Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

DAΦNE Operations Update

Catia Milardi
on behalf of the DAΦNE Team

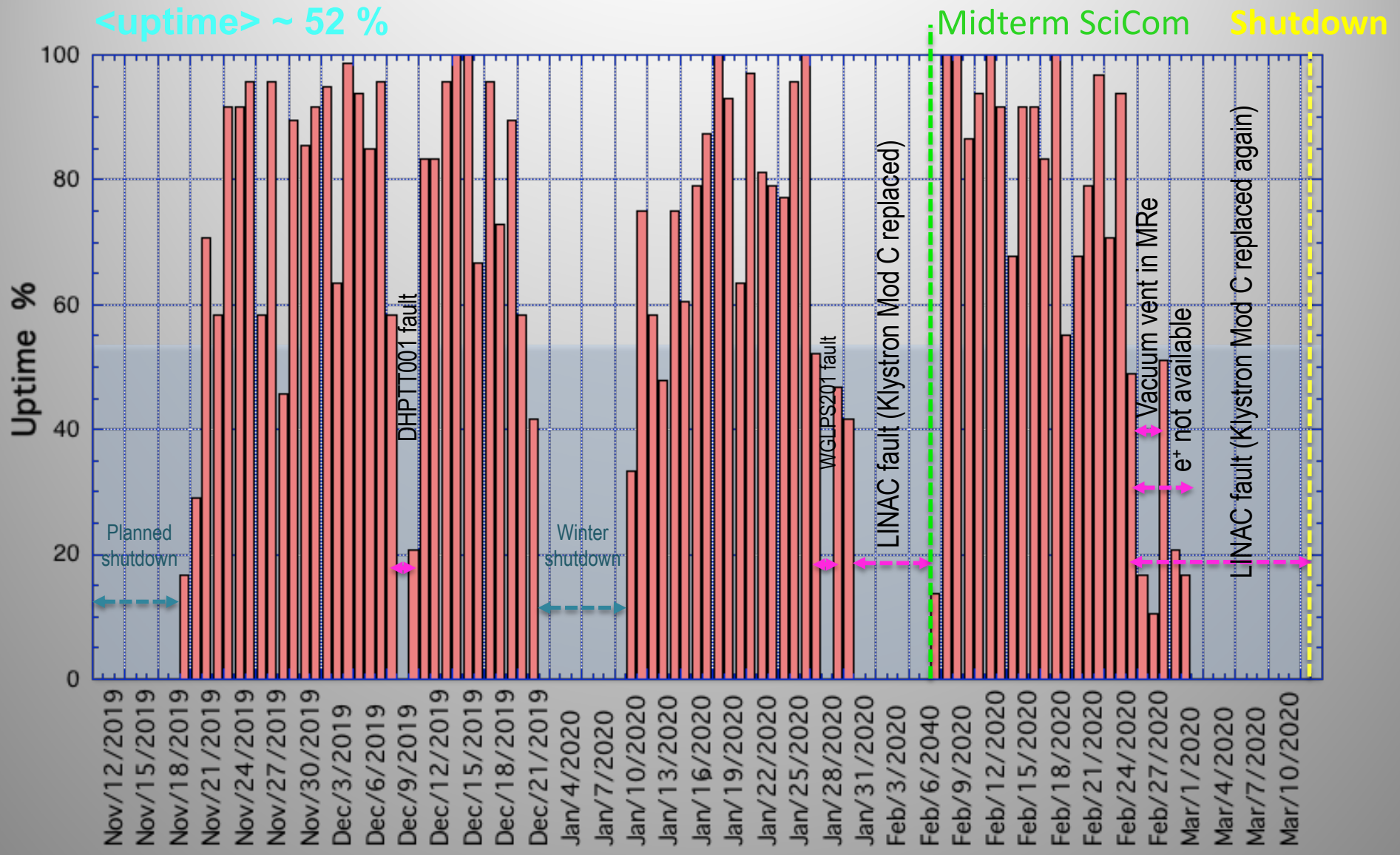
59th Scientific Committee Meeting Mar 7, 2020

Outline

DAΦNE since the last SciCom

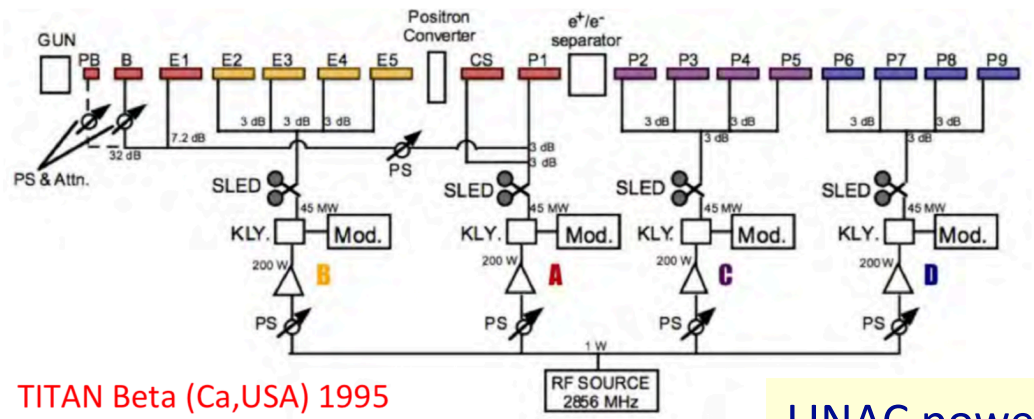
- *Collider Uptime*
- *Crab-Waist Optics*
- *Luminosity Diagnostics*
- *Plans*

DAΦNE Uptime since last SciCom



Operations were scheduled to end by April 10th .

LINAC Faults (RF Plant C)



TITAN Beta (Ca,USA) 1995

LINAC power distribution

Jan 29th – Feb 7th

Replacement:

- Klystron filament PS
- Several hardware components
- Klystron replaced after working ~ 67000 hours
- New klystron conditioning took four days only

LINAC operation at 25 Hz interleaved with klystron conditioning

Feb 24th

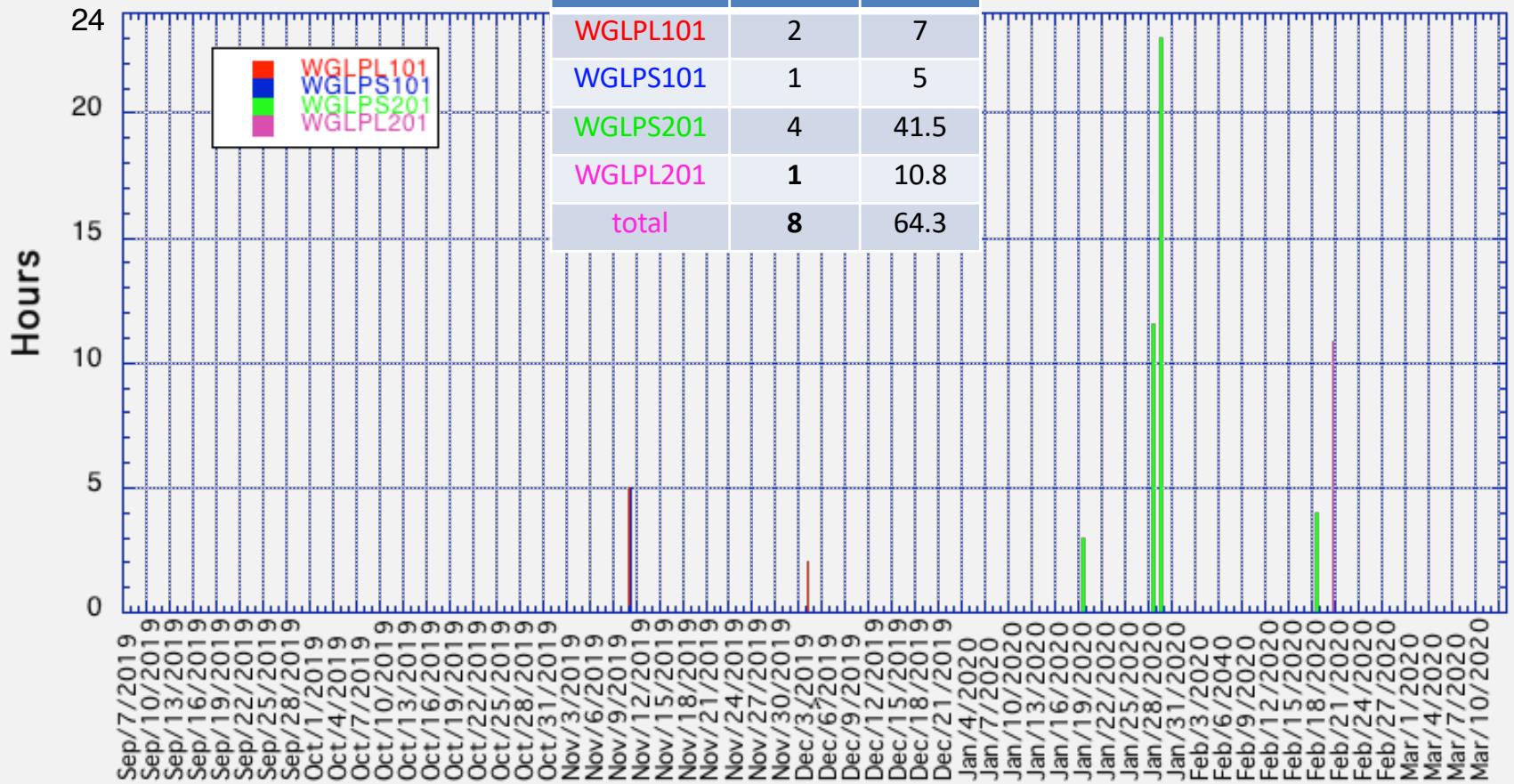
- Klystron conditioning interleaved with e^- beam production
- On **Mar 6th** the new klystron had to be replaced
- *conditioning has been much more demanding, it was still in a early stage by March 12th*

