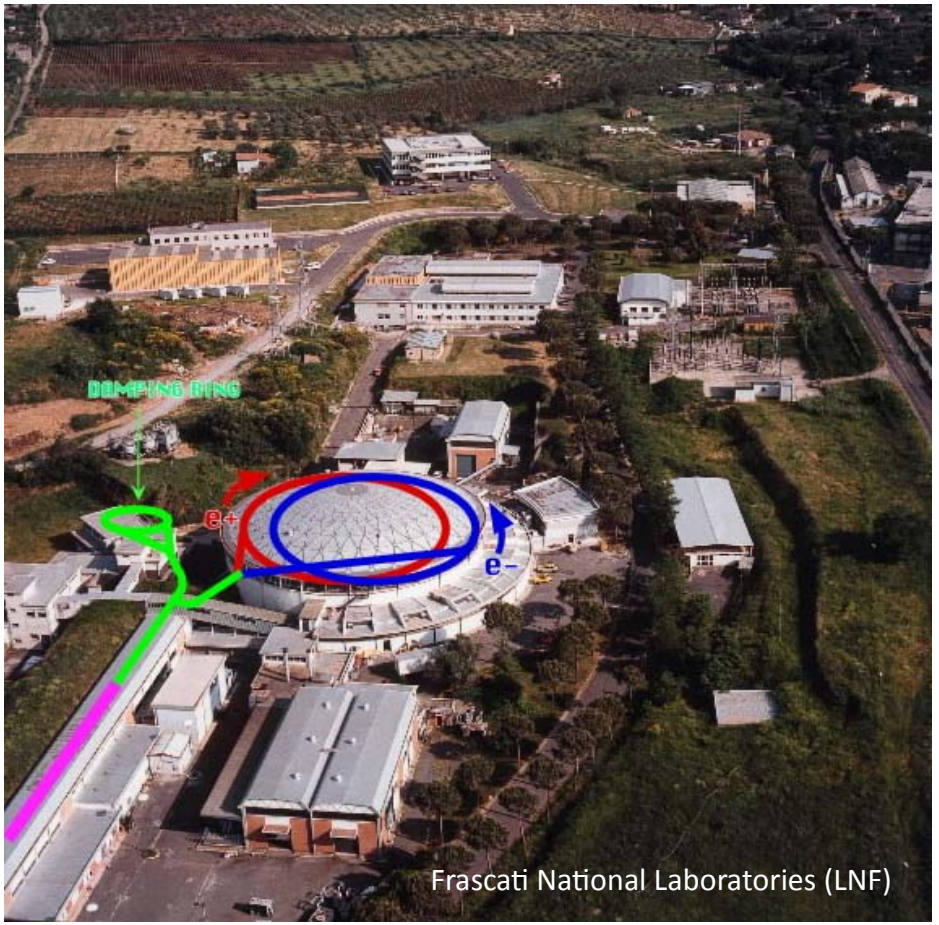
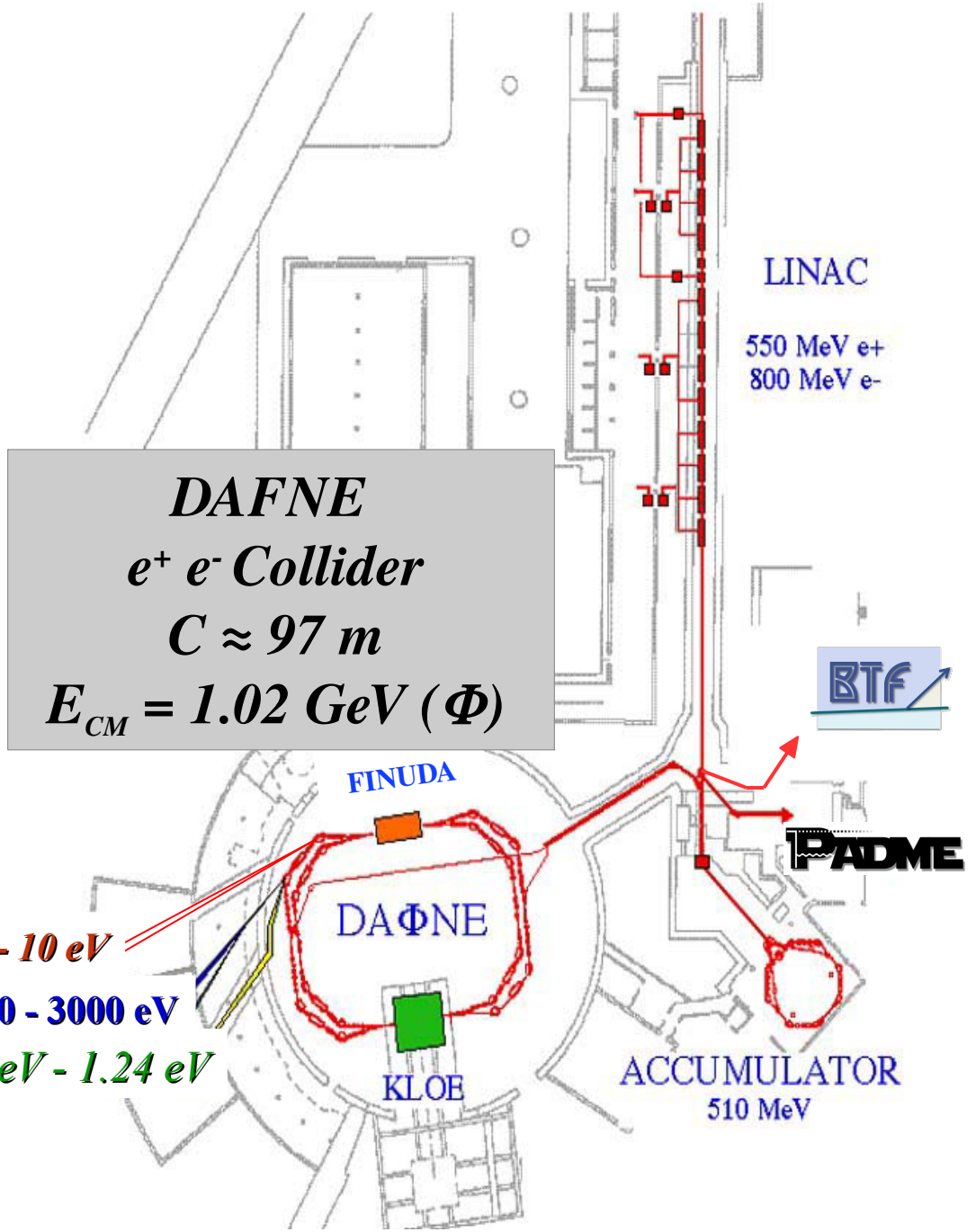
DAFNE Status

Antonio De Santis (LNF)

on behalf of DAFNE team

The DAFNE Accelerator Complex





LNF are also part of the European synchrotron light Infrastructures network

DAFNE History & Plans

DAFNE is an electron-positron collider designed in the mid ‘90s, it came into operation in 2000.

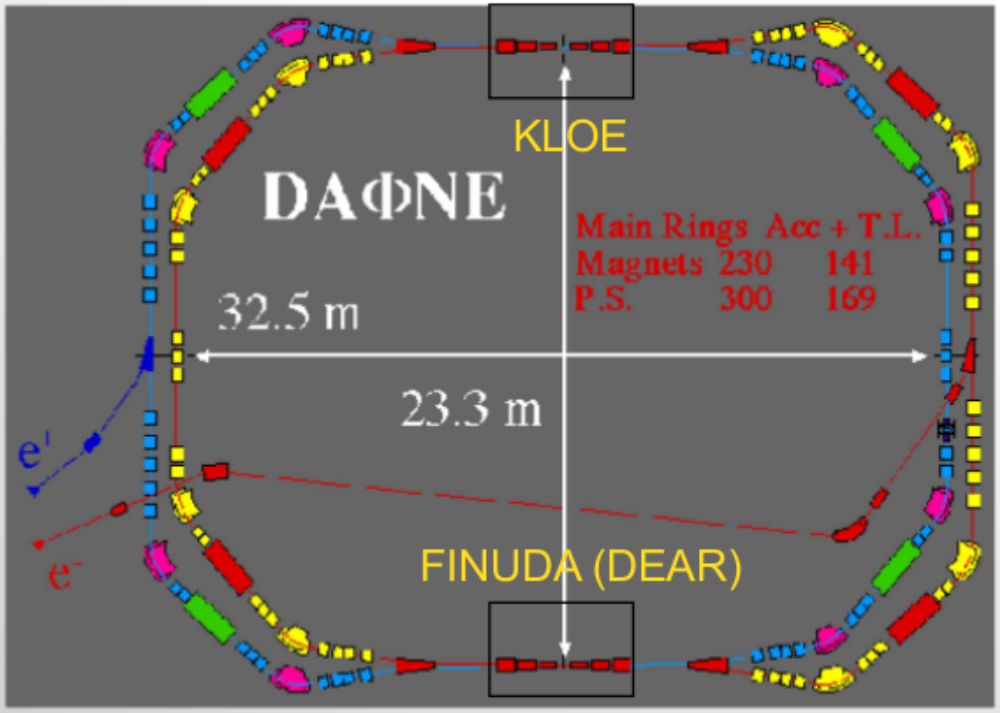
It has been providing data in consecutive data-taking periods to:

- KLOE, DEAR and FINUDA experiments until 2007 with it’s original designed Interaction Region
- SIDDHARTA and KLOE-2 between 2008-2009 and 2014-2018 with **Crab-Waist Interaction Region**

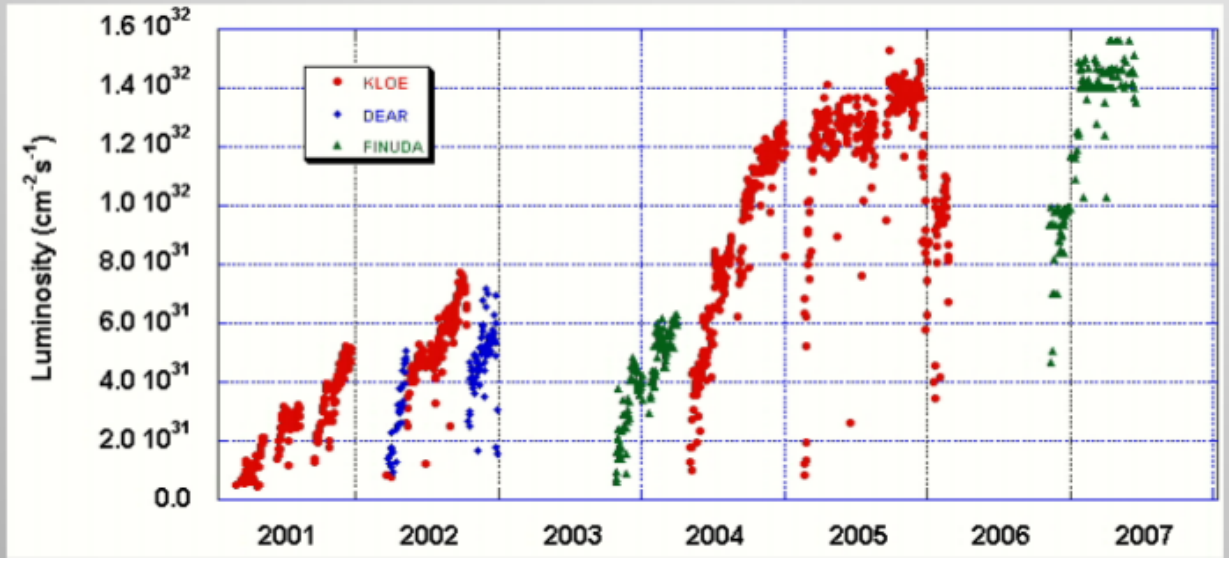
A new Physics Run of SIDDHARTA-2 has been approved and a revised Interaction Region, always with Crab-Waist scheme is on-going.

Because of pandemic, currently the DAFNE LINAC is delivering data to the PADME experiment.

Luminosity achievements (native configuration)



"Proposal for a Φ-factory", G. Vignola et al., LNF-90/031 (IR),1990.



