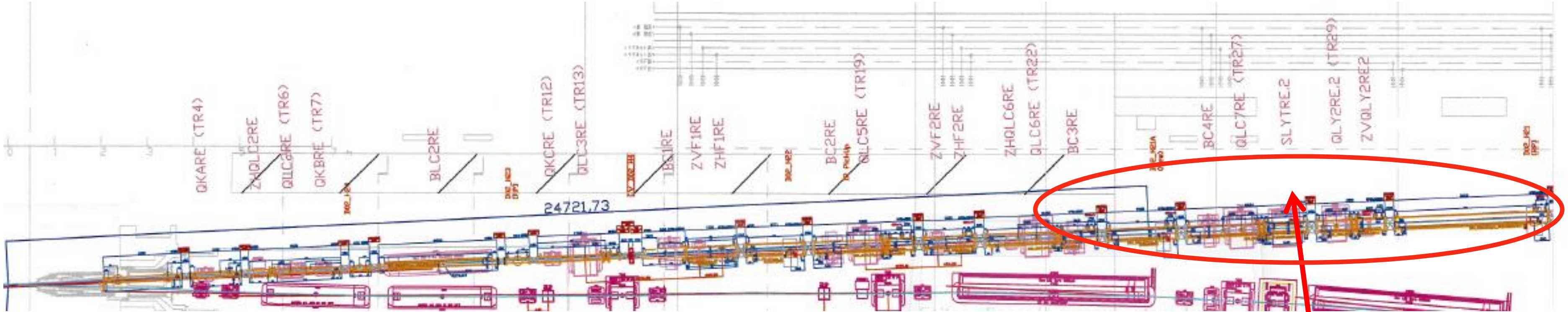
Material/ Geometry	Beam pipe thickness (mm)	Achievable precision in 1ms for L=10^{34} $cm^{-2}.s^{-1}$ (aimed: 10^{-2})	Achievable precision in 1ms for L=8 10^{35} $cm^{-2}.s^{-1}$ (aimed: 10^{-3})
Cu	**6**	**~8 10^{-2}**	**1.4 10^{-2}**
Cu	1	2.7 10^{-2}	4 10^{-3}
Al	1	1.7 10^{-2}	2.5 10^{-3}
Ti	1	2 10^{-2}	3 10^{-3}
Be	1	1.3 10^{-2}	1.9 10^{-3}
Cu Window+radiator	**6**	**7.5 10^{-3}**	**1.1 10^{-3}**

Sensor locations in HER ?

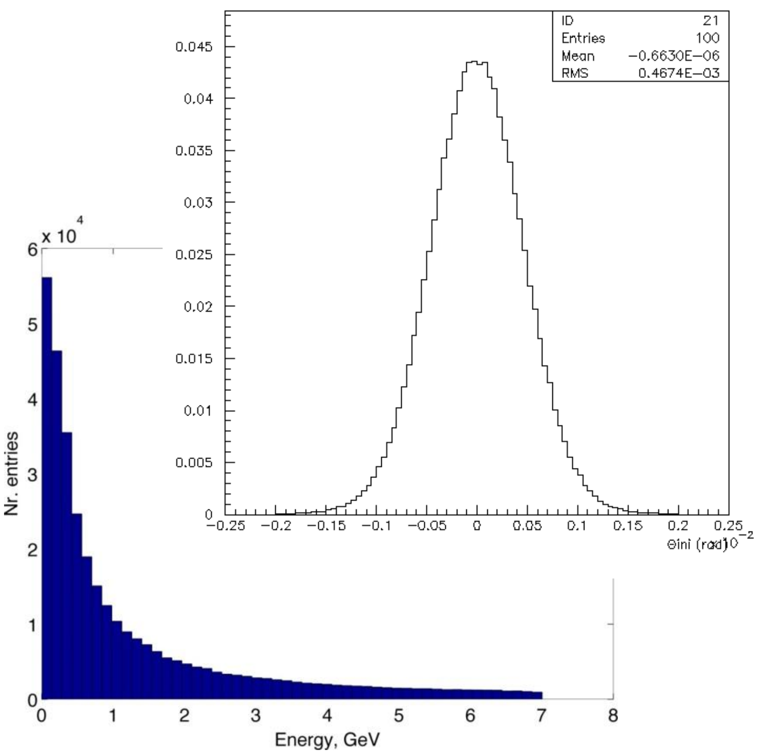


HER: “non linearity” of deflected e^- with energy, low rates.