Mod C full operation is mandatory for the BTF-PADME activities too

Water Leakage from WIGGLER hoses in MRp

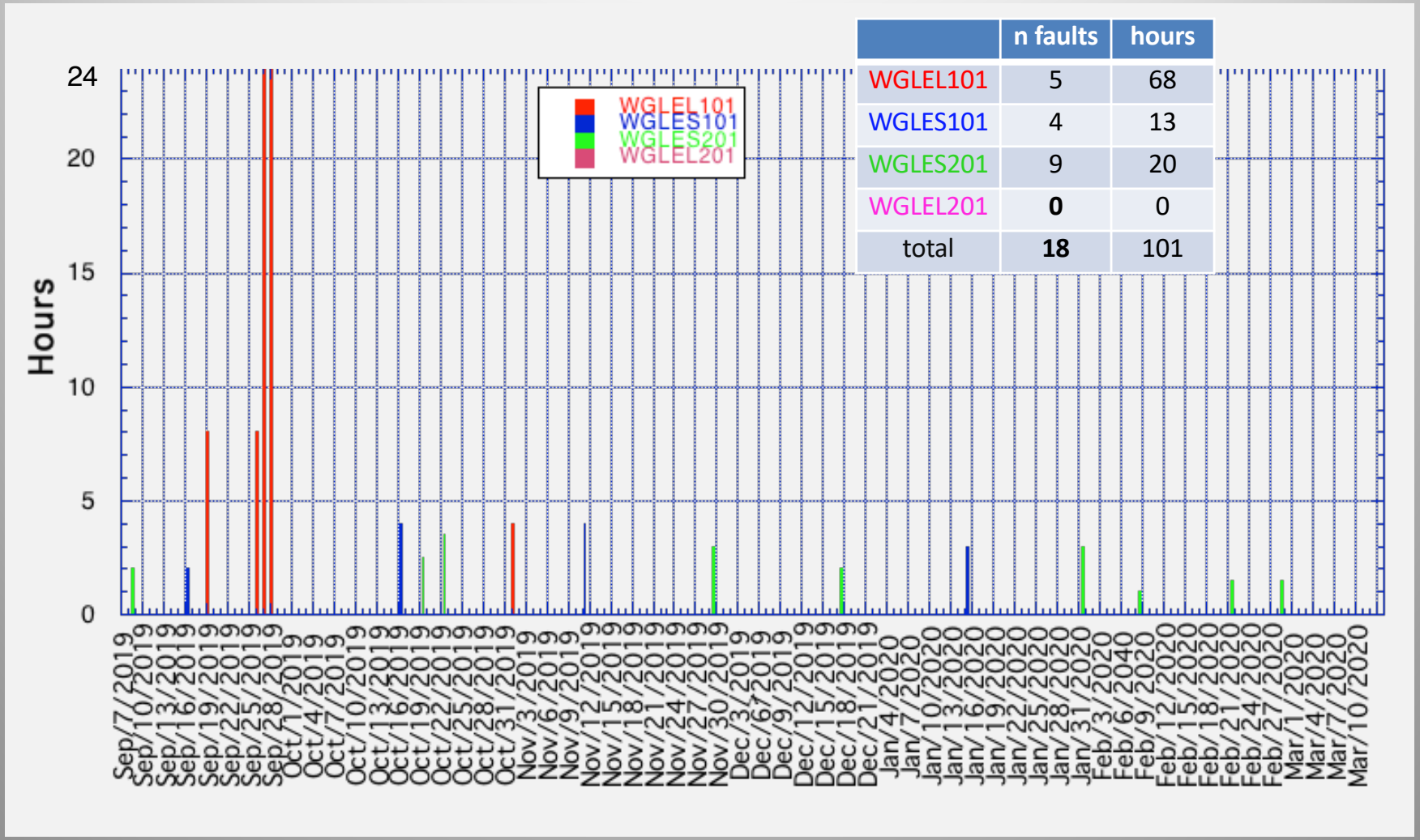
(Spt 6th 2019 – Mar 12th 2020)

	n faults	hours
WGLPL101	2	7
WGLPS101	1	5
WGLPS201	4	41.5
WGLPL201	**1**	10.8
total	**8**	64.3



Water Leakage from WIGGLER hoses in MRe

(Spt 6th 2019 – Mar 12th 2020)

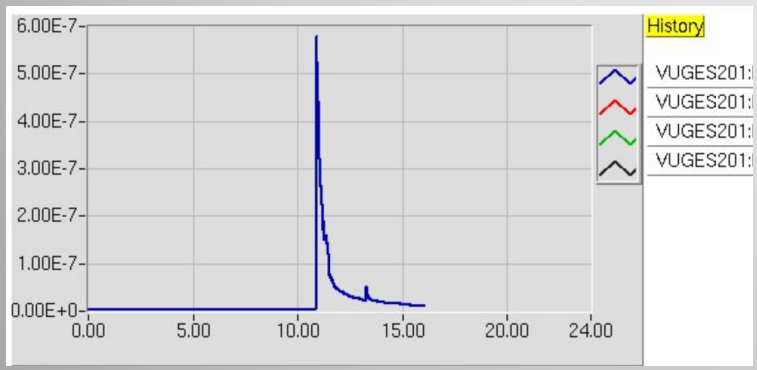


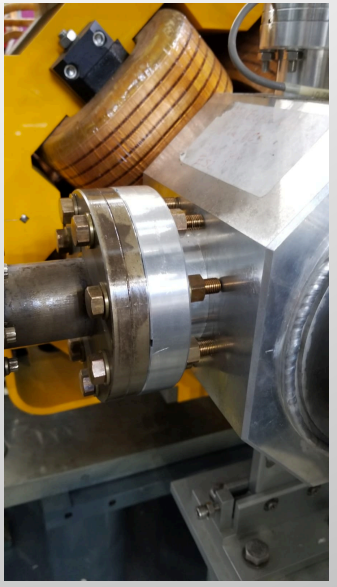
	n faults	hours
WGLEL101	5	68
WGLES101	4	13
WGLES201	9	20
WGLEL201	**0**	0
total	**18**	101

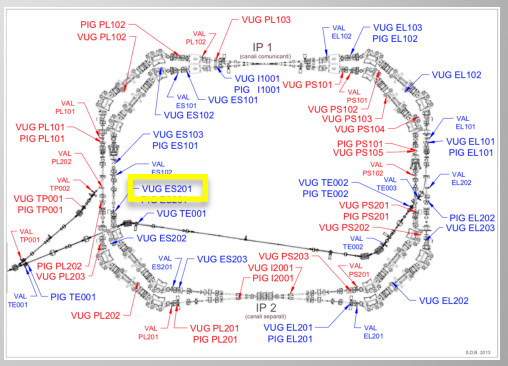
Recently some hoses of different kinds have been installed adopting alternative assembly approach for testing.

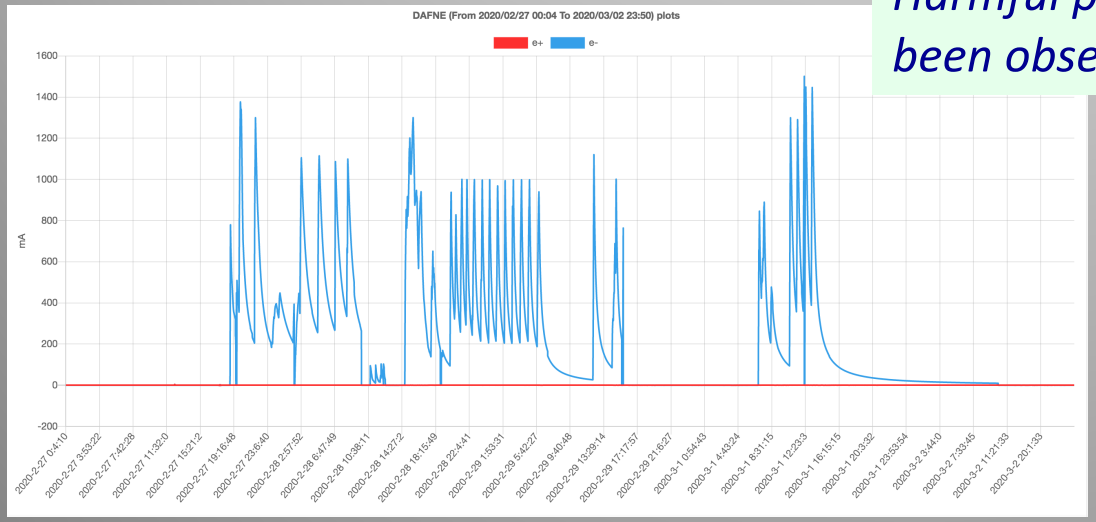
Vacuum Vent in MRe (Feb 27th 2020)

Vacuum vent from a flange in the ES2 section has been temporary sealed

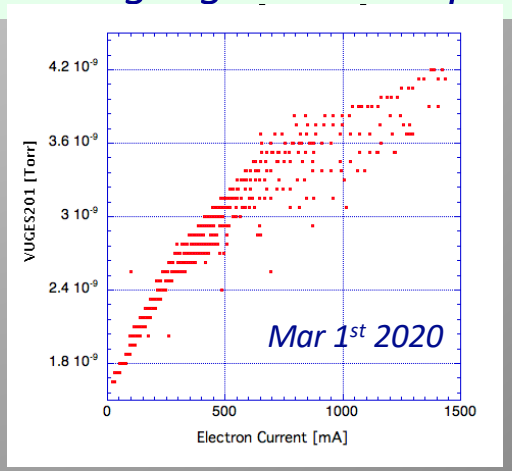








Harmful pressure rise and beam blowup have been observed during high current operations



Other Faults

Magnet Power Supplies

Hardware components of the MRs closed orbit acquisition system

Power Amplifier of the vertical FBK in MRp (2 FAULTS)
500 W Power Amplifier for a possible second horizontal FBK in MRp is still under repair

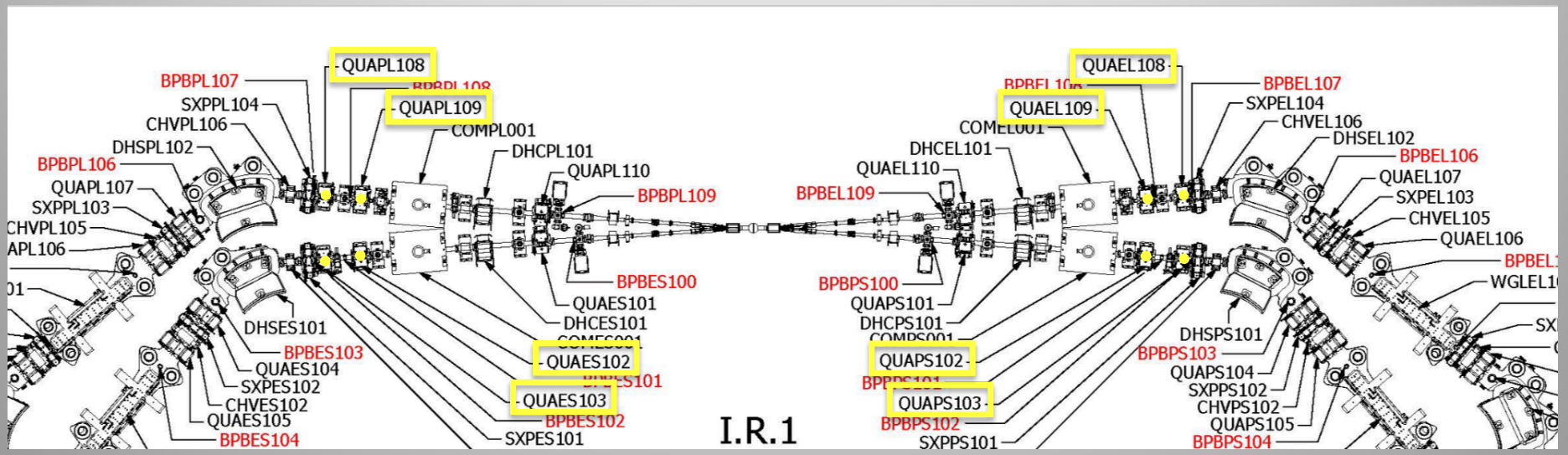
Following I'll briefly review the results presented during the mid-term SciCom held on Feb 6th according reviewers recommendation

It is proposed to organize an ***extraordinary mid-term meeting (possibly by video-conf) of the Scientific Committee with all stake holders in early 2020 (end of January, beginning of February)****, in order to take account of progress made and to discuss, accordingly, the implementation of the remaining run plan for the first half of 2020*

Betatron Coupling Correction

11- 20 Nov 2019 Safety System Checks, maintenance, BTF cleaning

IR quadrupole alignment has been revised relying on harmonic analysis of the coupling components in the steering magnets Response Matrix as well.