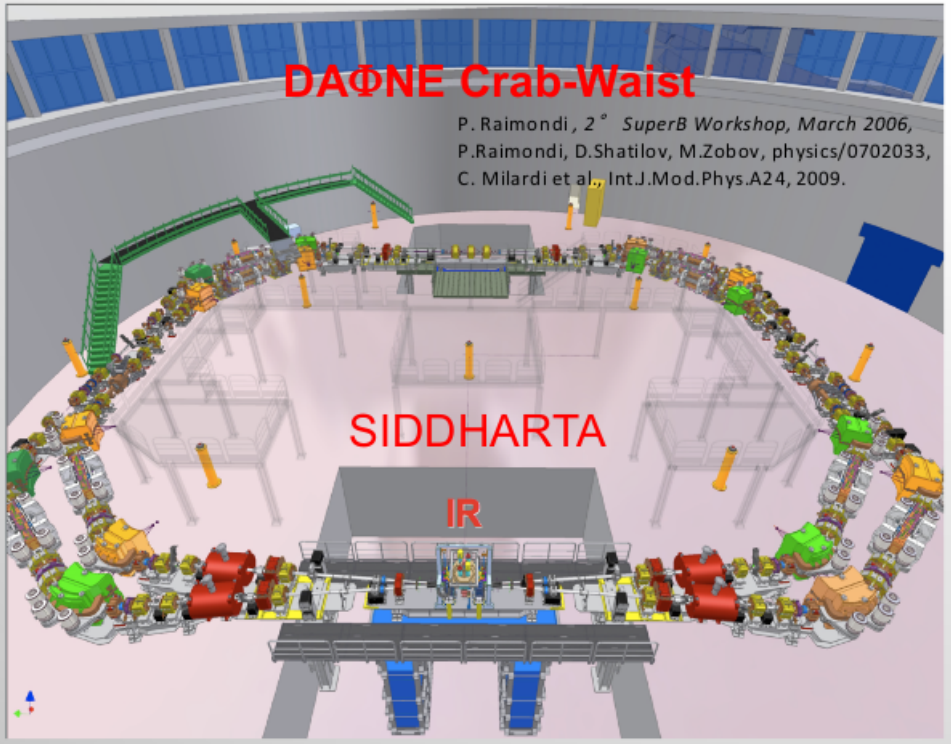
	DAΦNE native
Energy (MeV)	510
$\theta_{cross}/2$ (mrad)	12.5
ε_x (mm•mrad)	0.34
β_x^* (cm)	160
σ_x^* (mm)	0.70
$\Phi_{Piwinski}$	0.6
β_y^* (cm)	1.80
σ_y^* (μm) low current	5.4
Coupling, %	0.5
Bunch spacing (ns)	2.7
I_{bunch} (mA)	13
σ_z (mm)	25
N_h	120

L_{logged} (fb^{-1}) 2001÷2007

KLOE	3.0
FINUDA	1.2
DEAR	0.2

Crab-Waist Collision Test Run

Tested with the SIDDHARTA detector in 2008÷2009



	DAΦNE native	DAΦNE *Crab-Waist*
Energy (MeV)	510	510
$\theta_{cross}/2$ (mrad)	12.5	25
ε_x (mm•mrad)	0.34	0.28
β_x^* (cm)	160	23
σ_x^* (mm)	0.70	0.25
$\Phi_{Piwinski}$	0.6	1.5
β_y^* (cm)	1.80	0.85
σ_y^* (μm) low current	5.4	3.1
Coupling, %	0.5	0.5
Bunch spacing (ns)	2.7	2.7
I_{bunch} (mA)	13	13
σ_z (mm)	25	15
N_h	120	120

- Large Piwinski angle and Crab-Waist scheme provided:
  optimal control of the beam-beam interaction
  a factor 3 higher L_{peak}
  complete elimination of the LRBB

$L_{peak} = 4.5*10^{32}\ cm^{-2}\ s^{-1}$
$L_{\int 1\ day} = 15.0\ pb^{-1}$
$L_{\int 1\ hour} = 1.033\ pb^{-1}$ *(test run)*
$L_{\int run} \sim 2.8\ fb^{-1}$ *(logged by the experiment)*

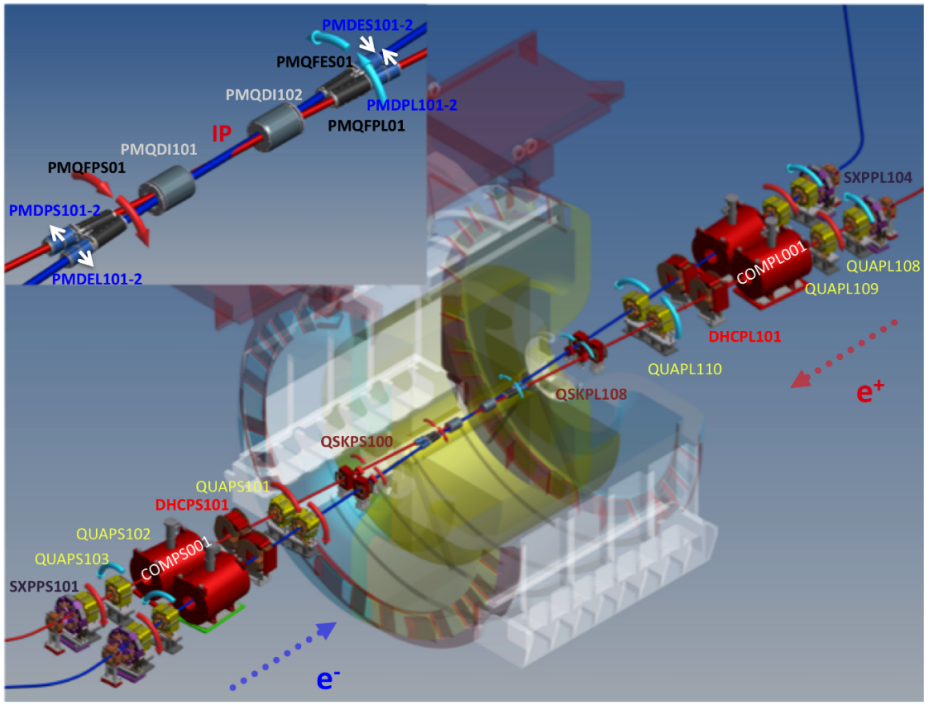
M. Zobov et al., Phys.Rev.Lett.104:174801, 2010.

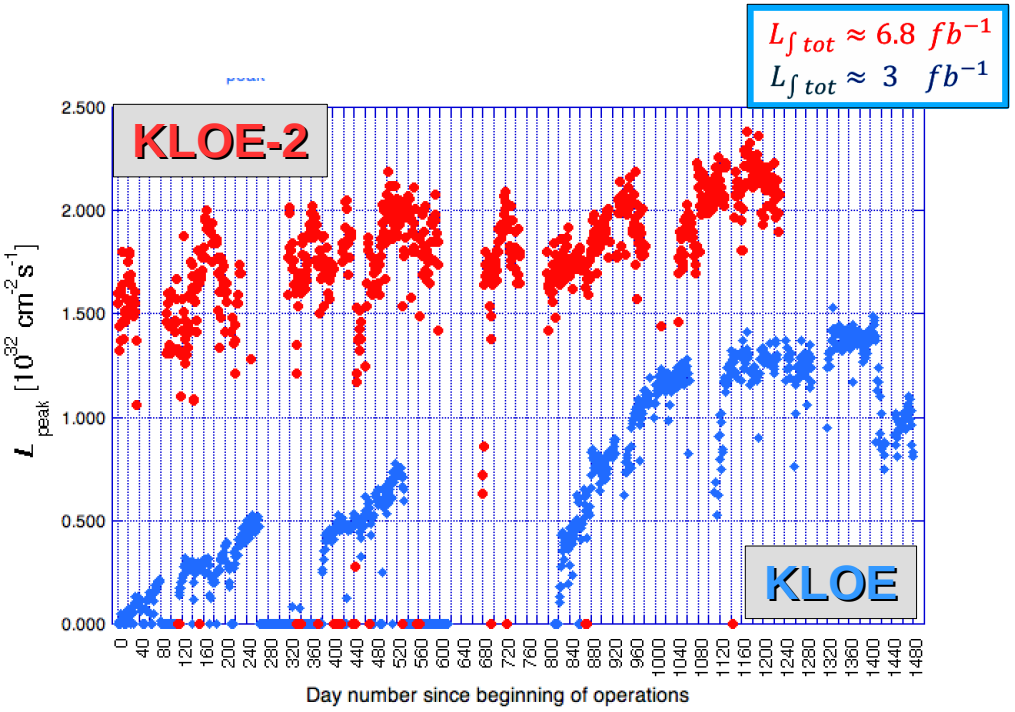
Crab-Waist Collision with KLOE-2

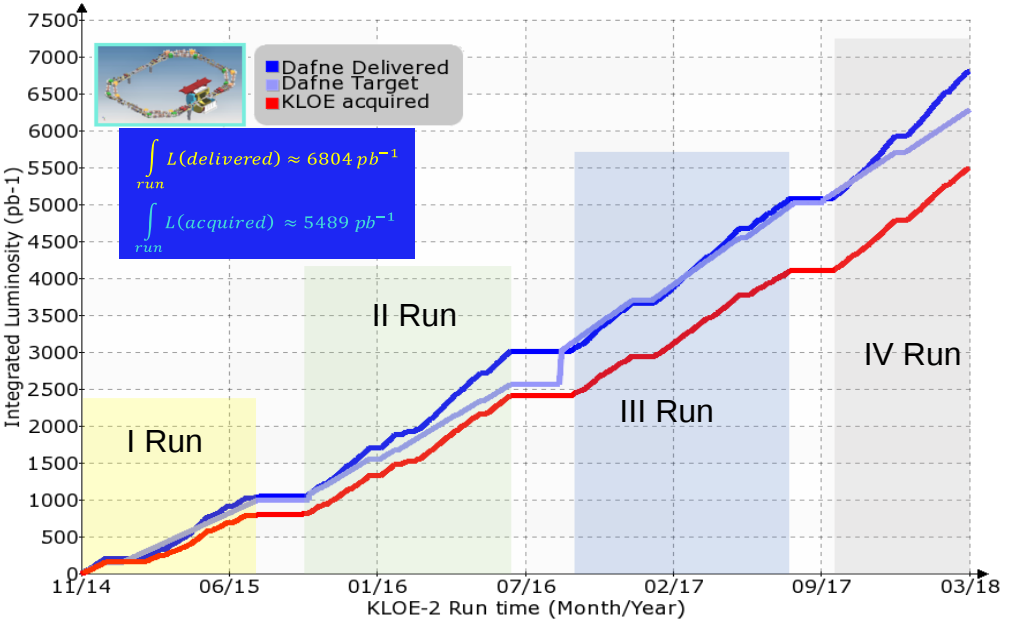
Crab-Waist collision scheme implemented for the first time with a large detector including a high intensity axial field.