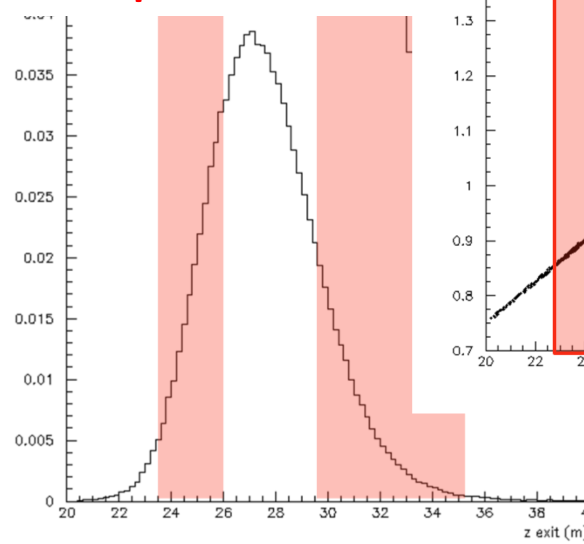
Sensor locations in HER : γ detection ?

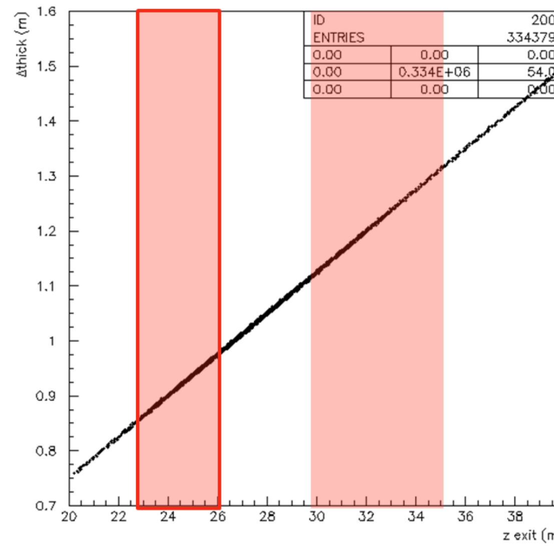


γ spot hits ante-chamber edge at SLYTRE2 (~ 27.4m downstream IP), with a mean angle of 5.9 mrad

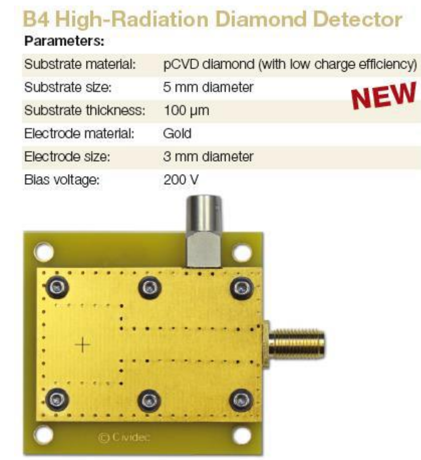


Photon spot σ : ±2.2 m





Diamond sensors

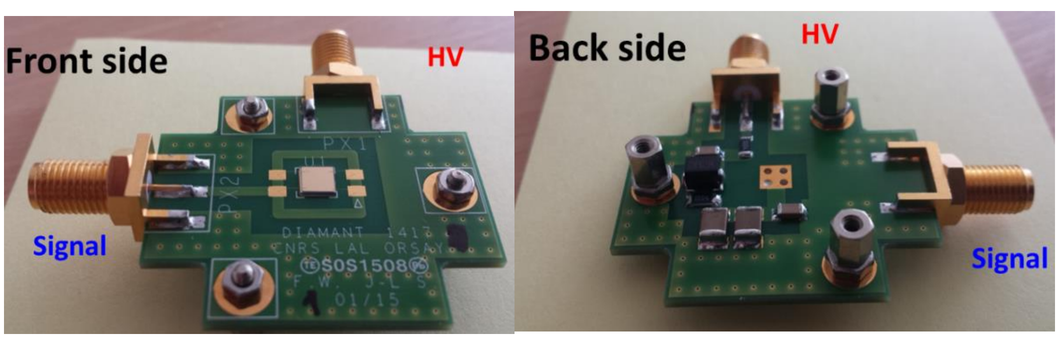


- Chemical Vapor Deposition (CVD) diamonds: studied since over a decade as alternative sensor technology for particle accelerators and detectors.
  - High tolerance to all types of radiation
  - Can be operated at room temperature as a low noise detector
  - Fast signal collection.