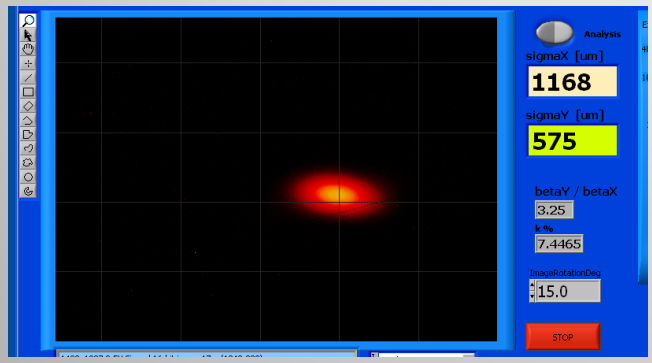


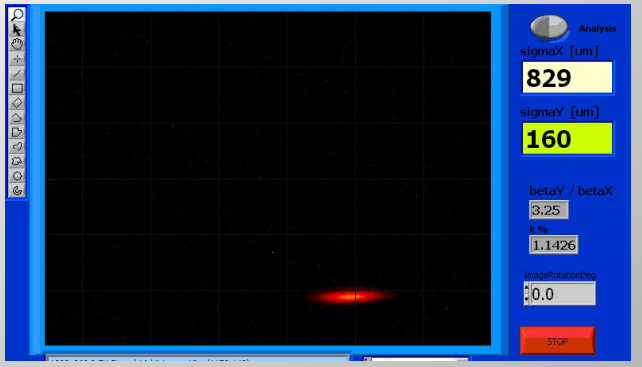
Measurements confirmed a systematic error, of the order of 0.9 degrees, in the rotation of two quadrupoles in each one of the four IR branches.

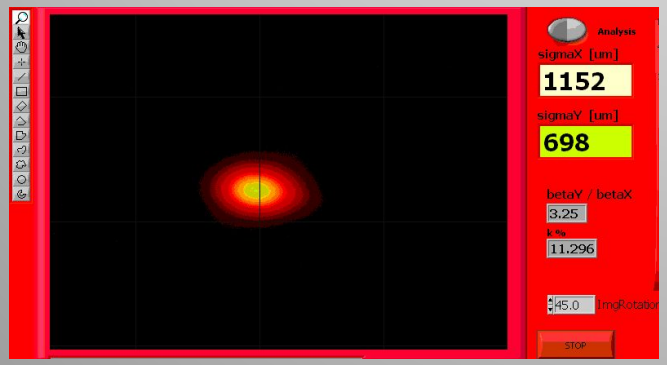
This downside had no relevant impact on DAΦNE operations because, regardless the large coupling, both beams have been stored in order to recover optimal dynamic vacuum conditions.

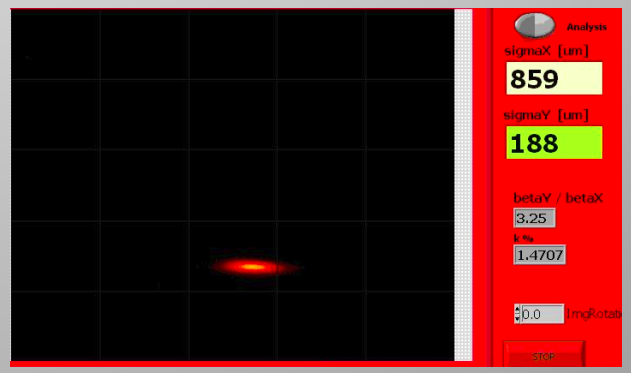
Betatron Coupling Correction

Detuned Optics
Linear lattice









Betatron Coupling as measured at the SLM was dramatically reduced
Coupling components in the steering magnets Response Matrix became negligible

MRs Optics Development

Coupling correction allowed to do reliable beta function measurements in order to optimize the model and move to the **low-β collision optics**

Dec 16th low-β optics applied

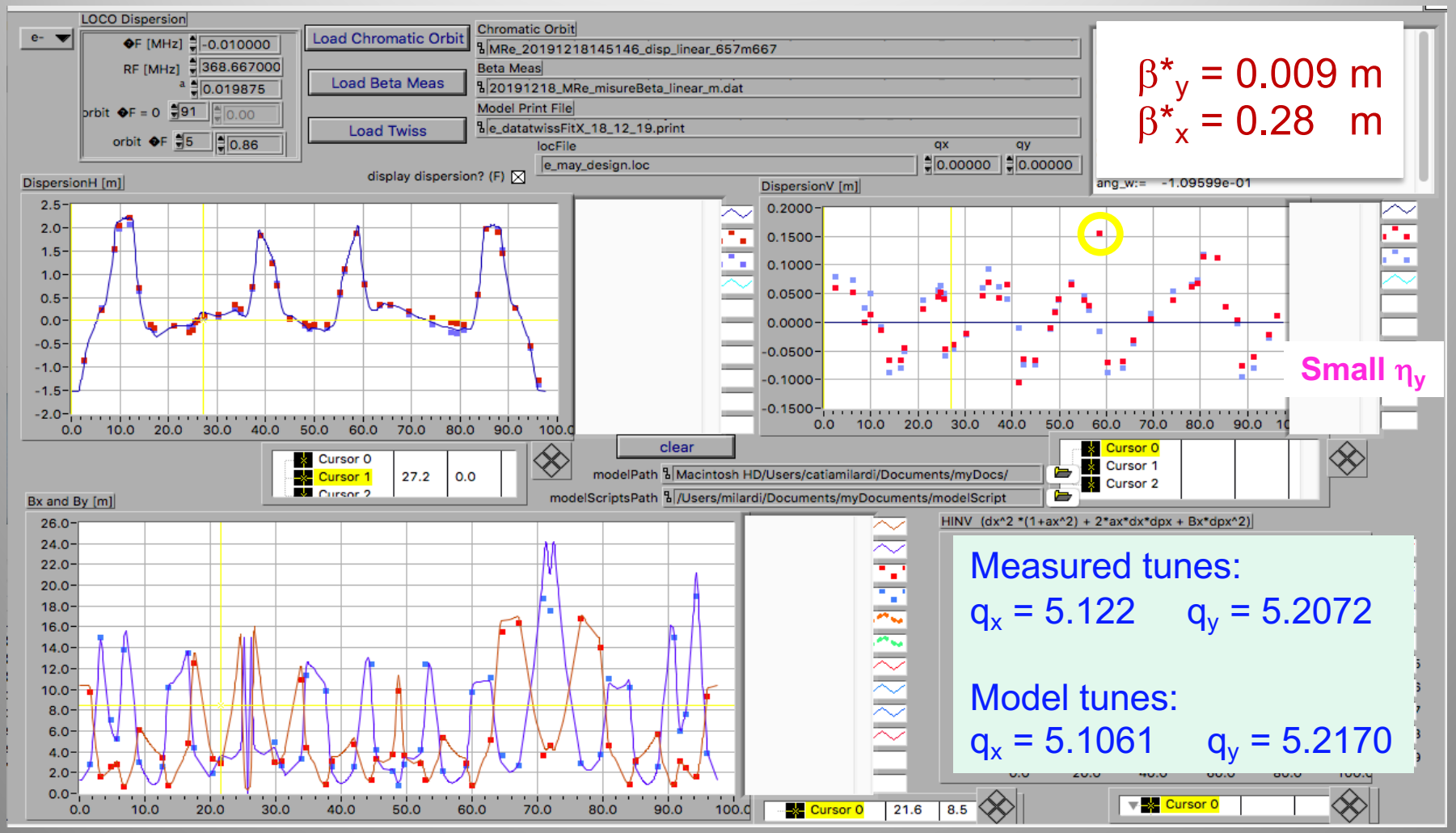
Dec 18th ÷ 20th optics optimization and measurements:

- Orbit steering and steering magnets minimization after including some new measured BPM offsets
- Twiss function measurements on linear optics
- Chromaticity correction