PM's reused with new lattice scheme to correct coupling

The new approach to collision provided a ~60% improvement in terms of L_{peak}





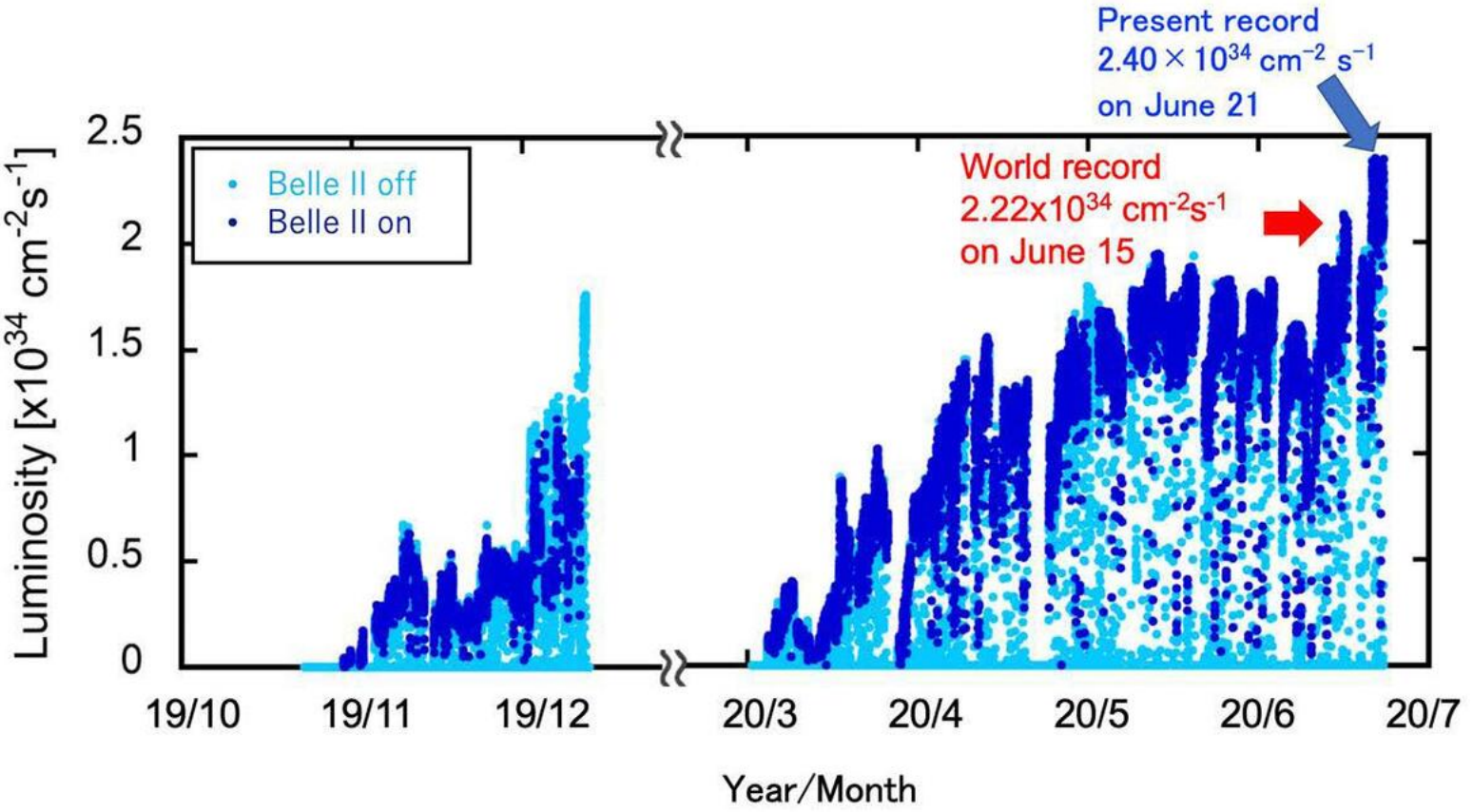


Crab-Waist Colliders

Colliders	Location	Status
DAΦNE	Φ-Factory Frascati, Italy	In operation (SIDDHARTA, KLOE-2, **SIDDHARTA-2**)
SuperKEKB	B-Factory Tsukuba, Japan	*Crab-Waist adopted in April 2020*
SuperC-Tau	C-Tau-Factory Novosibirsk, Russia	Russian mega-science project
FCC-ee	Z,W,H,tt-Factory CERN,Switzerland	100 km, CDR
CEPC	Z,W,H,tt-Factory China	100 km, CDR released in September 2018
HIEPA	2-7 GeV China	Considered option

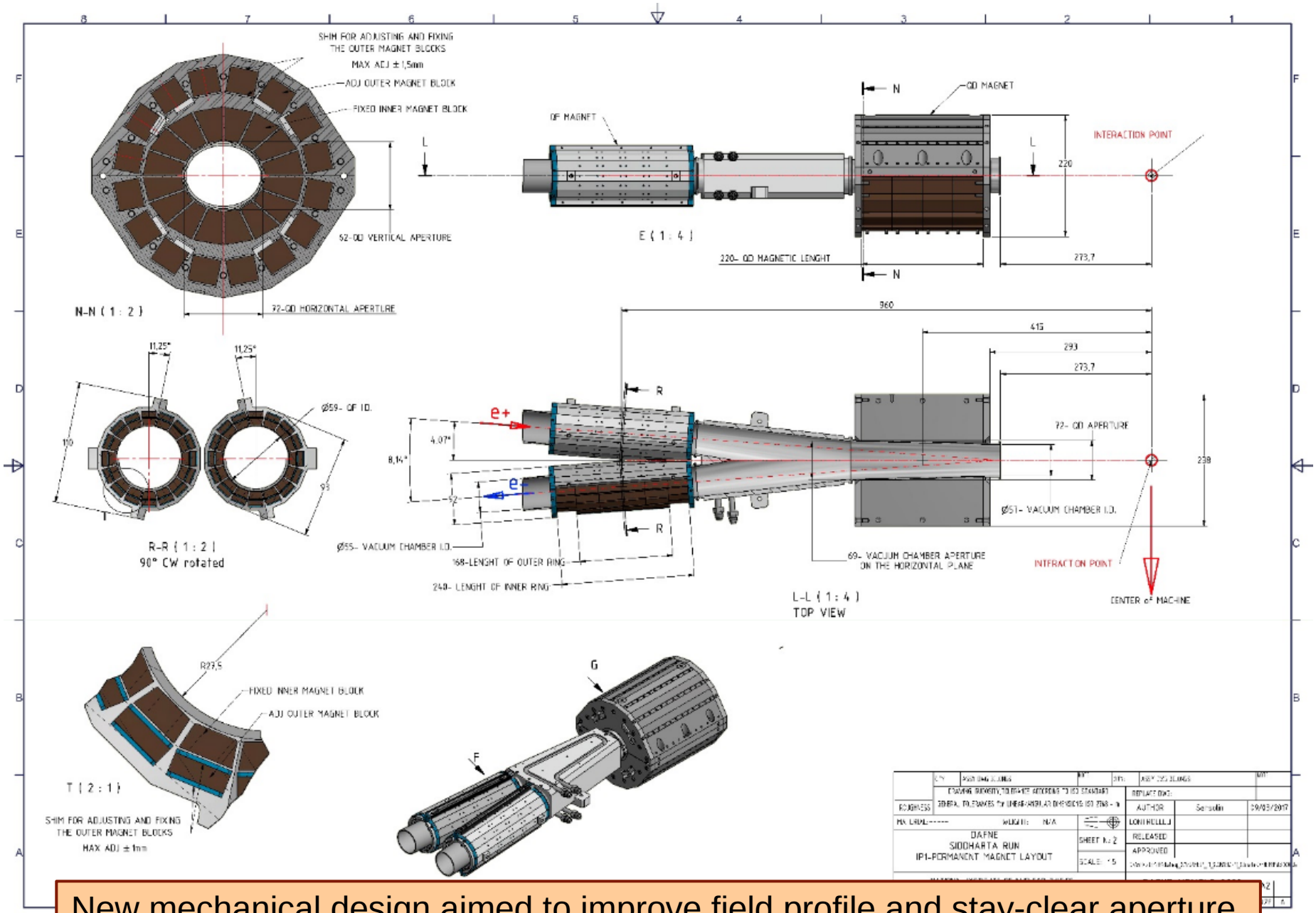
Crab-Waist in the world

SuperKEKB collider achieves the world's highest luminosity (KEK press release of 26 June 2020)



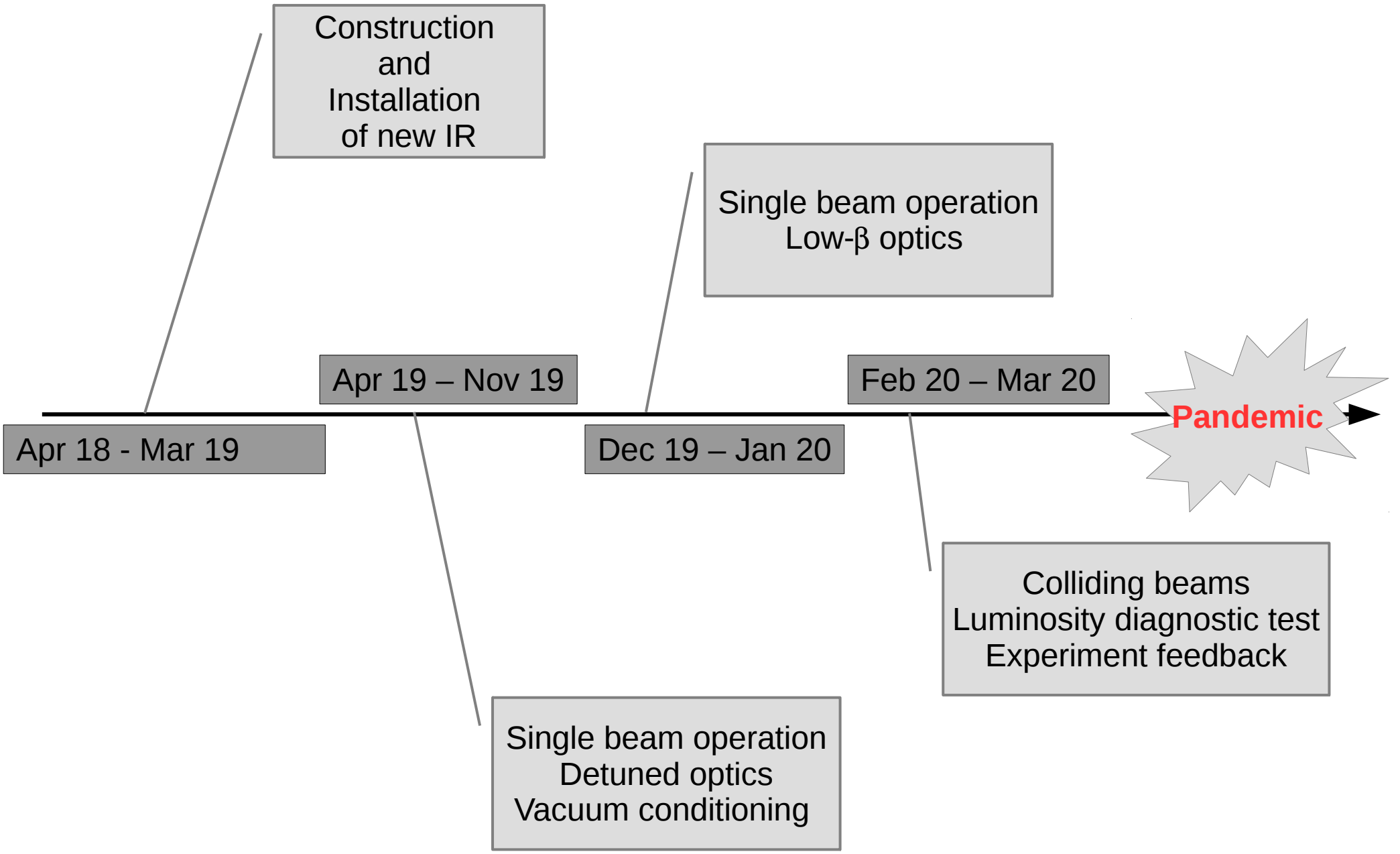
"…The most recent improvement was completed in April 2020, with the introduction of the "crab waist", first used at the DAΦNE accelerator in Frascati, Italy, in 2010, and which reduces the beam size and stabilizes collisions…"

DAFNE for SIDDHARTA-2: new IR



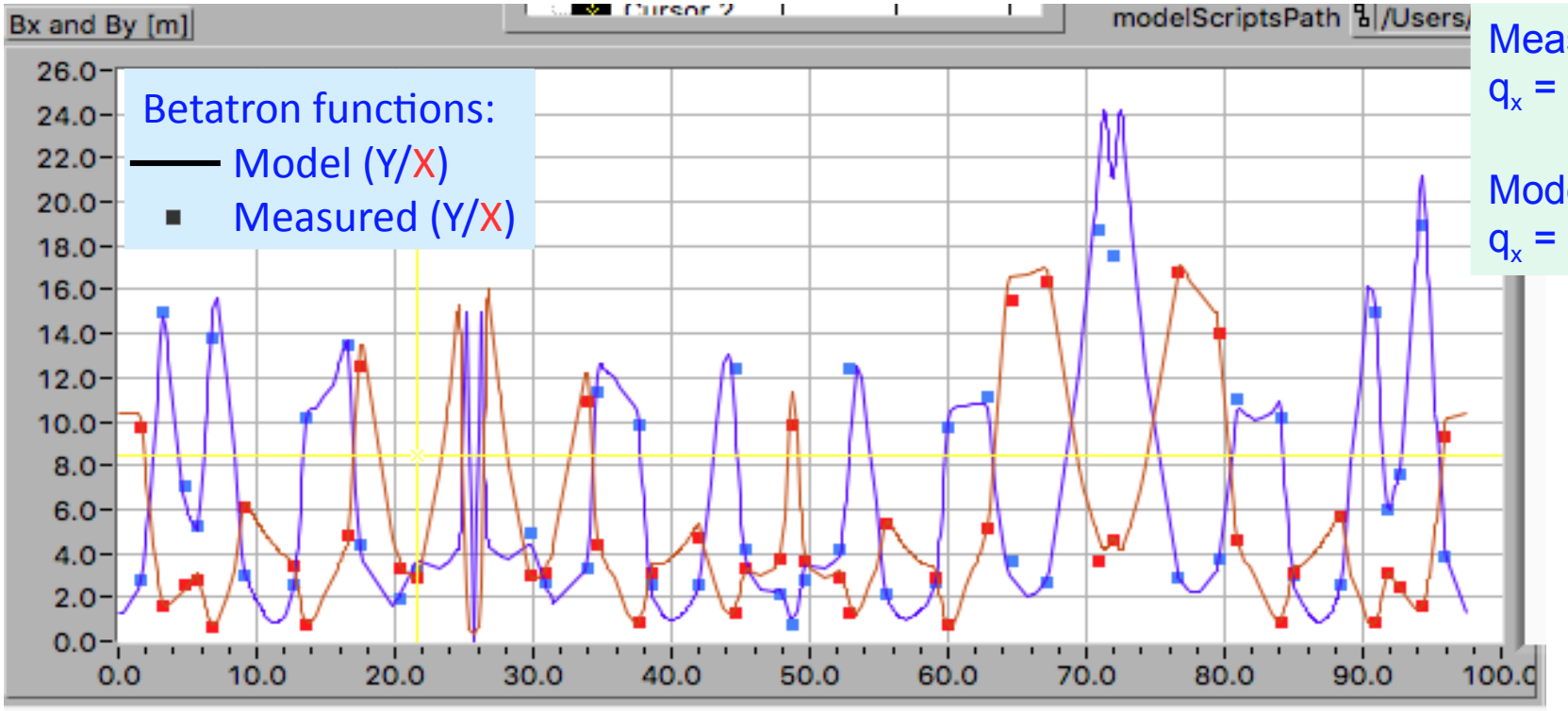
New mechanical design aimed to improve field profile and stay-clear aperture to reduce background on the detector