- Diamond sensor technology is already used and studied at LAL since 2012 at PHIL and for beam halo study at ATF2 (prototype of ILC final focus)

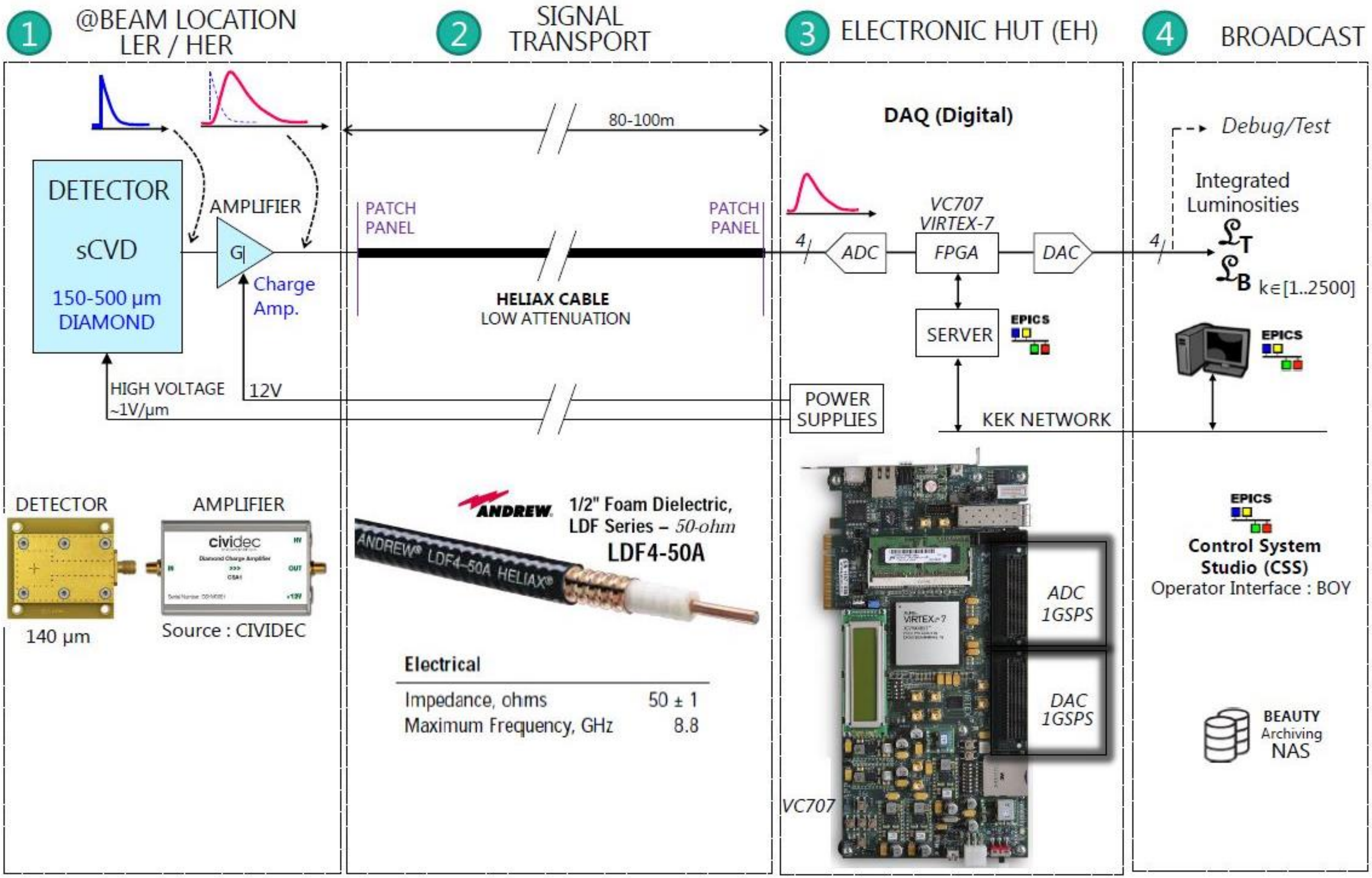
- For SuperKEKB: signal width < 1-2 ns, since 4 ns bunch spacing

• Mono-crystalline 140 um thick 5x4mm2 diamond 1 ns FWHM
• For initial operation (2016): fast charge amplifier 10 ns FWHM + 500um sCVD (β source tests and linearity tests have been performed)
Both available as off the shelf components from CIVIDEC + LAL-made diamonds
• For nominal luminosity (after 2017): develop faster charge amplifier with 2-3 ns FWHM no change in ADC + FGPA 1 GHz readout scheme