MRe Twiss Functions

Low-β Optics
Linear lattice

Saturated and/or disconnected BPMs



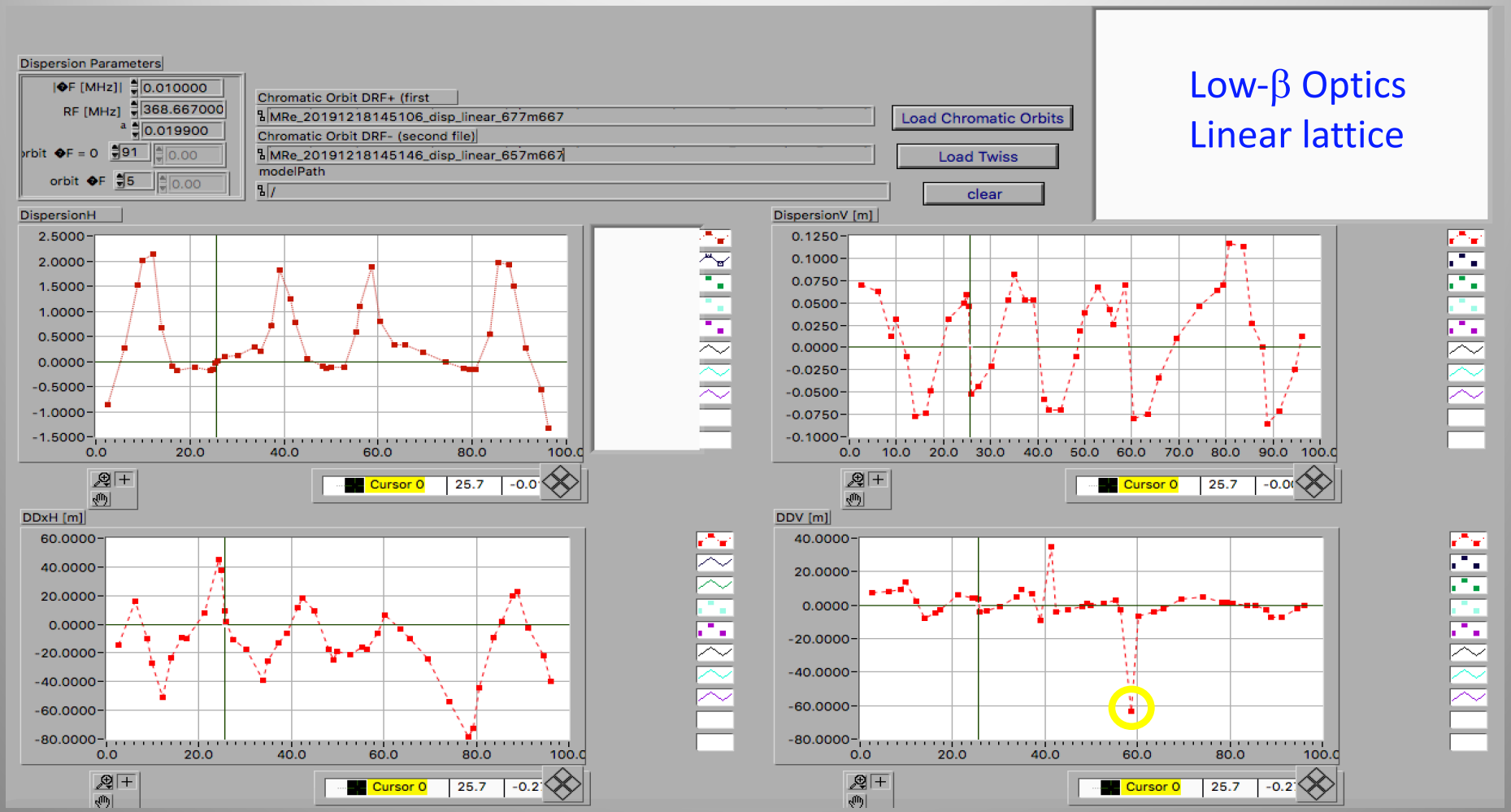
$\beta^*_y = 0.009$ m
$\beta^*_x = 0.28$ m

Small η_y

Measured tunes:
$q_x = 5.122$ $q_y = 5.2072$

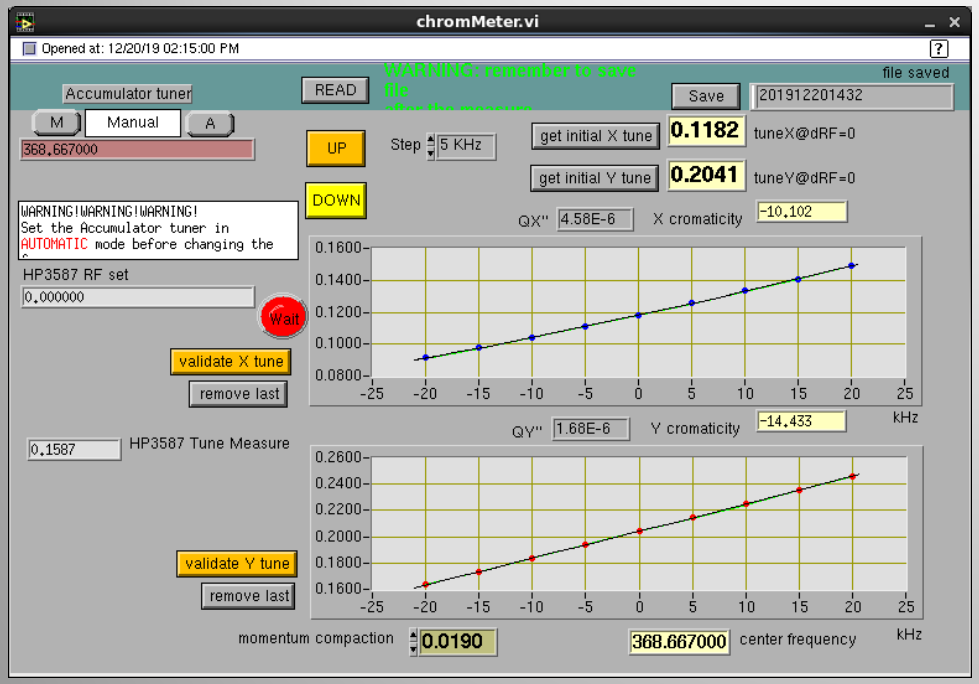
Model tunes:
$q_x = 5.1061$ $q_y = 5.2170$