SIDDHARTA-2 Physics run time line



All periods includes planned beaks (Summer/Christmas) and unplanned one (delay/faults)

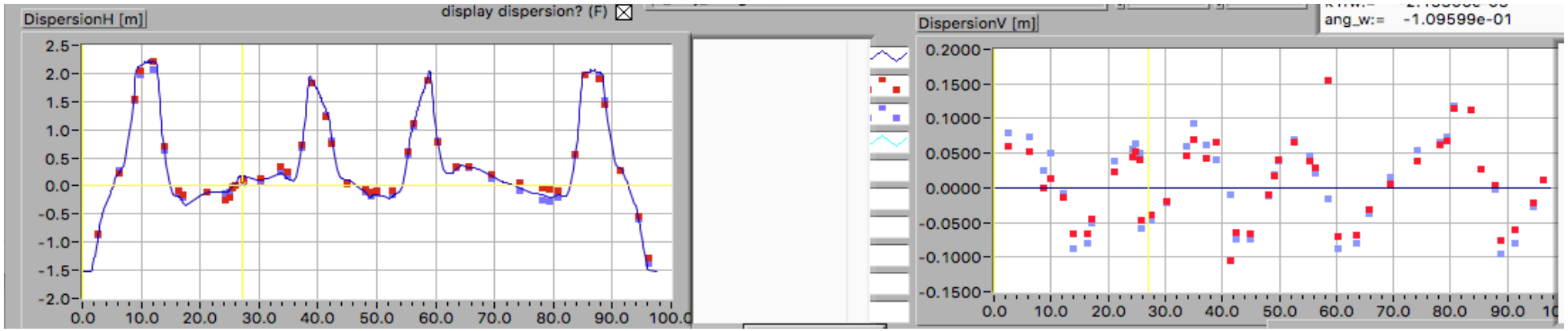
Electron ring: linear lattice optics



Measured tunes:
q_x = 5.122 q_y = 5.2072

Model tunes:
q_x = 5.1061 q_y = 5.2170

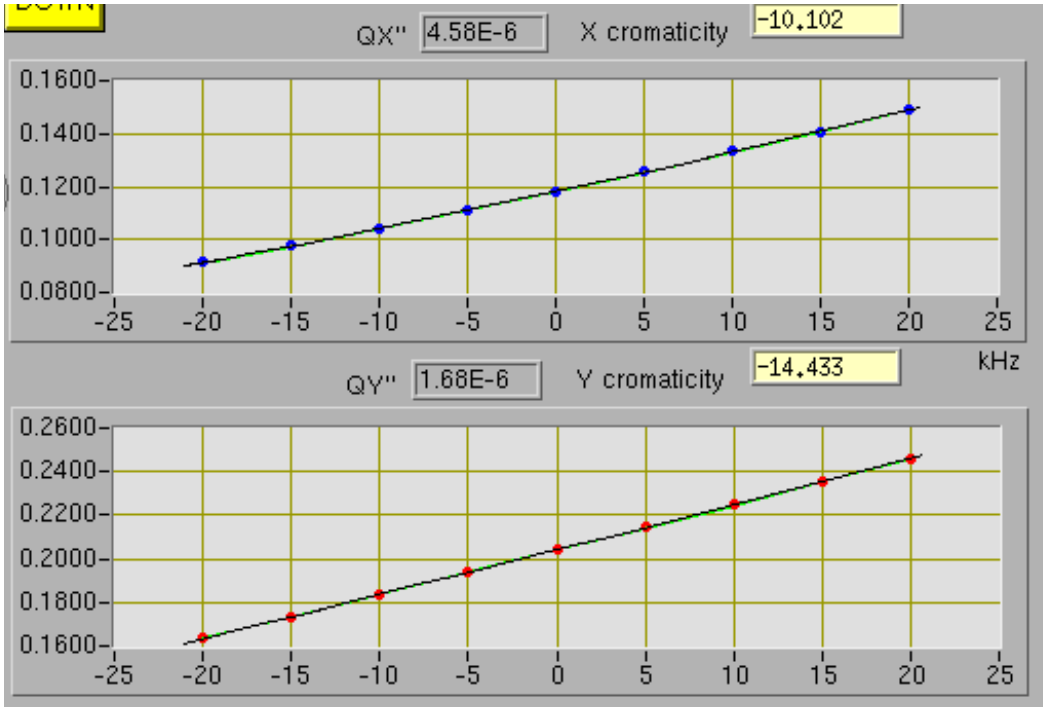
β^*_y = 0.009 m
β^*_x = 0.28 m



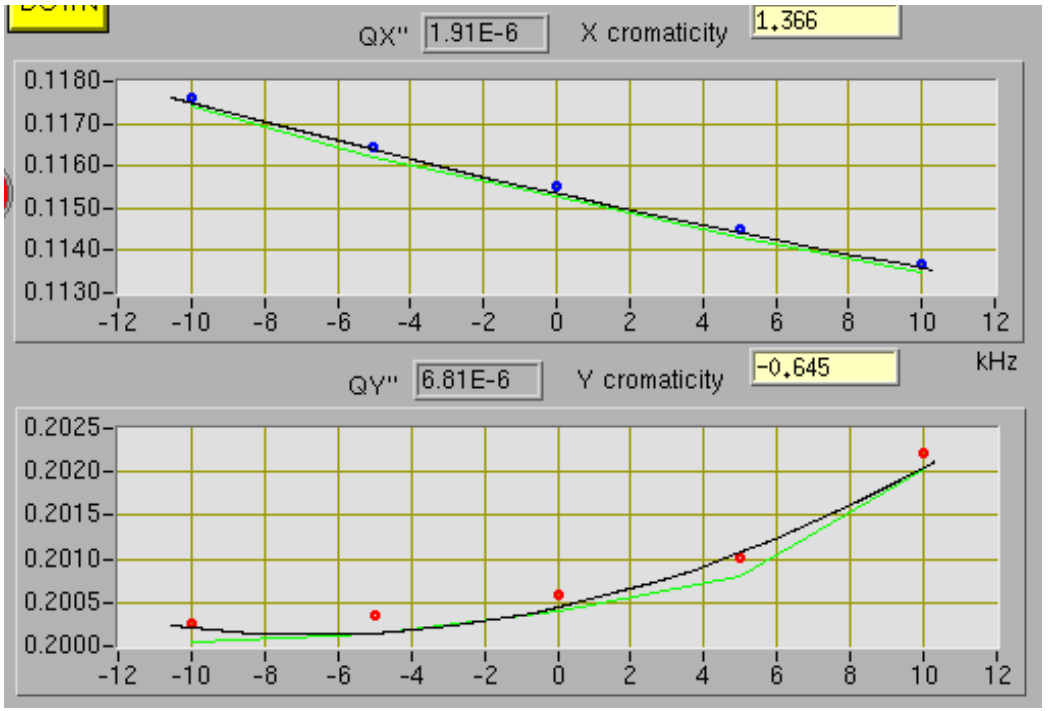
Dec 19 – Jan 20

Electron ring: Chromaticity

Natural ξ



Corrected ξ



- **ξ" negligible**
- **Wide Energy Aperture**

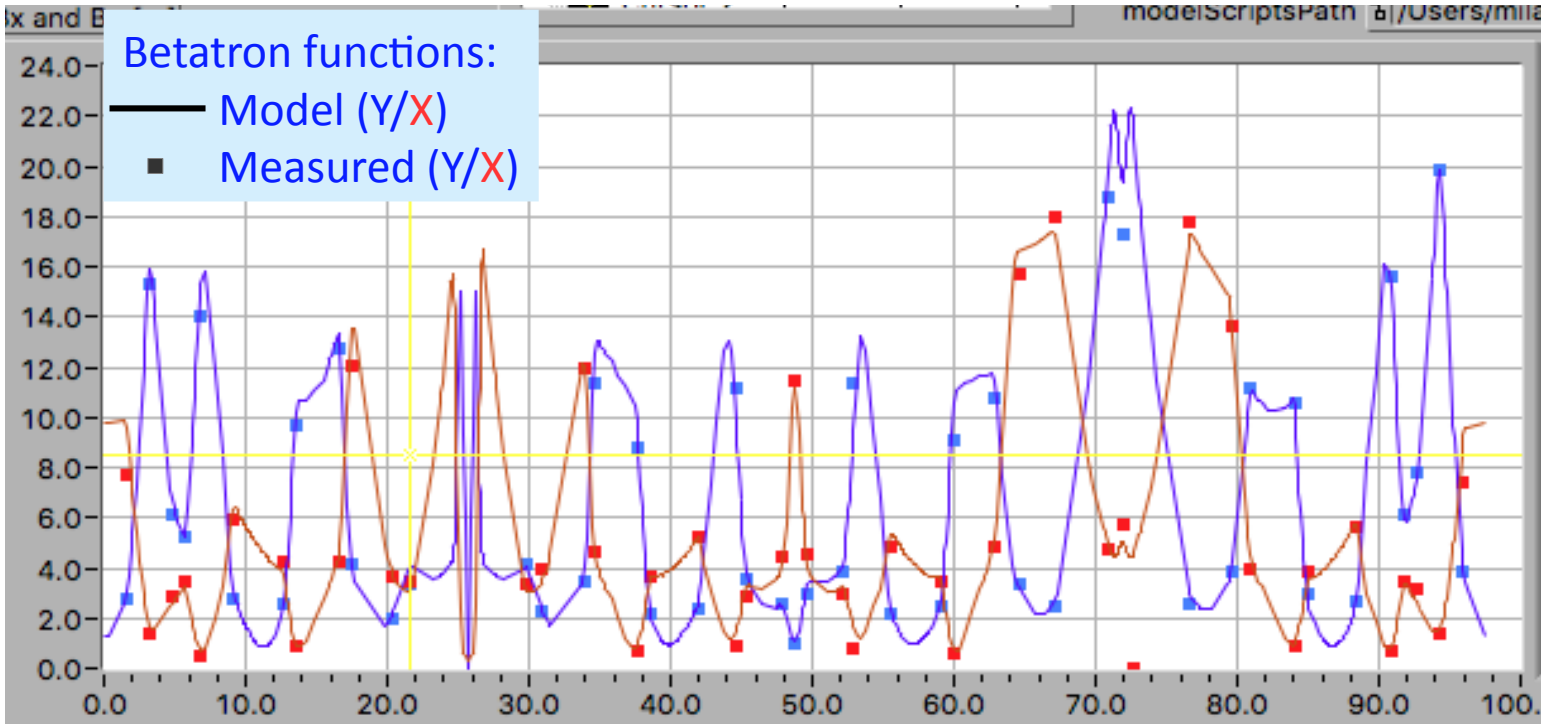
  $-0.7\% \Delta E/E \leq A_E \leq 1.1\% \Delta E/E$