Diamond prepared @ LAL (05/2015): 500µm sCVD diamond from E6 with Ti/Pt/Au metallization from GSI

Readout


1 @BEAM LOCATION LER / HER
2 SIGNAL TRANSPORT
3 ELECTRONIC HUT (EH)
4 BROADCAST
80-100m
DETECTOR
sCVD
150-500 µm DIAMOND
AMPLIFIER
G
Charge Amp.
PATCH PANEL
PATCH PANEL
HELIAX CABLE
LOW ATTENUATION
HIGH VOLTAGE ~1V/µm
12V
POWER SUPPLIES
DAQ (Digital)
VC707 VIRTEX-7
4
ADC
FPGA
DAC
SERVER
EPICS
KEK NETWORK
Debug/Test
Integrated Luminosities
$\mathfrak{L}_T$
$\mathfrak{L}_B$ k∈[1..2500]
EPICS
DETECTOR
AMPLIFIER
cividec
140 µm
Source : CIVIDEC
ANDREW
1/2" Foam Dielectric, LDF Series – 50-ohm
LDF4-50A
ANDREW® LDF4-50A HELIAX®
Electrical
Impedance, ohms 50 ± 1
Maximum Frequency, GHz 8.8
ADC 1GSPS
DAC 1GSPS
VC707
EPICS
Control System Studio (CSS)
Operator Interface : BOY
BEAUTY Archiving NAS

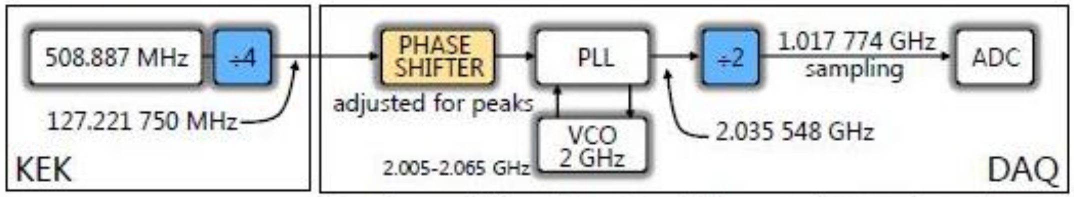
Synchronization

Cring (m)	3016.315
RF tick (MHz)	508.887
RF period (ns)	1.965
Tround-trip (µs)	10.061

The DAQ will use the **127.221 MHz** clock to synchronize the DAQ

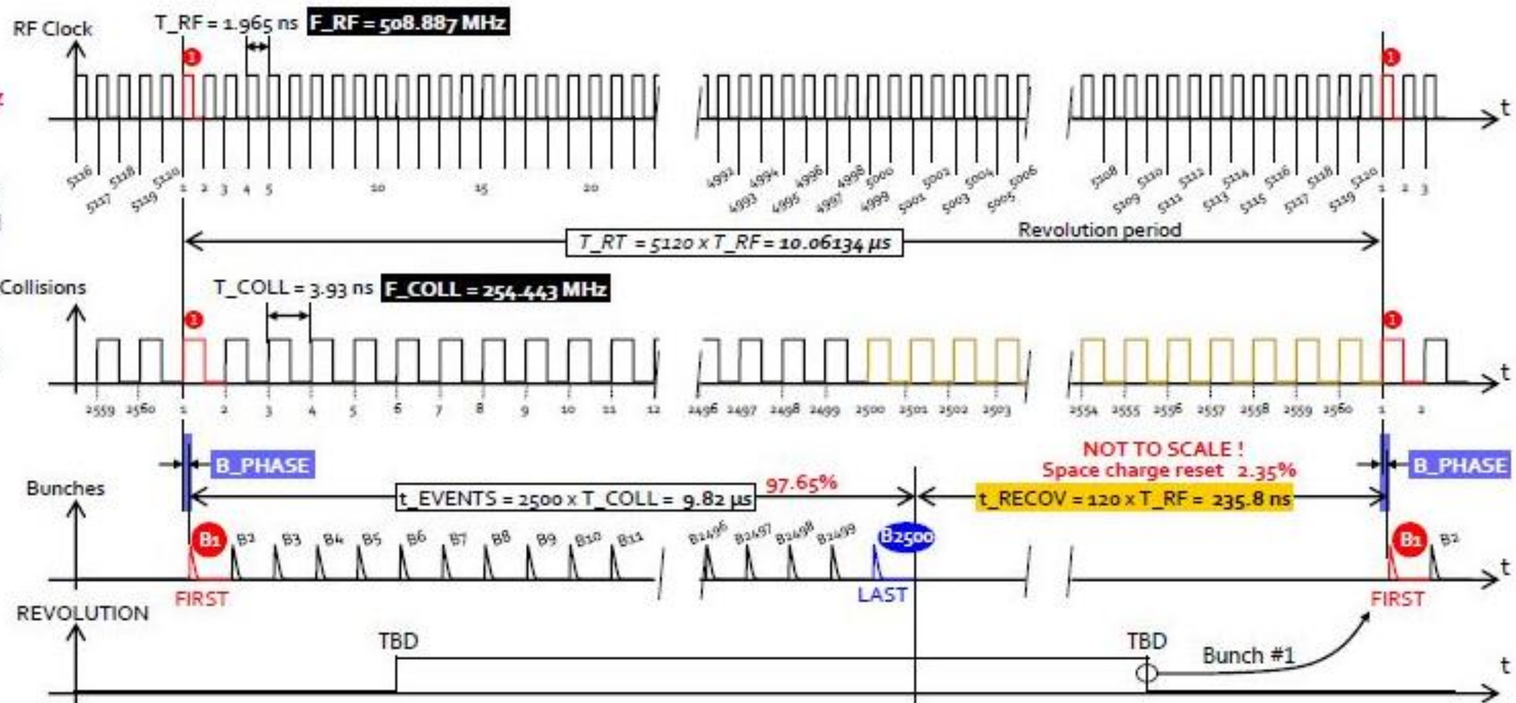
RF_clock (508.887 MHz) / 4 = 127.221 MHz