η_x and η_x" in MRe

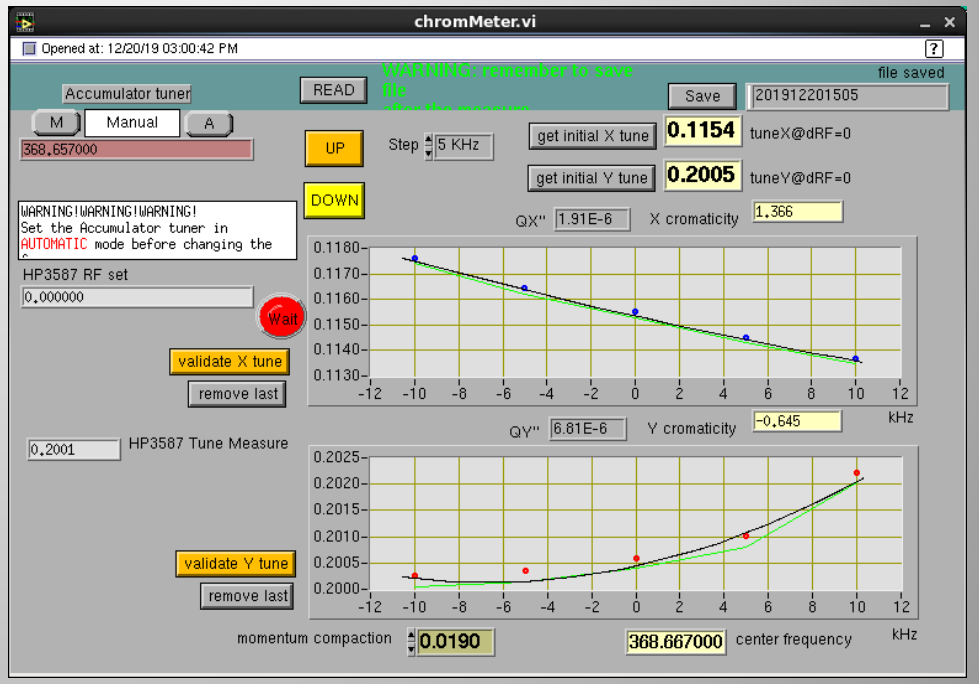


MRe Chromaticity

Natural ξ



Corrected ξ



- **ξ'' negligible**
- **Wide Energy Aperture**

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

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

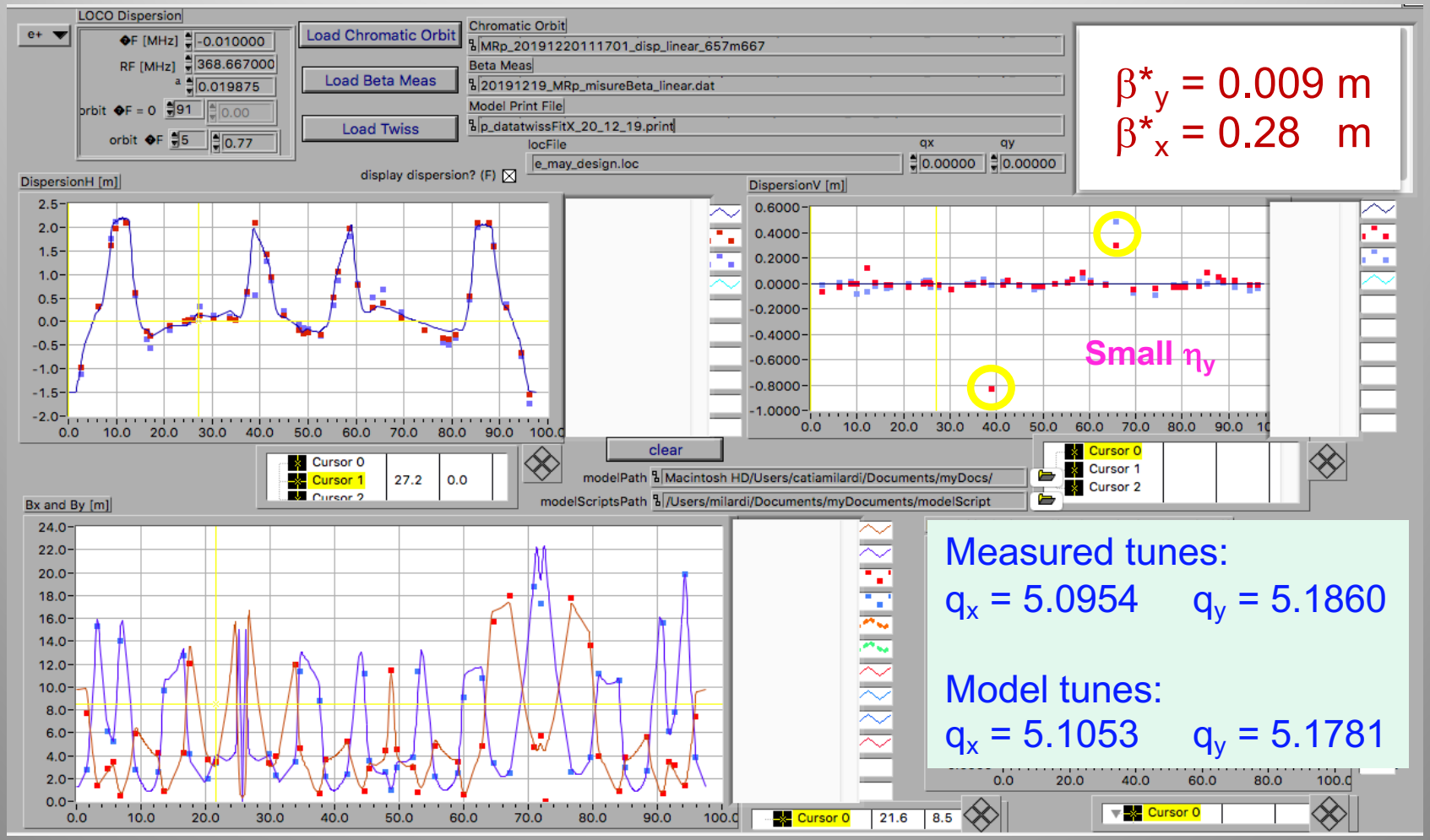
  has negligible impact on beam orbit

  does not affect σ_y
- **good lifetime**

MRp Twiss Functions

Low-β Optics
Linear lattice

Saturated and/or disconnected BPMs

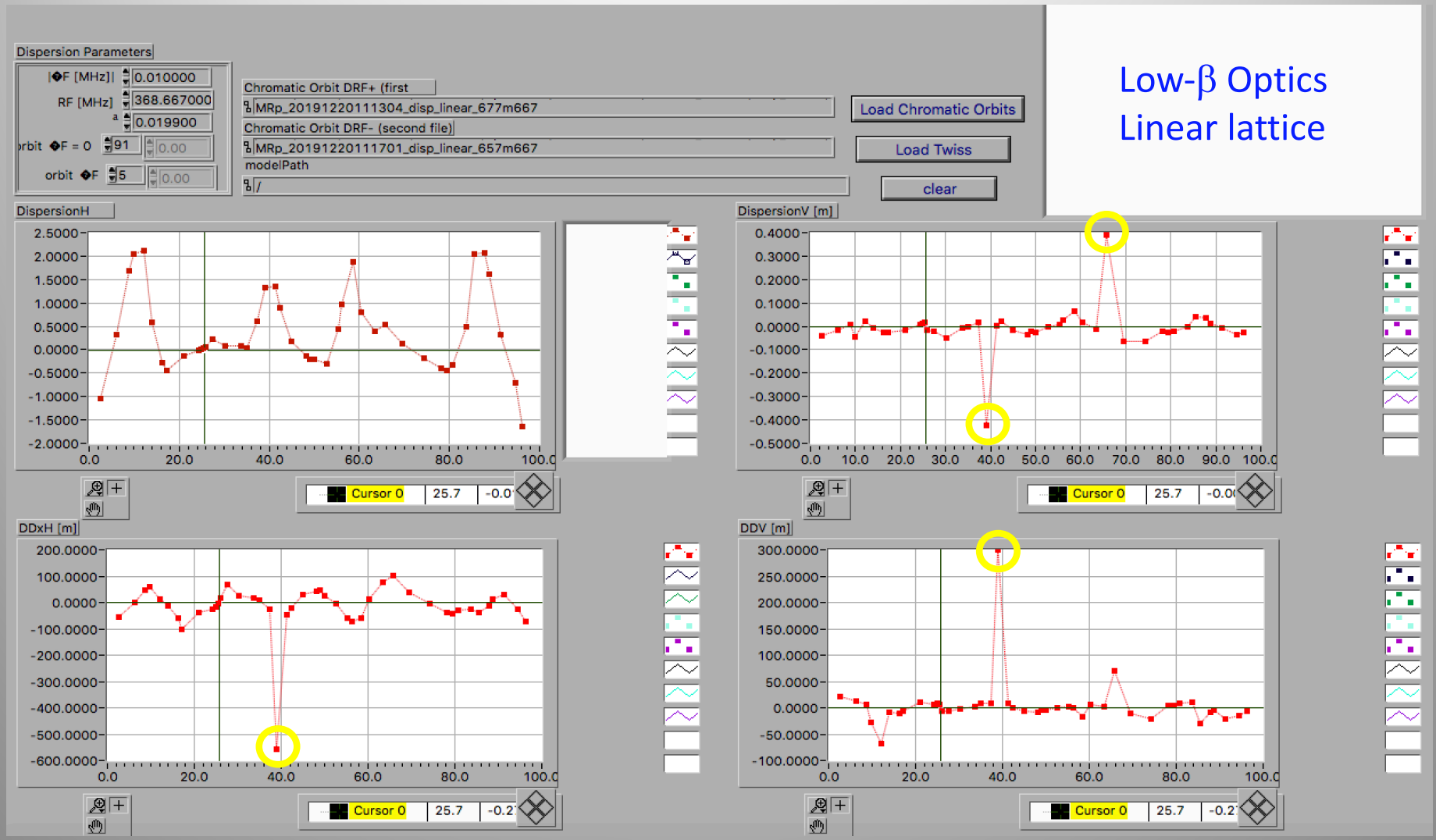


$\beta^*_y = 0.009$ m
$\beta^*_x = 0.28$ m

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

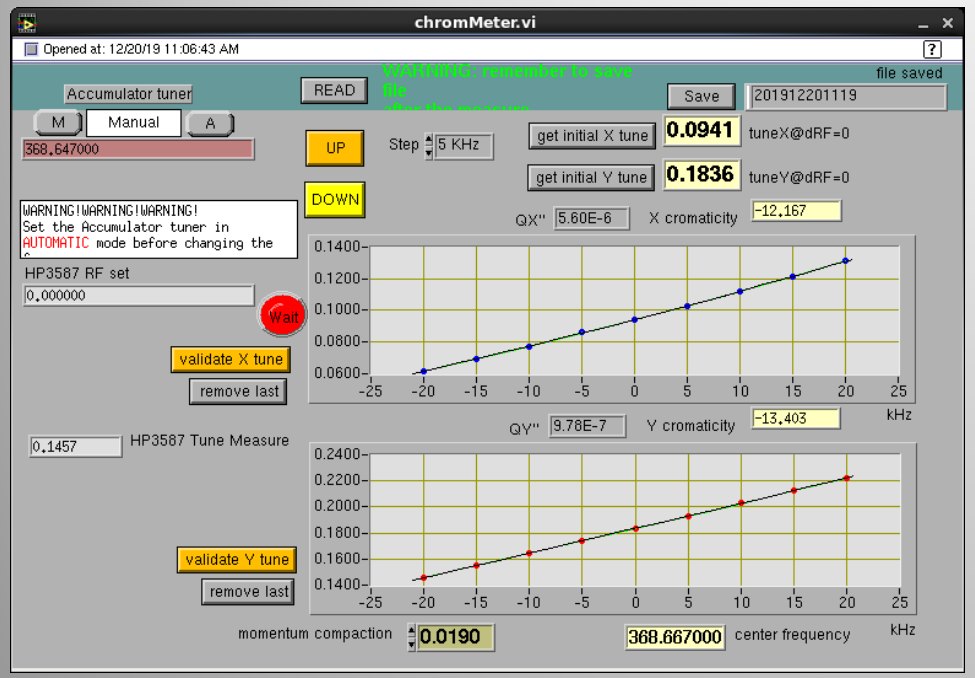
Model tunes:
$q_x = 5.1053$ $q_y = 5.1781$