  A_E is a factor 2 higher than the best achieved with the detuned optics
- **SXTs setup**:

  has negligible impact on beam orbit does not affect σ_y
- **good lifetime**

Dec 19 – Jan 20

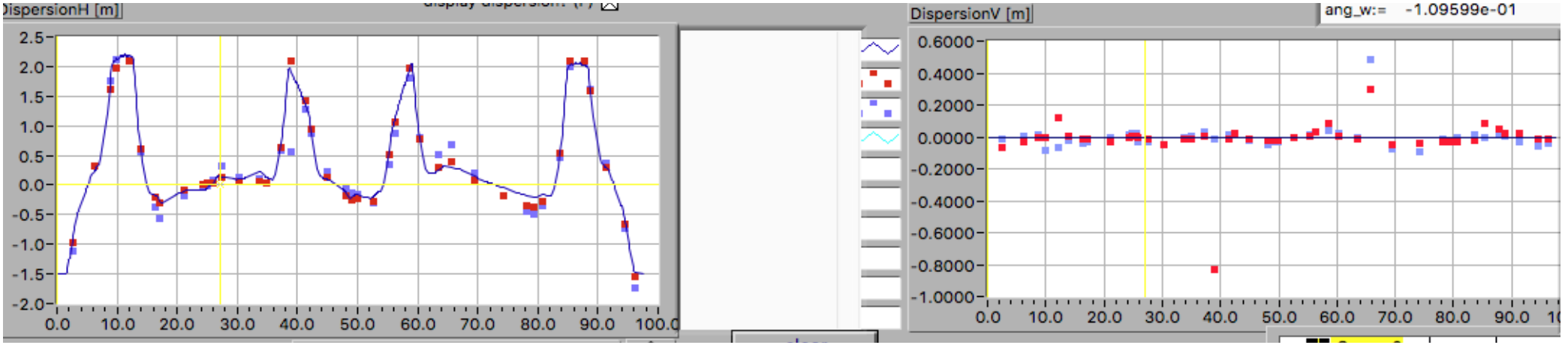
Positron ring: linear lattice optics



Measured tunes:
$q_x = 5.0954$ $q_y = 5.1860$

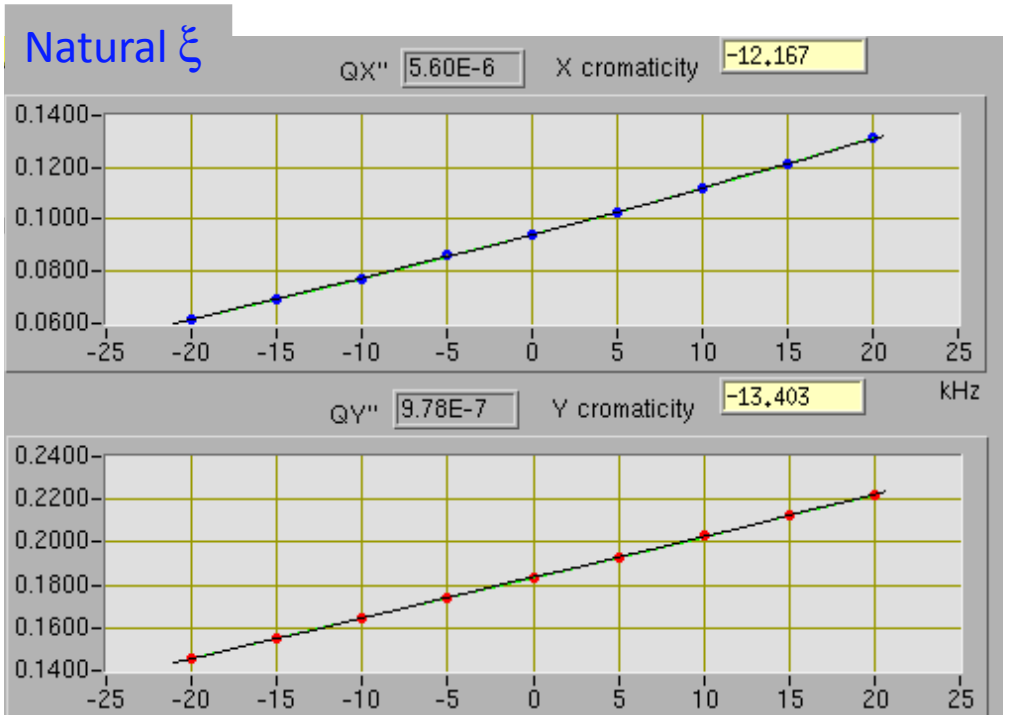
Model tunes:
$q_x = 5.1053$ $q_y = 5.1781$

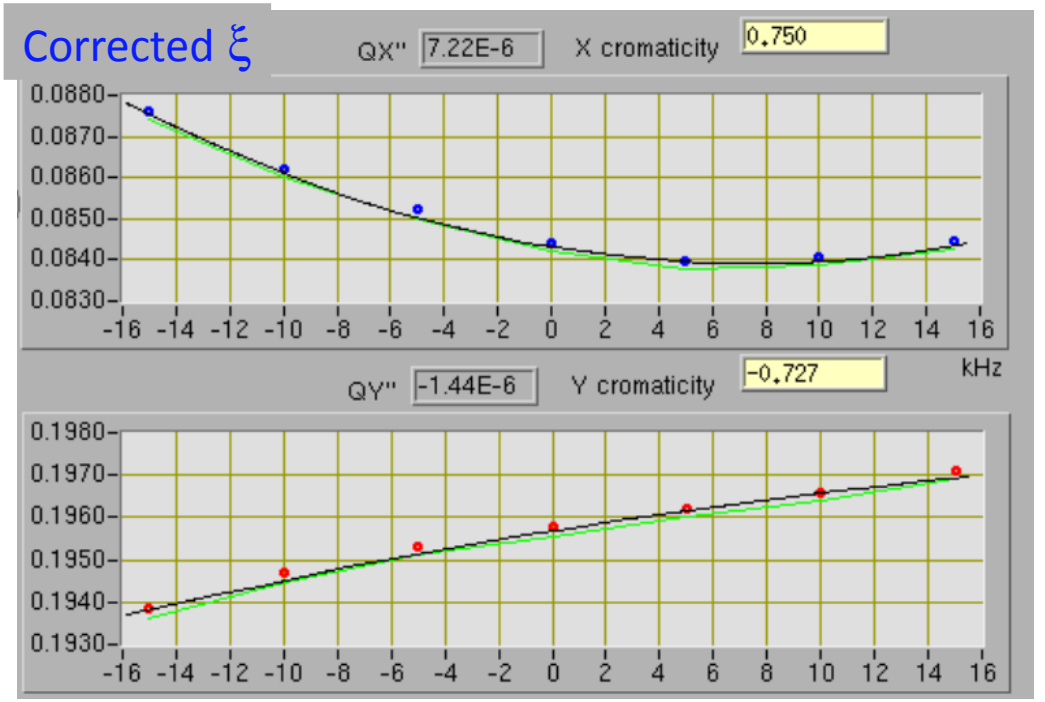
$\beta^*_y = 0.009$ m
$\beta^*_x = 0.28$ m



Dec 19 – Jan 20

Positron ring: Chromaticity





- **ξ" negligible**
- **Wide Energy Aperture:**
  - 0.9% $\Delta E/E \leq A_E \leq 1.3\% \Delta E/E$
  - A_E is a factor 2 higher than the best achieved with the detuned optics
- **SXTs setup**

  has negligible impact on beam orbit does not affect σ_y
- **good lifetime**

Dec 19 – Jan 20

Crab-Waist Optics Features

$\beta^*_y = 0.008$ m
$\beta^*_x = 0.26$ m

$\alpha^*_y = -2.08$ E-07
$\alpha^*_x = 5.6$ E-05

$\eta^*_x = \eta'^*_x = 0.0$

$\beta^{septum}_x = 11.52$ m
$\Delta\nu_x = \pi$ (between Injection KCKs)
η_x negligible at: RF and RCR

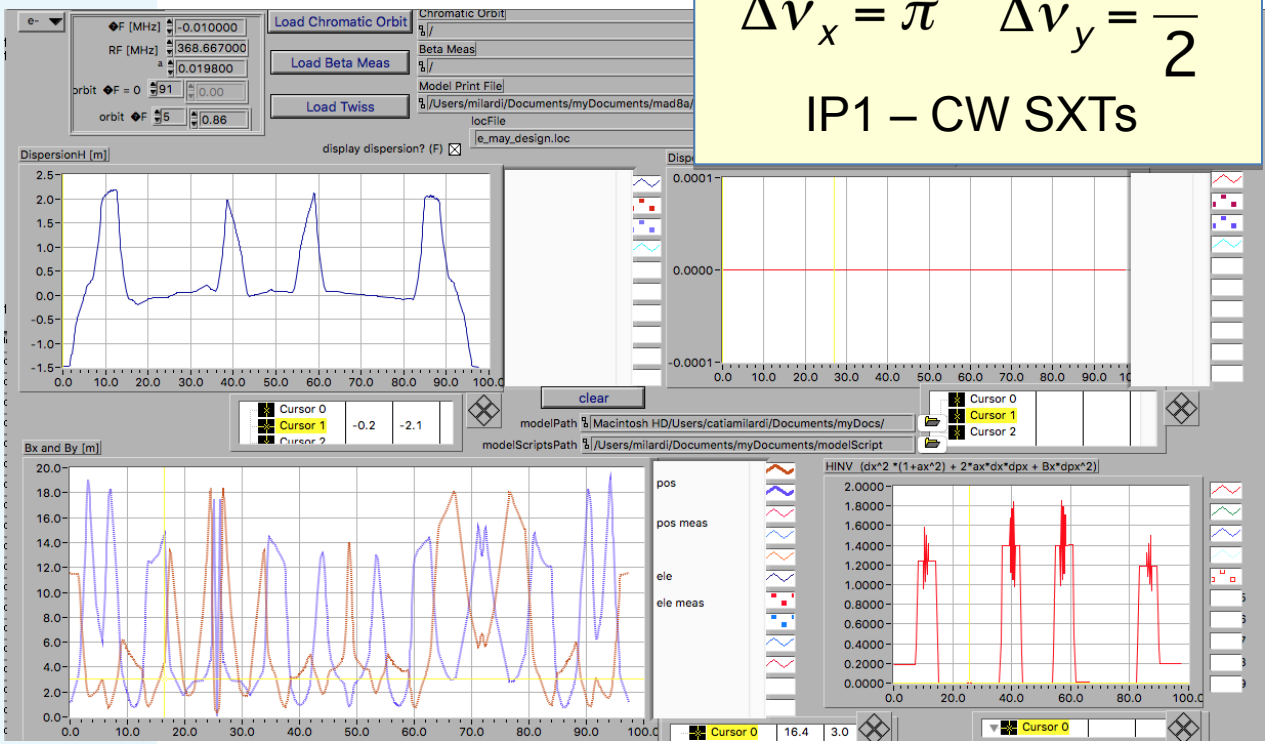
$\nu_x = 5.105$
$\nu_y = 5.16$

$\Delta\nu_y$ IP1- CW SXTs verified by closed orbit bump

CW SXTs strength increased by ~ 7% wrt. the SIDDHARTA run

$$\Delta\nu_x = \pi \quad \Delta\nu_y = \frac{\pi}{2}$$

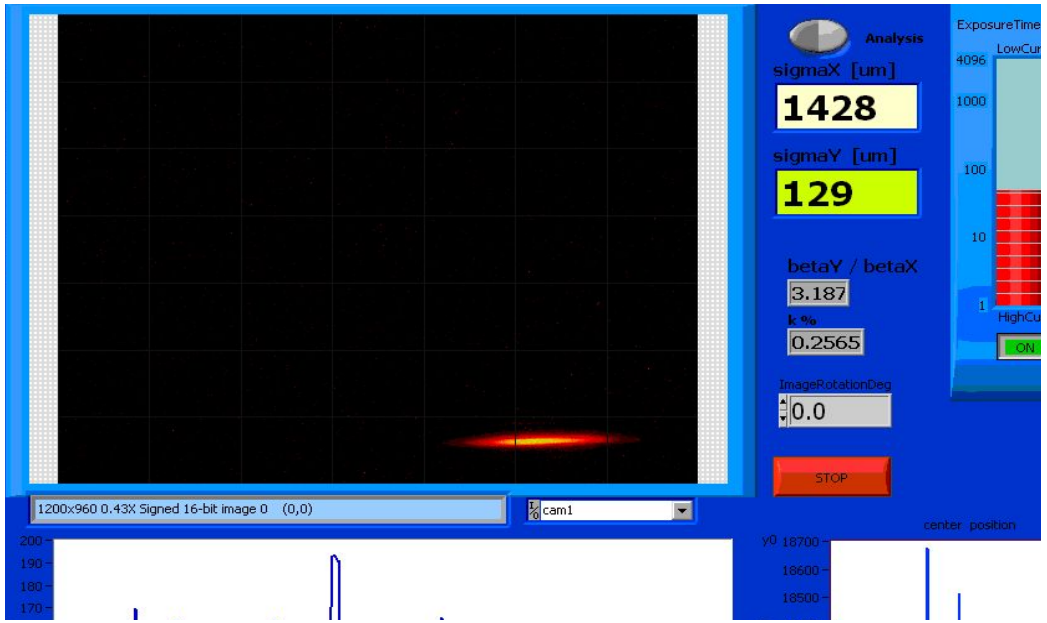
IP1 – CW SXTs



$$k_s = \frac{\chi}{2\theta}\frac{1}{\beta^*_y \beta^{sext}_y}\sqrt{\frac{\beta^*_x}{\beta^{sext}_x}}$$