A PLL will generate the **2.035 548 GHz** clock for the ADC, as follow :



The **phase shifter** allows to set the sampling on the pulse peak of each bunch B1-B2500

- The accelerator RF Clock frequency is F_RF = 508.887 MHz
- The ring round-trip period T_RT is 5120 times the RF Clock period
- The max collision frequency is F_RF / 2 : F_COLL = **254.443 MHz**
- The phase between RF Clock and collision bunches is called **B_PHASE**
- The **REVOLUTION** signal (square) is used to **number** the bunches from 1 to 2500



Program during JENNIFER

- Finalize beam pipe geometry optimization in LER for e^+ detection → decision by SuperKEKB vacuum group for installation in 2017

- Evaluation of scattered γ rates in the HER, using existing detailed 3D drawings of the beam pipe around the identified location 27 m from IP. (summer 2015)

- Improved simulation and evaluation of beam gas bremsstrahlung rates in the LER and HER for phase one tests and measurements in 2016 (summer 2015)

- Installation of the LAL digital DAQ at KEK and synchronization tests with the SuperKEKB RF clocks. (summer 2015 ?, according to KEK signal avaibility)

- 500um sensor(s) installation in LER, at 13.9m (autumn 2015)

- Phase 1 tests: bremsstrahlung detection and measurements (Winter 2016)

- 2016 Initial background measurement analysis. (Spring 2016)
  Finalise design of data acquisition for luminosity monitoring (Summer 2016)
  installation of sCVD in HER (Autumn 2016)
- 2017 First data for luminosity monitoring
  Analysis
  Optimization in context of luminosity feedback (4 sensors)
  Development of faster than 10 ns low noise charge amplifier to match 140 μm thick diamond signals with the design luminosity 8 10^{35} $cm^{-2}s^{-1}$ (just started @ LAL)

Collaborating teams on Luminosity Monitoring for Belle-II/SuperKEKB

LAL-Orsay

Philip Bambade
Frédéric Bogard – mech. eng.
Dima El Kechen – PhD student
Didier Jehanno – elec. Eng., DAQ
Viacheslav Kubytskyi
Cécile Rimbault

KEK

Yoshihiro Funakoshi – SuperKEKB
Ken-Ichi Kanazawa – SuperKEKB/vacuum pipe
Yukiyoshi Ohnishi – SuperKEKB/beam loss MC
Yusuke Suetsugu – SuperKEK/vacuum pipe
Sadaharu Uehara – Belle-II/ZDLM
Hiroyuki Nakayama – Belle-II/BEAST

Related collaborations:

- **SLAC** (U. Wienands et al.): luminosity feedback through dithering technique
- **IPHC-Strasbourg** (I. Ripp-Baudot et al.): characterize beam backgrounds in Belle-II

ZDLM = Zero Degree Luminosity Monitor

BEAST = Beam Exorcism for A STable Belle-experiment

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