η_x and η_x" in MRp

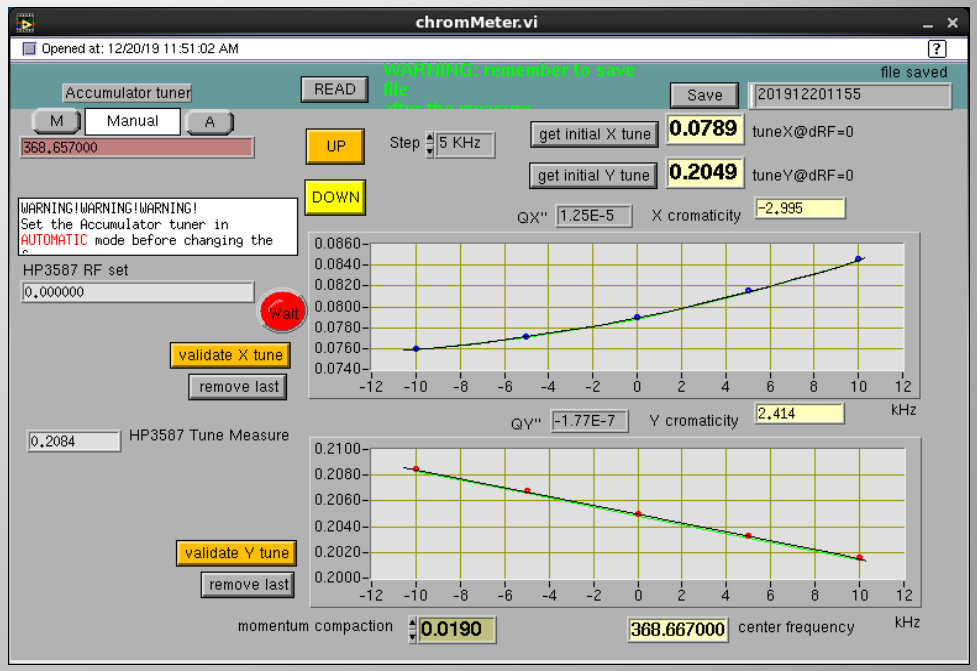


MRp Chromaticity

Natural ξ



Corrected ξ



- **ξ'' negligible**
- **Wide Energy Aperture**

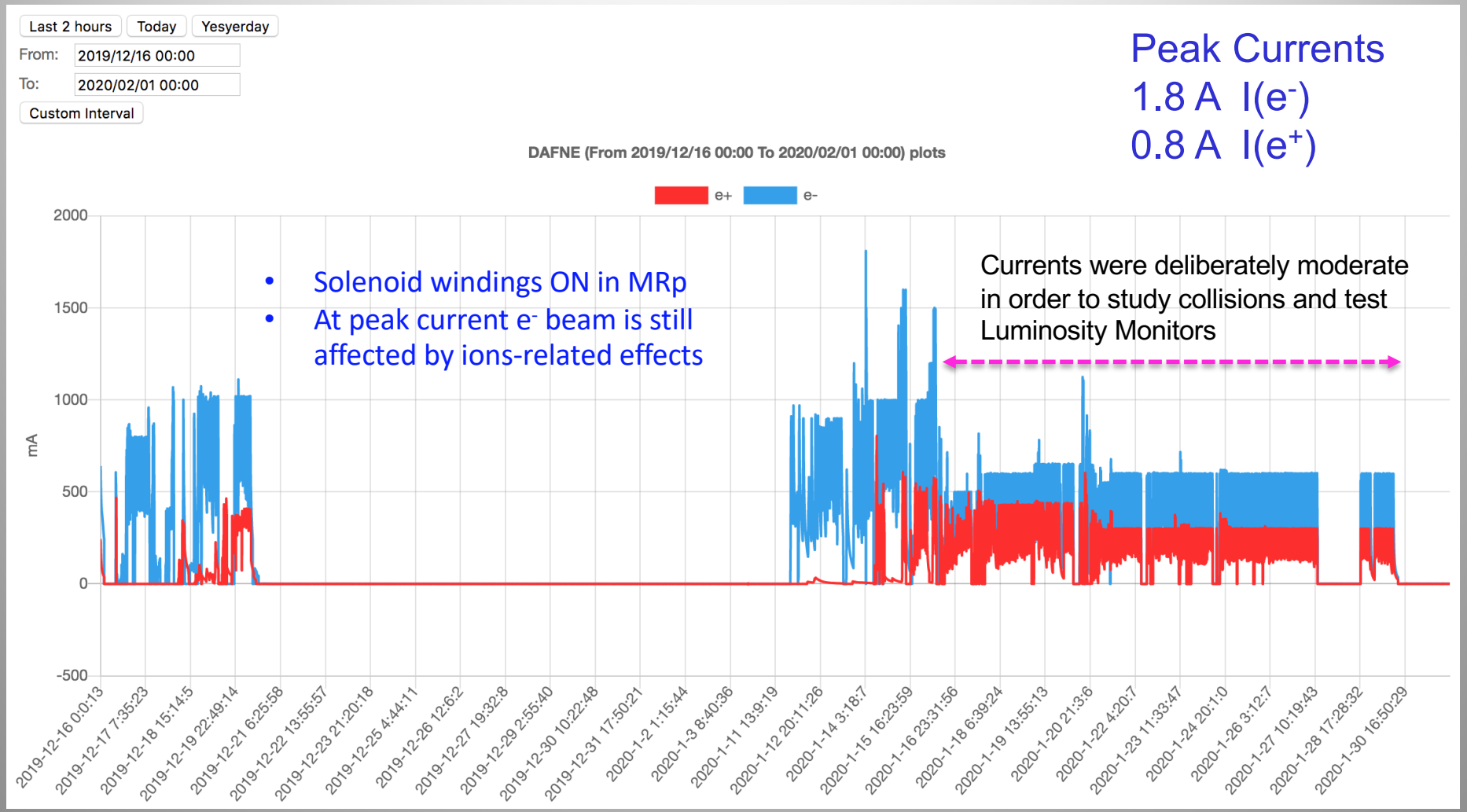
  $-0.9\%\ DE/E \leq A_E \leq 1.3\%\ DE/E$

  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**

Current trends with low-β Optics



- Solenoid windings ON in MRp
- At peak current e^- beam is still affected by ions-related effects

Currents were deliberately moderate in order to study collisions and test Luminosity Monitors

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

Collisions Studies

January 14th: first collision tests

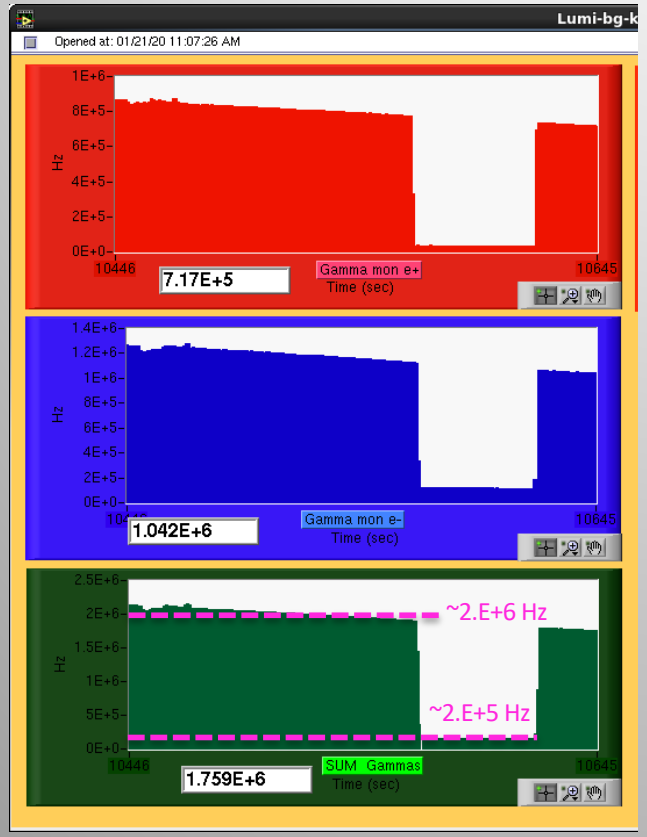
Tests on the CCAL-T luminosity monitor

Collimator optimization

Vertical beam-beam scan

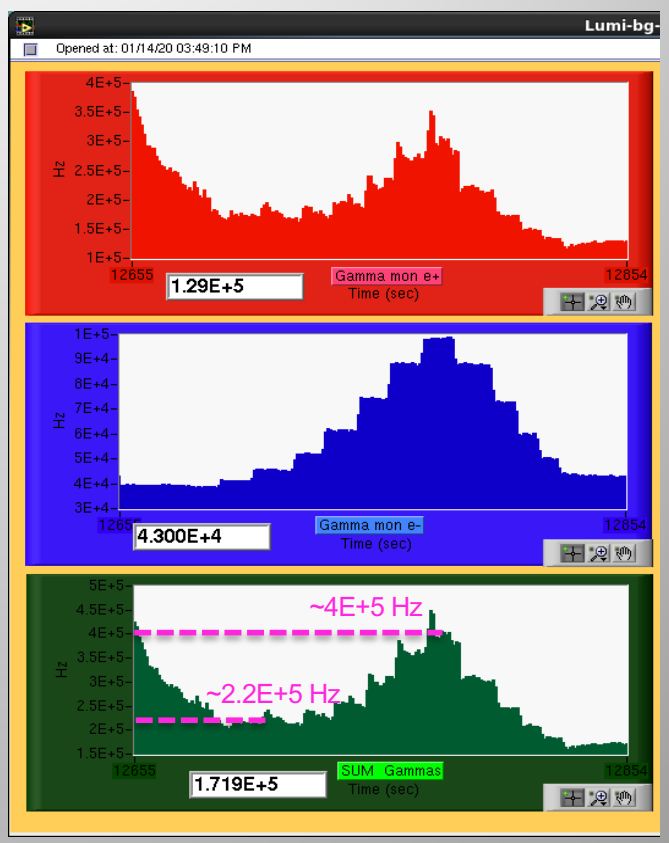
γ-monitor counting rate

After inserting Collimators



Separating beams longitudinally
counting rate decreases by ~ a factor 10

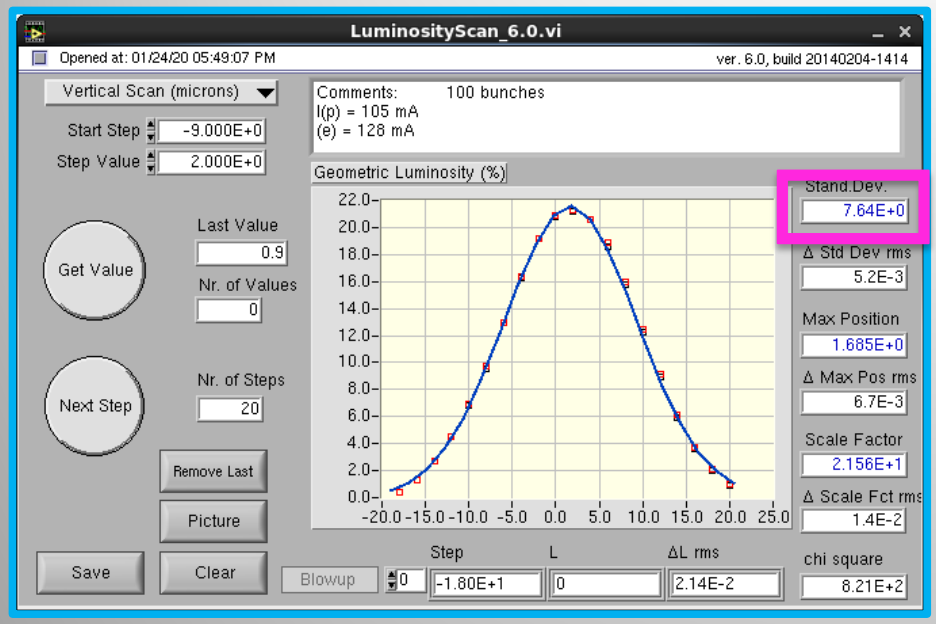
Before inserting Collimators



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

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

$\Sigma \sim 7.6\ \mu m$

$\sigma_y \sim 5.37\ \mu m$

DAΦNE activity program according reviewers recommendation

- *Although future planning is contingent on progress over the coming months,* ***draft planning for 2020 should be produced****. Planning can be versioned. (For example, see LHC schedule)*

DAΦNE Plan

6 – 22 Feb

MRs working point optimization *(it can have a huge impact on* ***background****)*

Collimator tuning for background suppression

Collision optimization

Luminosity studies

Long, stable, and reproducible collision runs in and out of collision and at different beam currents, in order to:

cross-check luminosity measured by the CCAL-T monitor and the SIDDHARTA-2 kaon monitor

optimize the background rejection in the CCAL-T measurement

24 – 25 Feb

Φ resonance energy scan

26 – 28 Feb

New collision optics with improved phase advances between *Crab-Waist* Sextupoles and IP

2 – 6 Mar

***Crab-Waist* Sextupoles beam alignment**

Since March the 6th we might be able to start the SIDDHARTINO run which, including contingency, should last for about 20 days.