Dec 19 – Jan 20

Betatron coupling in DAFNE main rings



$\kappa \sim 0.25\ \%$ at SLM

SXTs ON

CW SXTs ON

Few QSK ON

$\kappa \sim 0.7\ \%$ at SLM

SXT ON (induce small beam tilt)

solenoids ON

QSK OFF

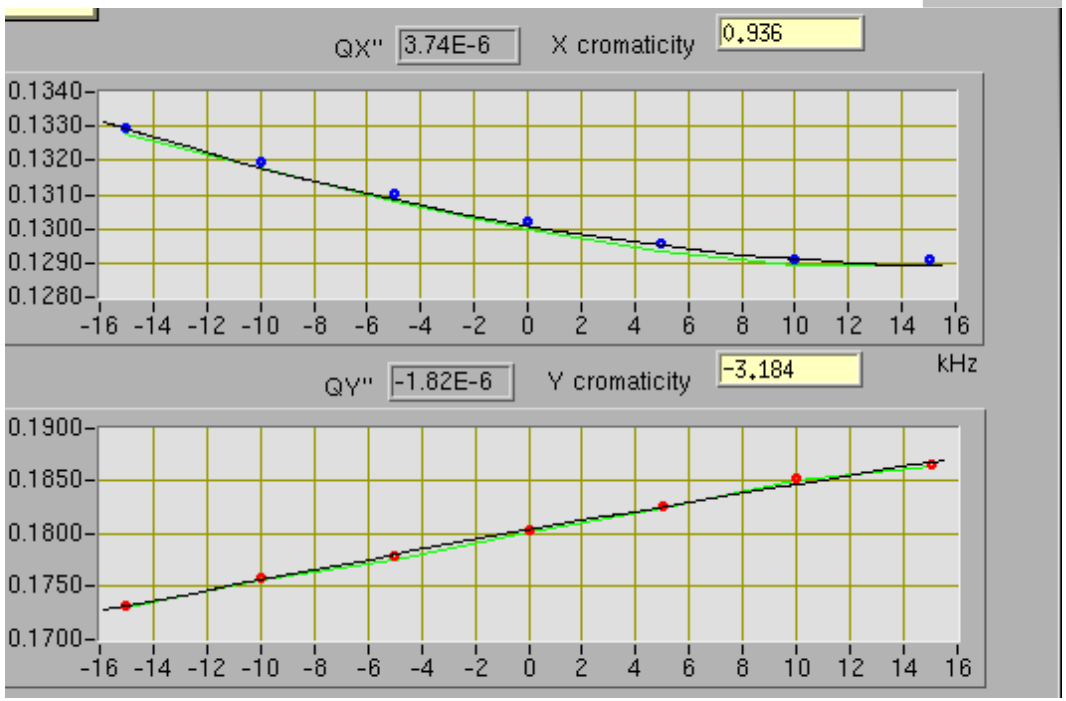
Measured Response Matrices of steering magnets do not show any evidence of coupling for either ring

Dec 19 – Jan 20

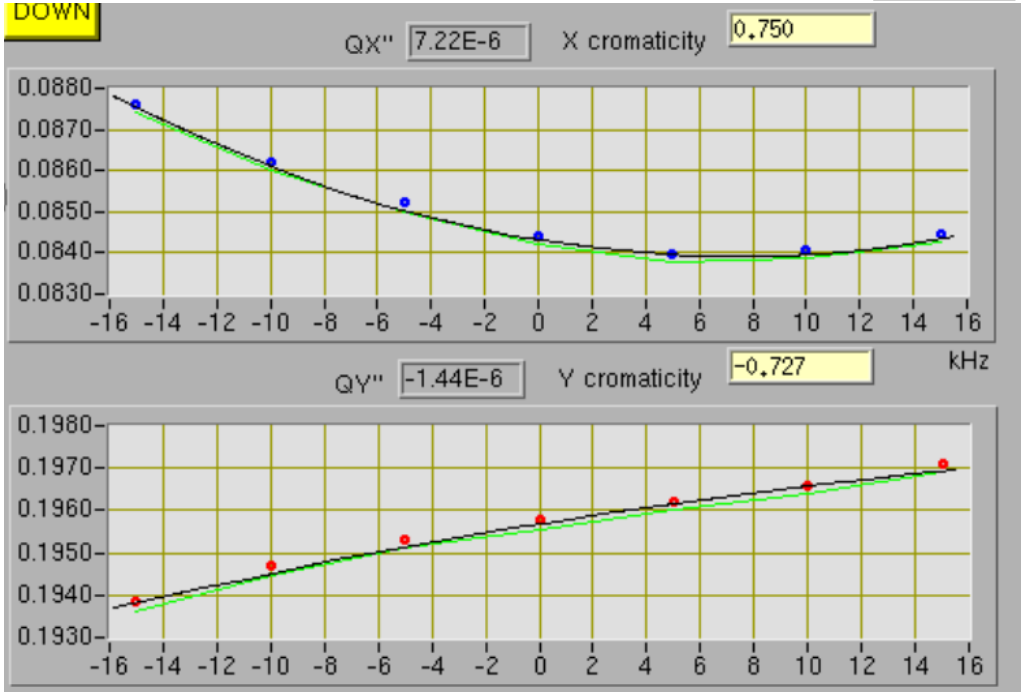
MRs corrected chromaticity with Crab-Waist SXP

MRe CW SXTs at 200 A

MRe



MRp



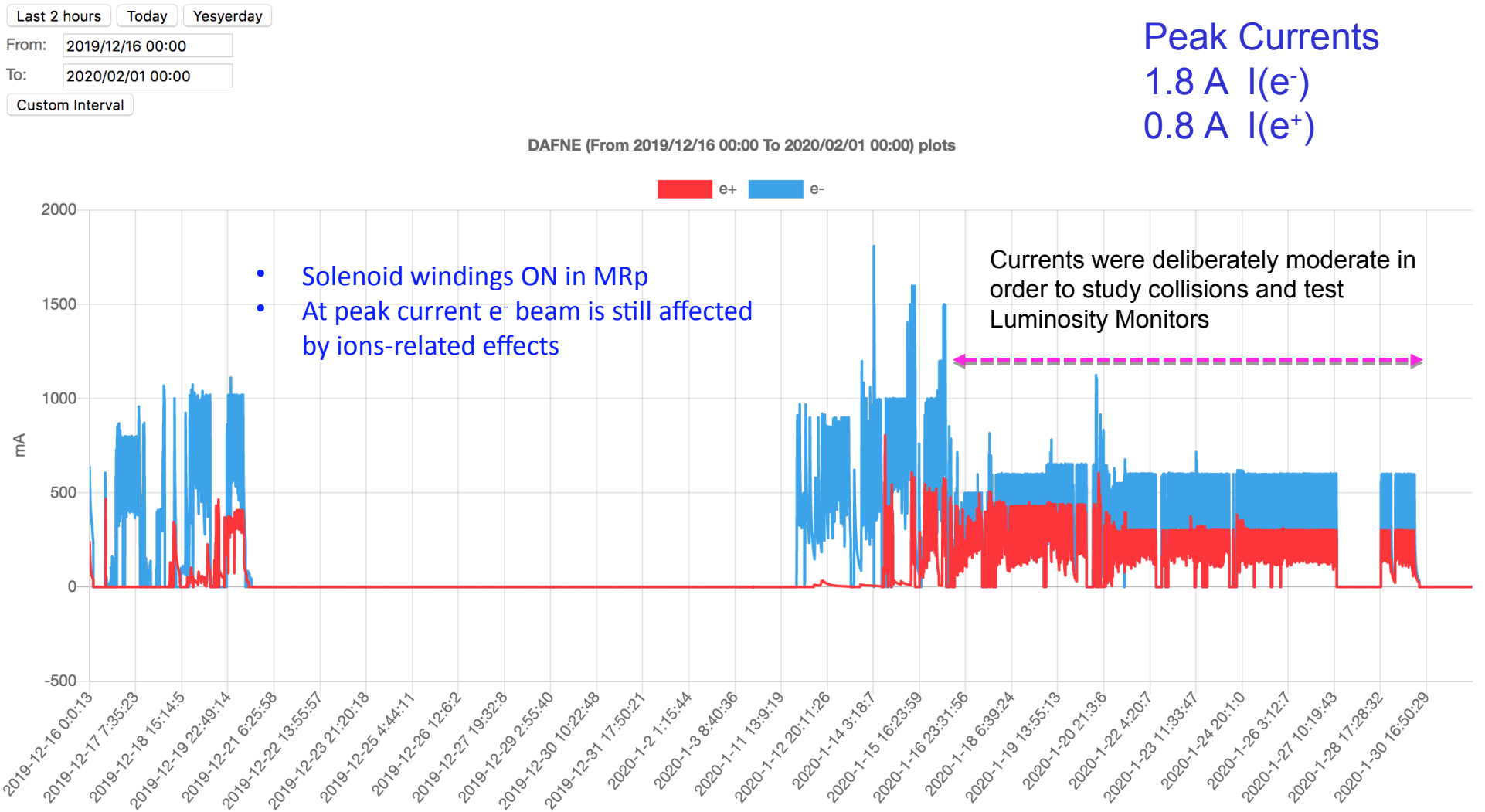
- **ξ“ negligible**
- **Wide Energy Aperture**

  $-0.7\% \Delta E/E \leq A_E \leq 1.1\% \Delta E/E$
- **SXTs setup**:

  has negligible impact on beam orbit and does not affect σ_y
- **good lifetime**

Dec 19 – Jan 20

Current trends with low-β Optics

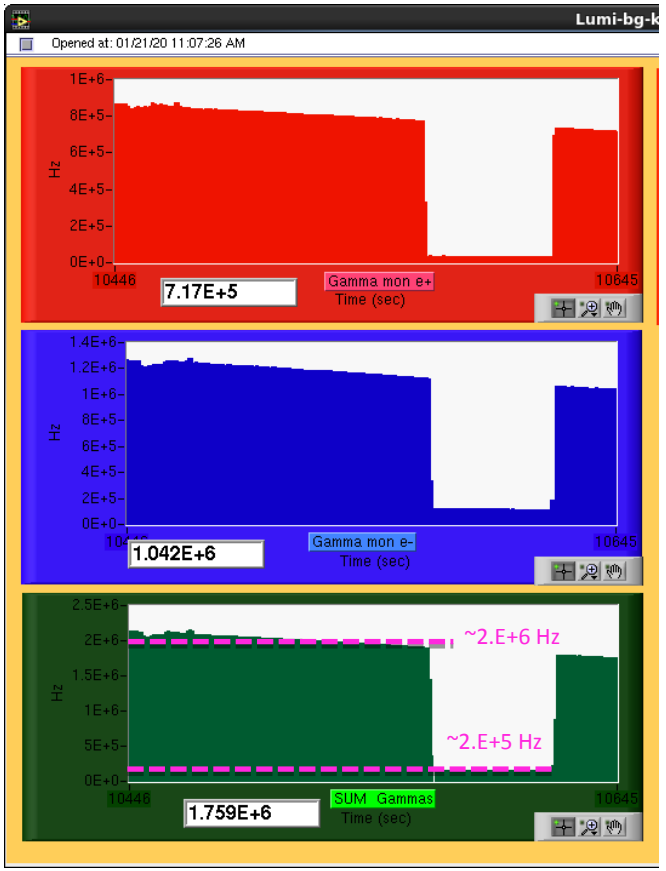


Peak Currents
1.8 A I(e^-)
0.8 A I(e^+)