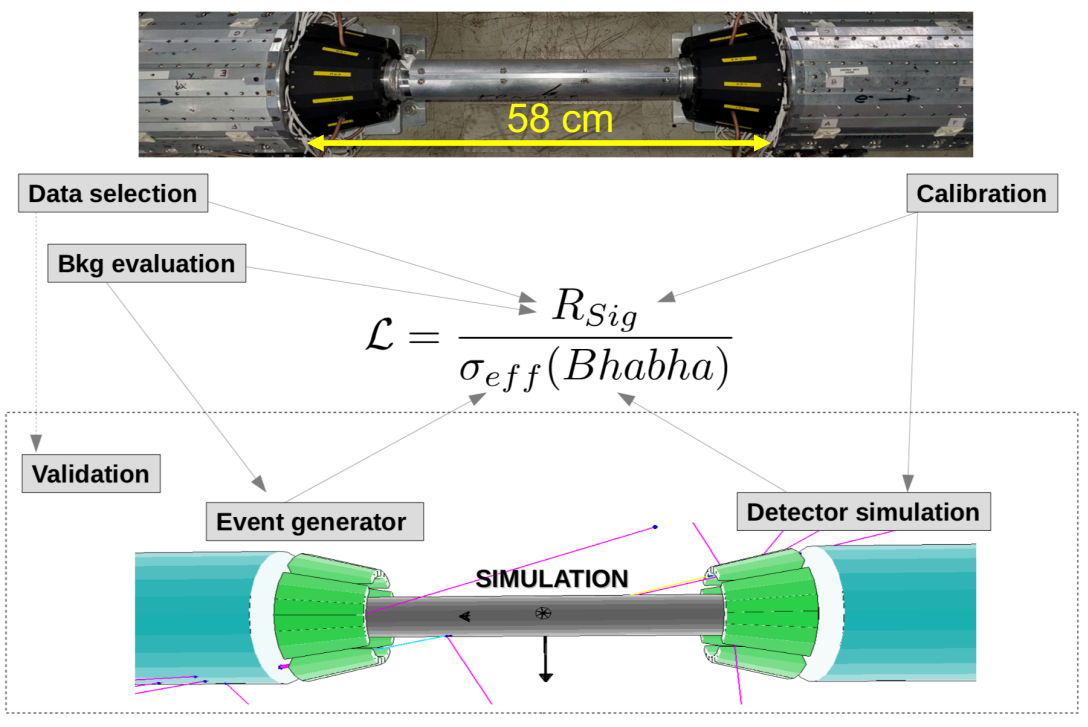
DAΦNE Plan

The general activity program has been extensively detailed on daily basis

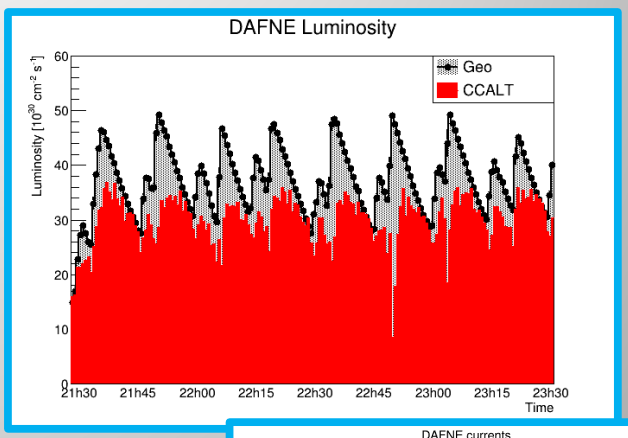
Date	Scheduled Activities
27/02/20 morning	Reference Orbits optimization, chromaticity measurements in MRp and MRe, tests with e+ beam about polarities of solenoids.
27/02/20 afternoons	CW SXTs alignment measurements in MRp, CW Sextupoles mechanical alignment
28/02/20 morning	TLs optimization, High currents tests and FBKs optimization
28/02/20 afternoons	TLs optimization, High currents tests and FBKs optimization
29/02/20	TLs optimization, Conditioning and/or Collisions tests with CW sextupoles OFF
1/03/20	TLs optimization, Conditioning and/or Collisions tests with CW sextupoles OFF
2/03/20 morning	CW Sextupoles mechanical alignment (if not previously done) and tests.
2/03/20 afternoons	Collisions optimization with CW Sextupoles OFF, test run with 1 bunch for CCALT, SIDDHARTINO acquisition tests
3/03/20 morning	CW sextupoles ON, chromaticity measurements on both rings
3/03/20 afternoon	Collisions optimization with CW sextupoles ON, SIDDHARTINO acquisition tests
4/03/20 morning	Collisions optimization with CW Sextupoles ON
4/03/20 afternoon	SIDDHARTINO acquisition tests

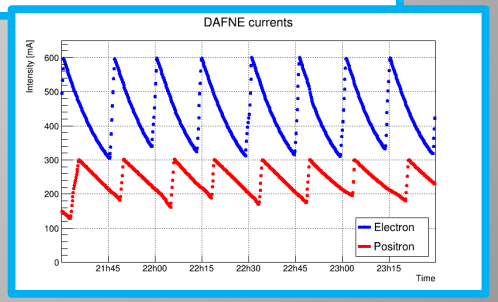
an example …

CCAL-T Luminometer



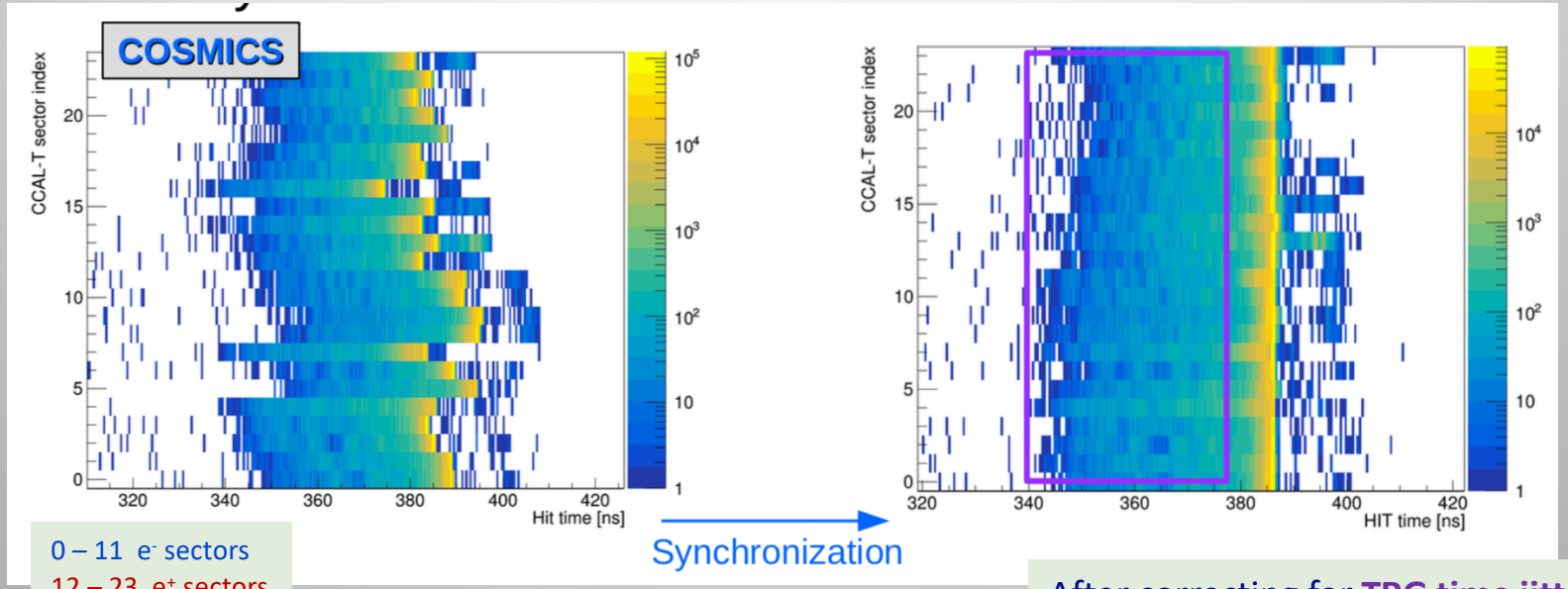
January 21st
100 bunches





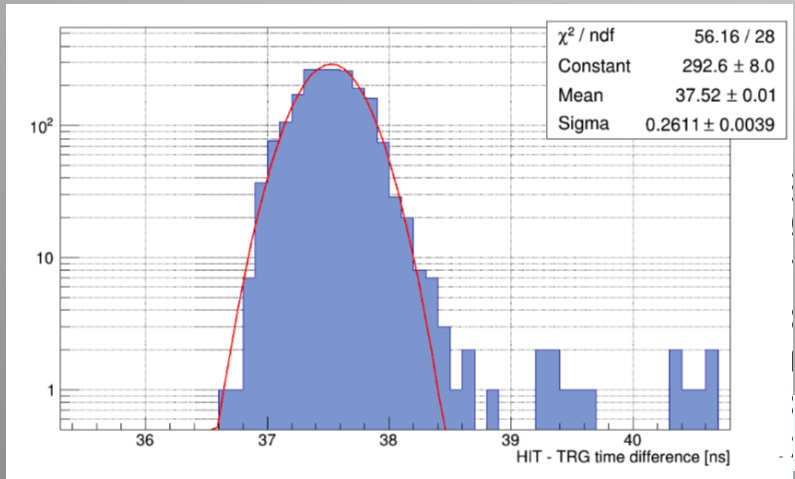
The first luminosity measurements were still affected by a relevant uncertainty.
Several attempts have been made in order to have a more reliable and general evaluation of the background.
A relevant step ahead has been done by studying in detail the synchronization of the different detector sectors and the detector occupancy, mainly concerning background spatial distribution.

Time synchronization and resolution



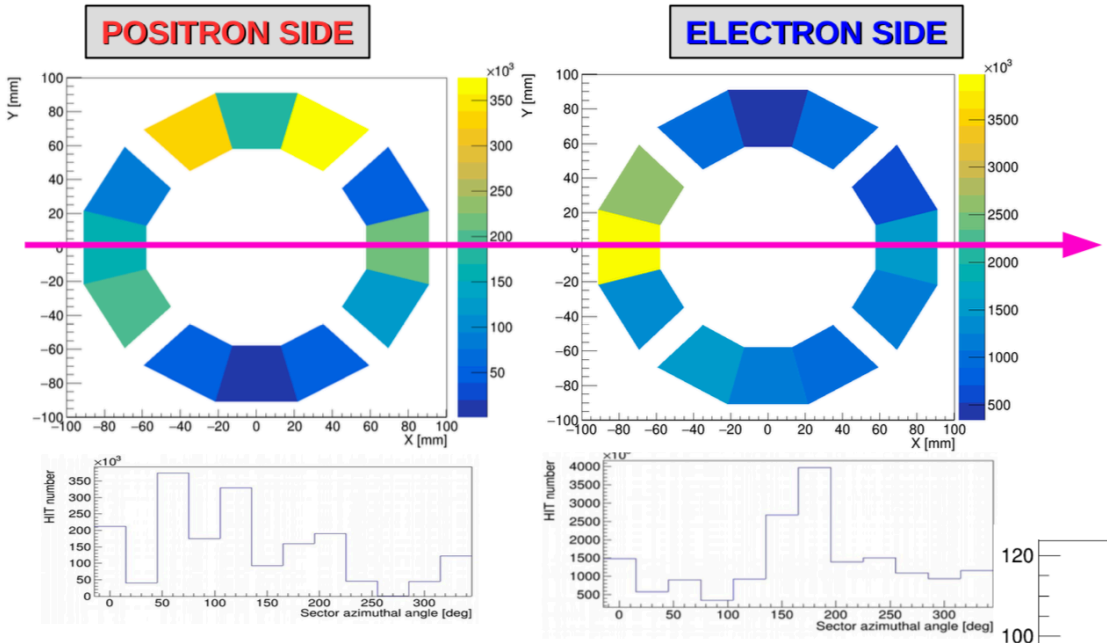
0 – 11 e^- sectors
12 – 23 e^+ sectors

After correcting for **TRG time jitter**
TRG Gate is acquired to allow for offline correction.
All corrections are performed offline.
In case of large time misalignment hardware correction is needed to avoid losses in trigger efficiency.