Dec 19 – Jan 20

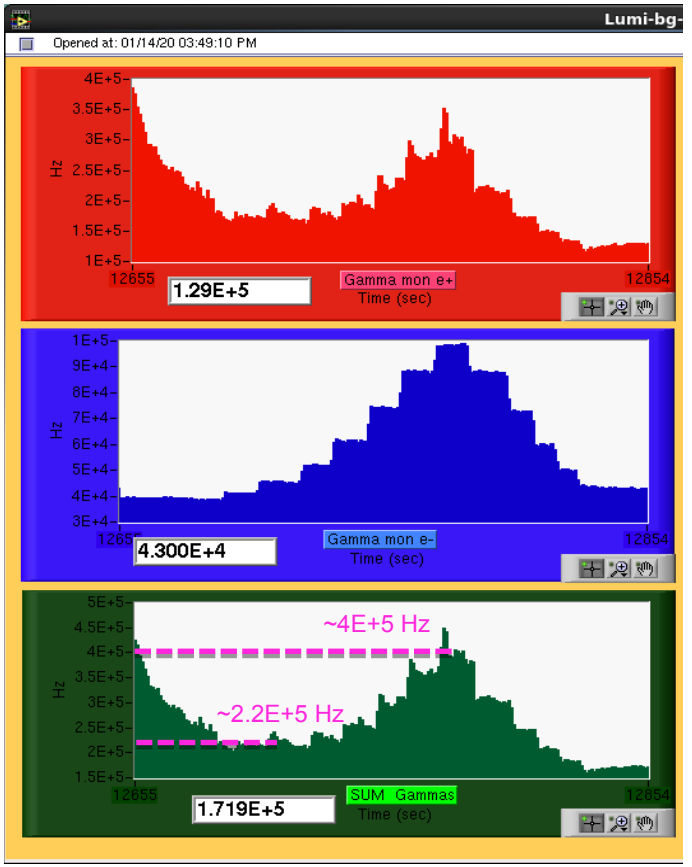
γ-monitor counting rate

After inserting Collimators



Separating beams longitudinally counting rate decreases by ~ a factor 10

Before inserting Collimators

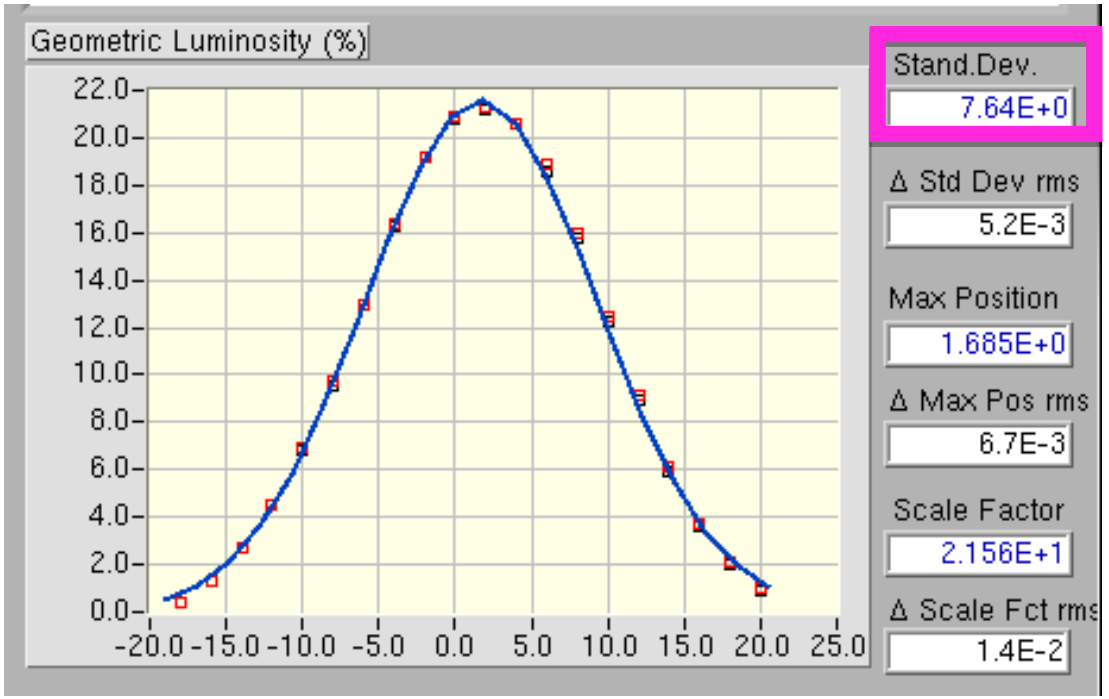


Separating beams vertically counting rate decreases by less than a factor 2

Present collimator setup has allowed to gain a factor of 5 in terms of signal to background ratio

Feb 20 – Mar 20

Low Current Vertical Beam-Beam Scan



$I^- = 128$ mA
$I^+ = 105$ mA
$n_b = 100$

- **Scan provides a clear evidence of an optimal beam-beam interaction**
- No meaningful difference doubling beam charge in collision
- Measurements are reproducible
- **Low-β optics is reliable**

Σ expected relying on nominal parameters
$\varepsilon = 0.28\ 10^{-6}$ [m rad]
$\beta_y = 0.009$ [m]
$\kappa \sim 1\%$ (conservative assumption)
$\Sigma = 7.1\ 10^{-6}$ [m]

Measurements
$\Sigma \sim 7.6\ \mu m$
$\sigma_y \sim 5.37\ \mu m$

Feb 20 – Mar 20

CCAL-T Luminosity monitor

Data selection

Calibration

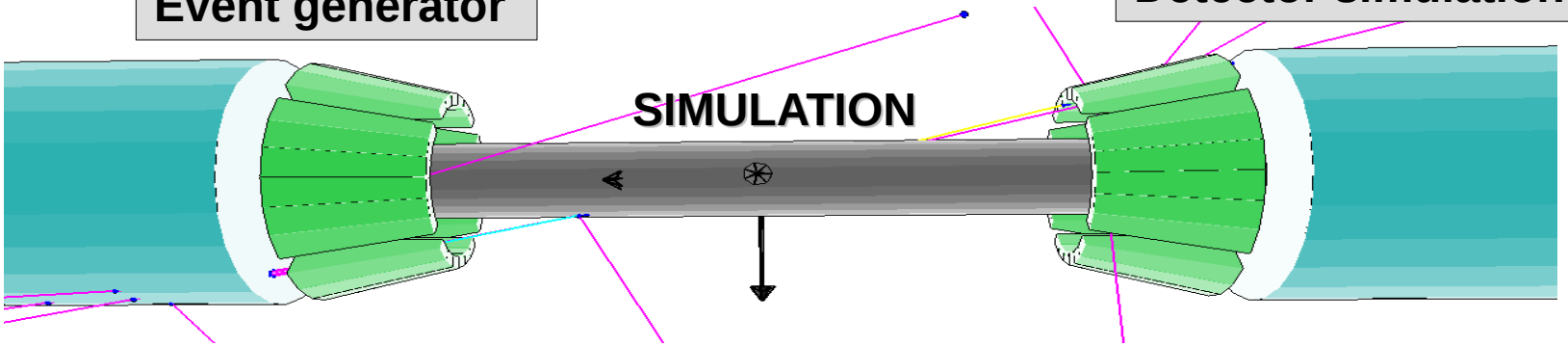
Bkg evaluation

$$\mathcal{L} = \frac{R_{Sig}}{\sigma_{eff}(Bhabha)}$$

Validation

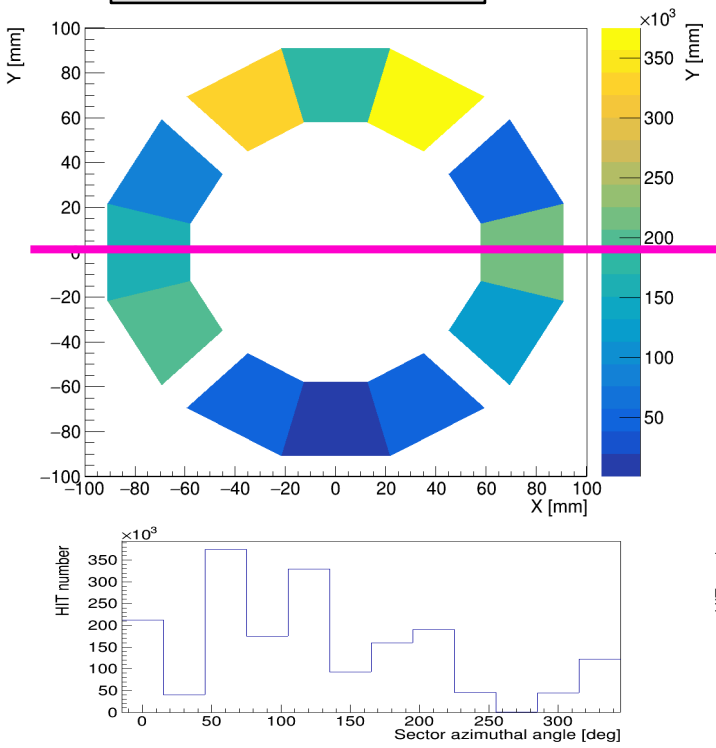
Event generator

Detector simulation

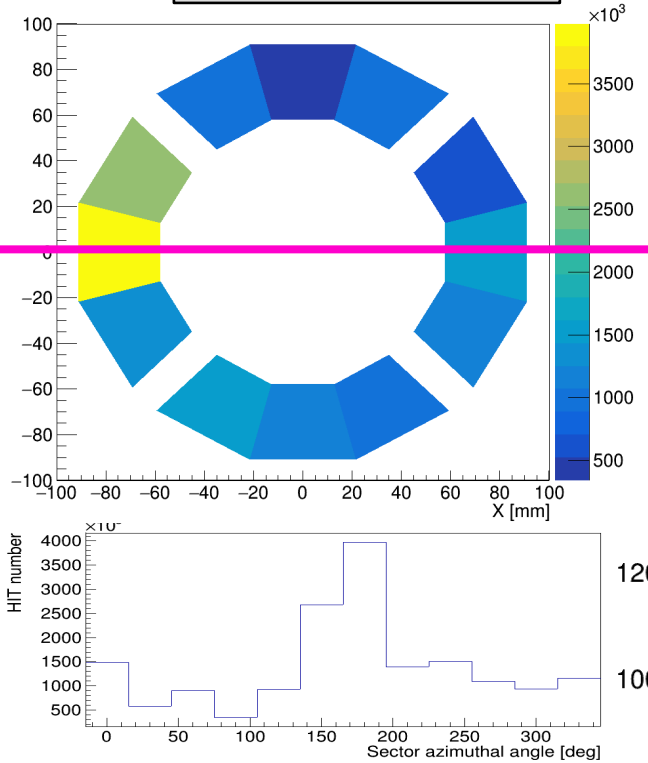


Luminosity monitor: detector occupancy

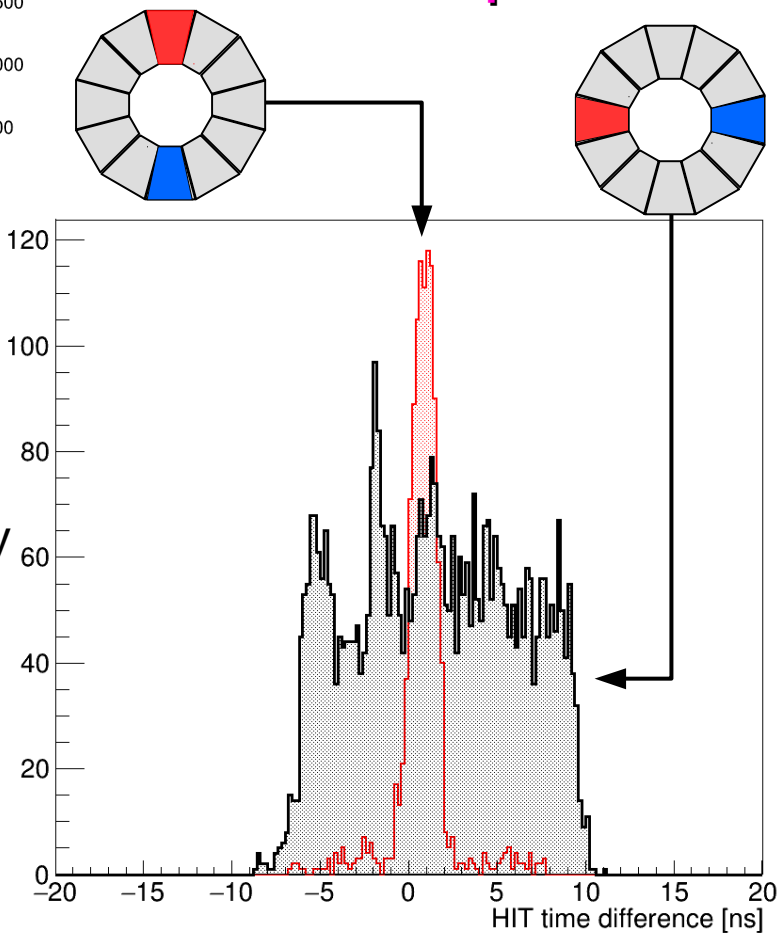
POSITRON SIDE



ELECTRON SIDE



When beams are not in collisions only background events are observed in the detector.
The highest background is expected (and observed) in the **Horizontal plane** .



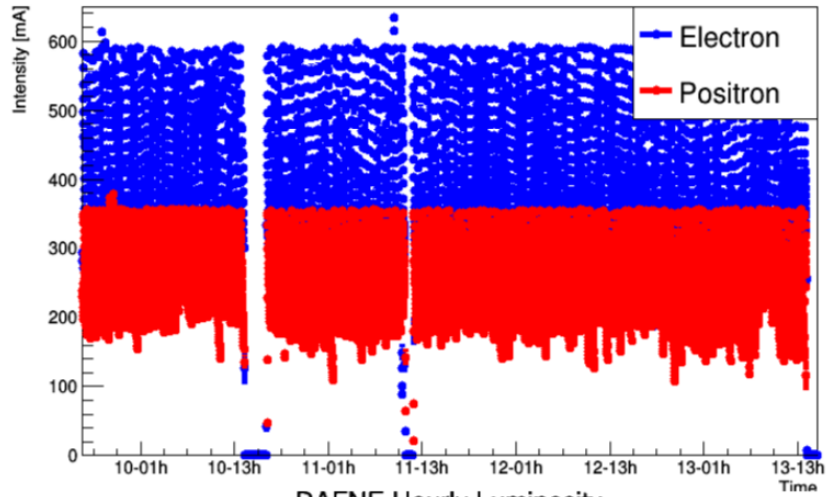
Signal and B**ackground** dominated sector pairs shows very different distribution. The time response calibration and alignment it is crucial to suppress background using time difference between fired sectors.

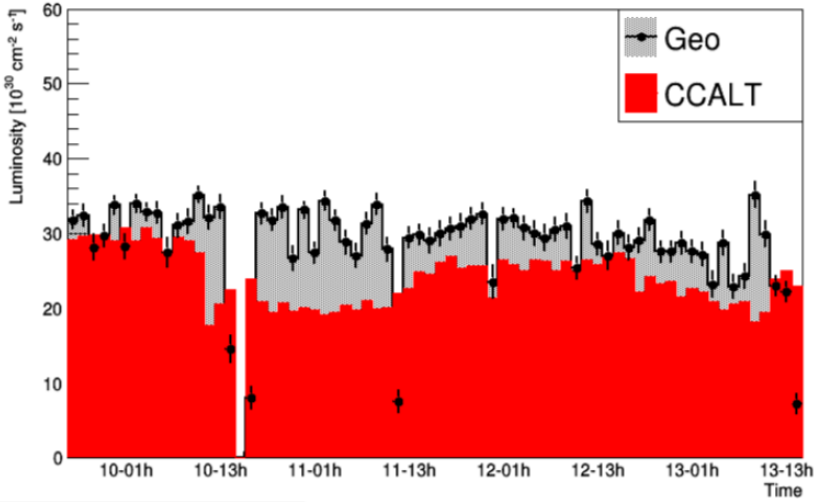
A broad time difference distribution within trigger window is observed for accidental coincidence, while a sharp peak characterize the signal sample.

Feb 20 – Mar 20

Luminosity monitor: measurements

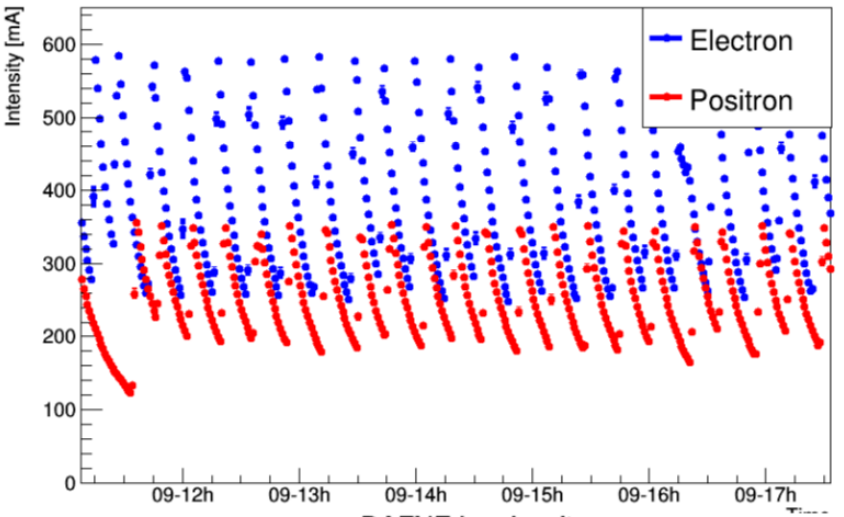
Feb 10-13

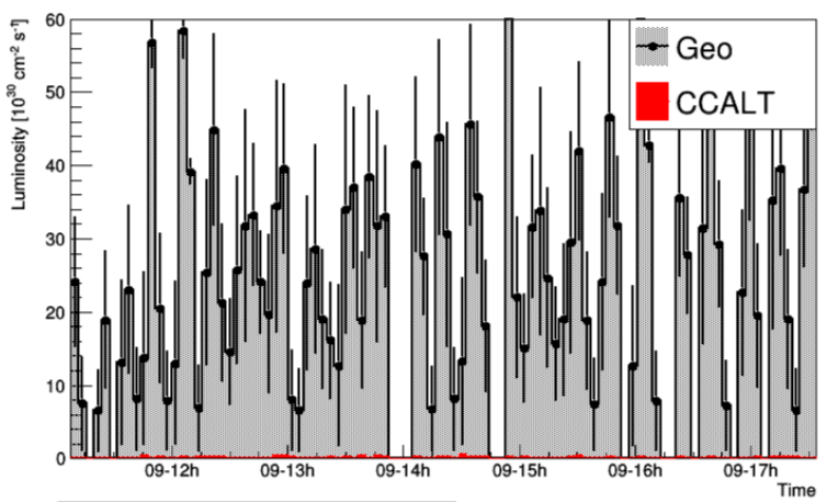




COLLISIONS

Feb 09



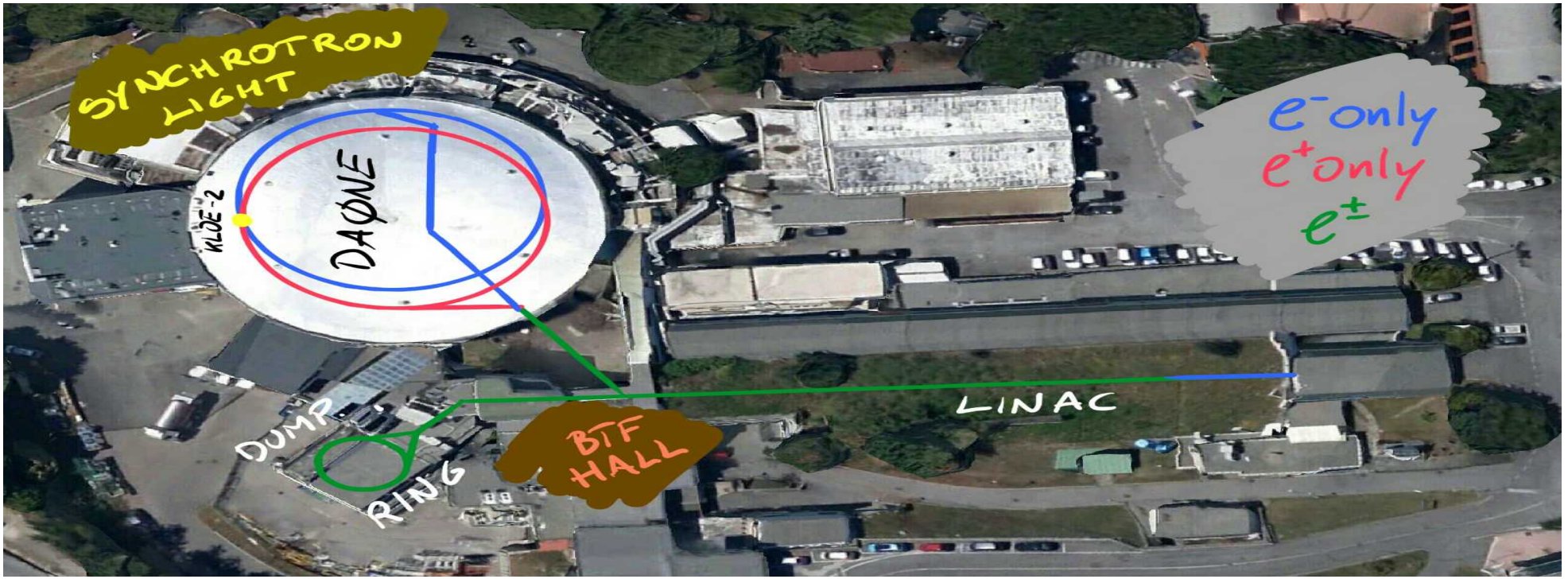


NO COLLISIONS

Only one signal enriched sector pair has been used. The expected cross section (MC) is 102 nb

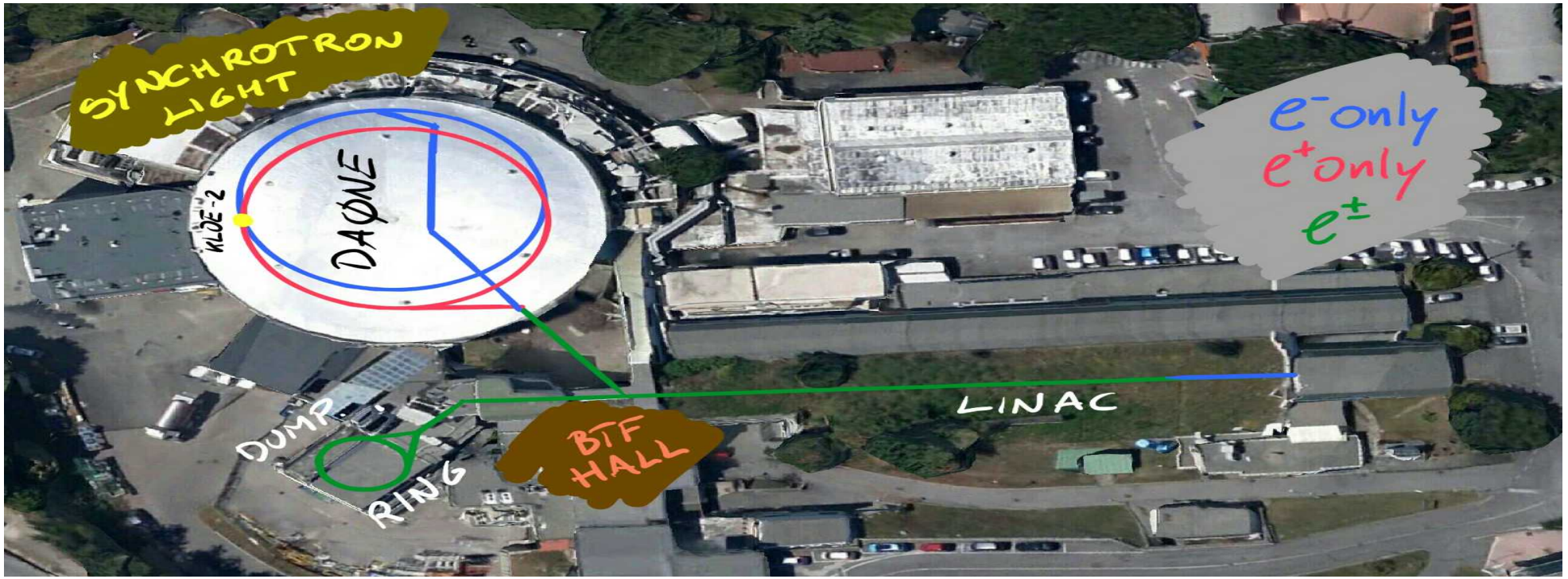
Feb 20 – Mar 20

Conclusions



- DAFNE already started testing collisions
- Experiment feedbacks are encouraging
- Pandemic is currently an issue for the operations
- All data and measurement collected will allow to have the quicker warm-up whenever DAFNE operations will be resumed

Thank for your attention



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