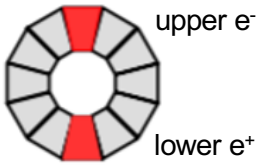


Single HIT time resolution

Detector Occupancy

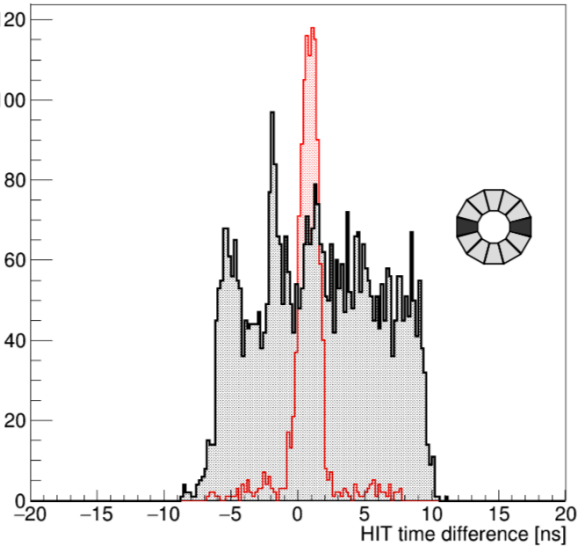


When beams are not in collision, the detector is expected to be occupied by background events only. The highest background is expected on the Horizontal plane

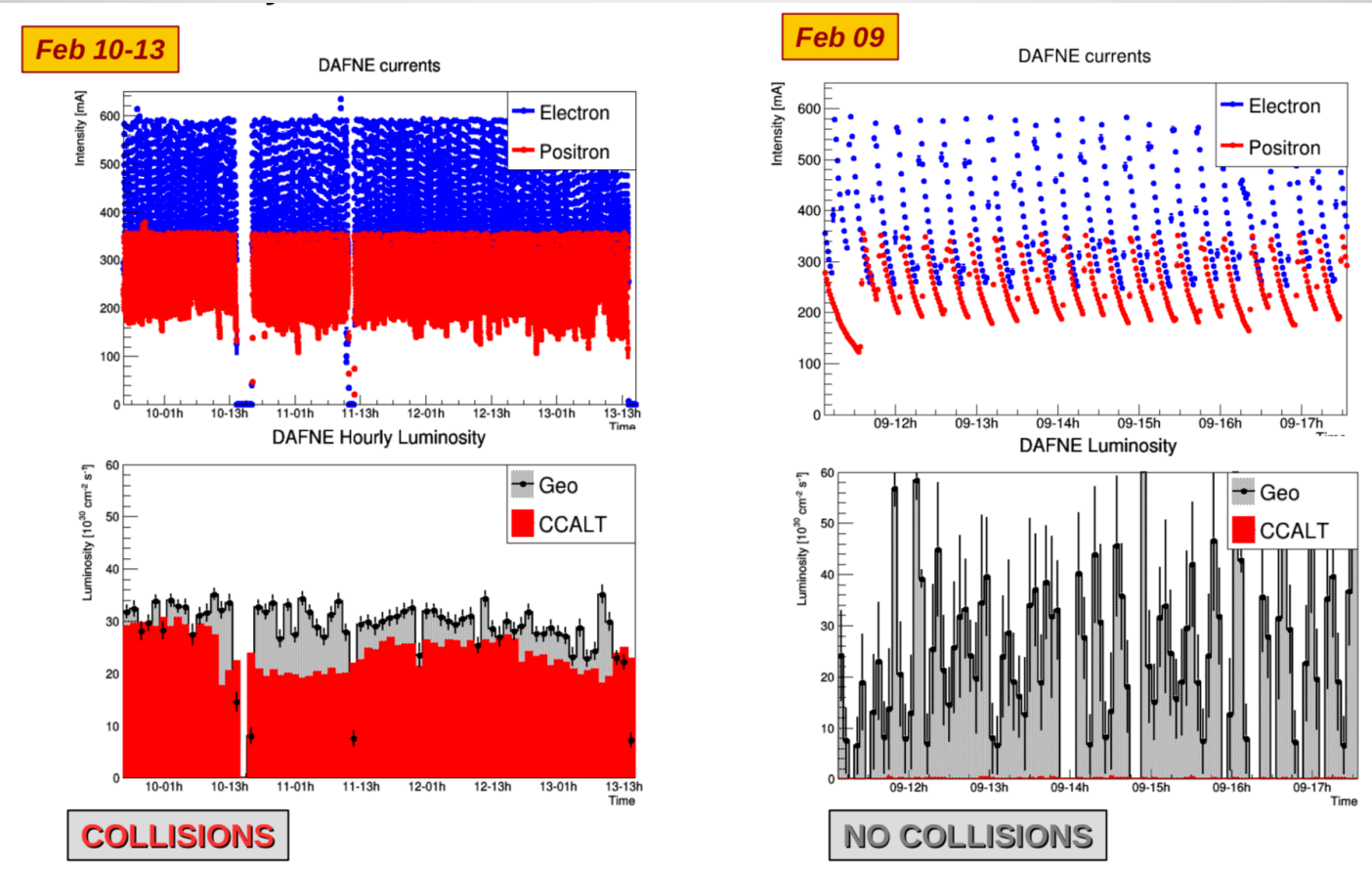


When properly synchronized and calibrated the time difference between **signal** and **background** dominated sector pairs exhibits a very different distribution.

A broadened distribution is observed for accidental coincidences, while a sharp peak characterises signal enriched samples

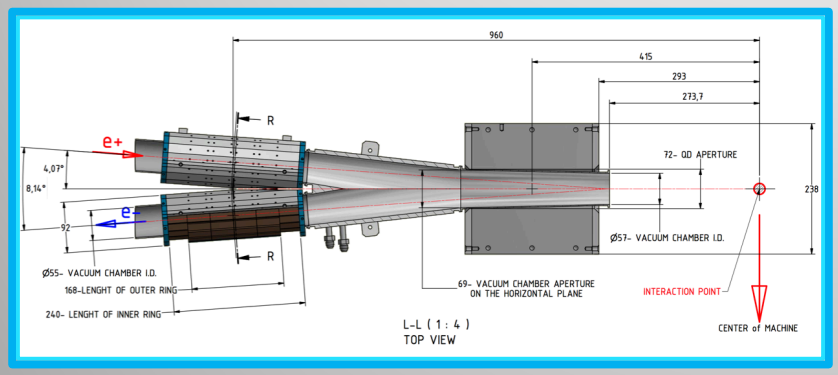


Luminosity measurements



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

Crab-Waist Optics & IR layout



	PMQD	PMQF
Beam Pipe Aperture H-V (mm) at IP (I row) and at Y (II row) side	57 69 - 55	54
Inner Apert. With Case H-V (mm)	72 - 62	58
Outer Diameter H-V (mm)	238 - 220	95.6
Mech. Length Inner-Outer (mm)	220	168 - 240
Nominal Gradient (T/m)	29.2	12.6
Integrated Gradient (T)	6.7	3.0
Good Field Region (mm)	±20	±20
Integrated Field Quality |dB/B|	5.00E-4	5.00E-4
Magnet Assembly	2 halves	2 halves

The **4 PMQF quads** had to be moved outward with respect to the IP by ~ 0.02 m.

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

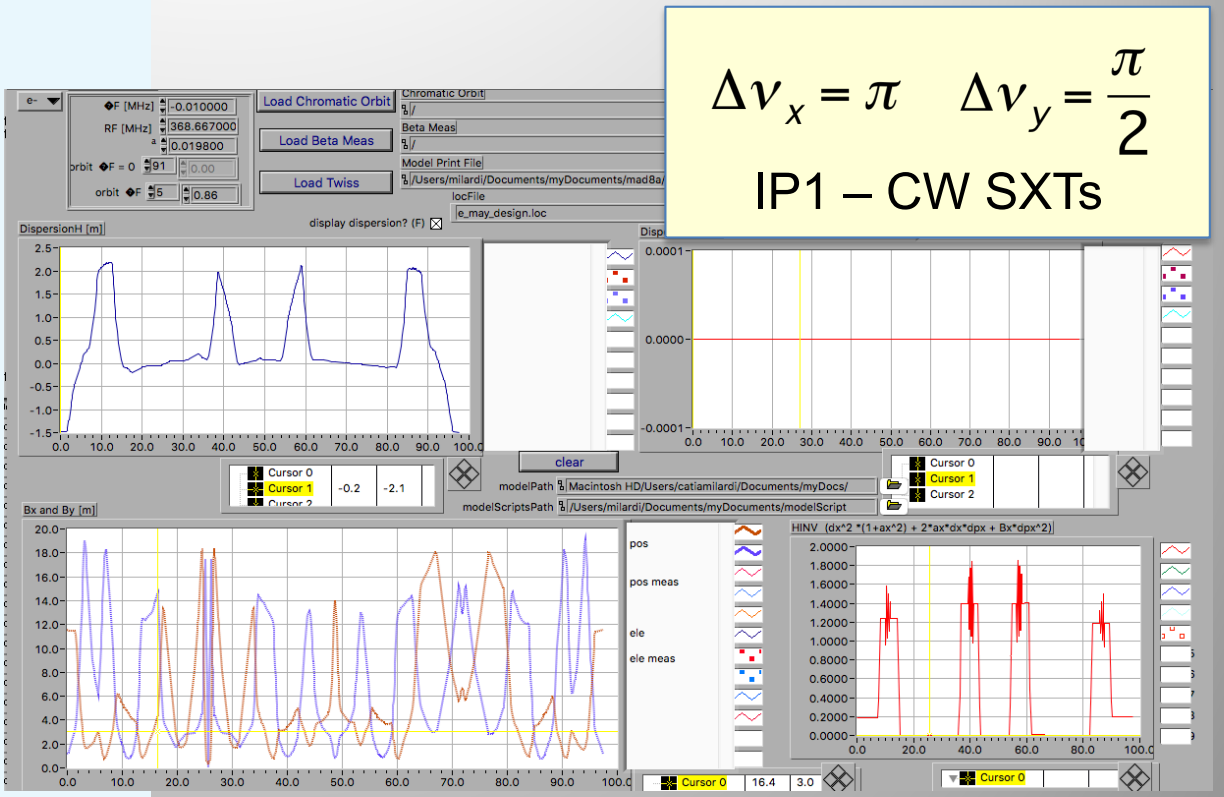
$\eta^*_x = \eta'^*_x = 0.0$

$\beta^{septum}_x = 11.52$ 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

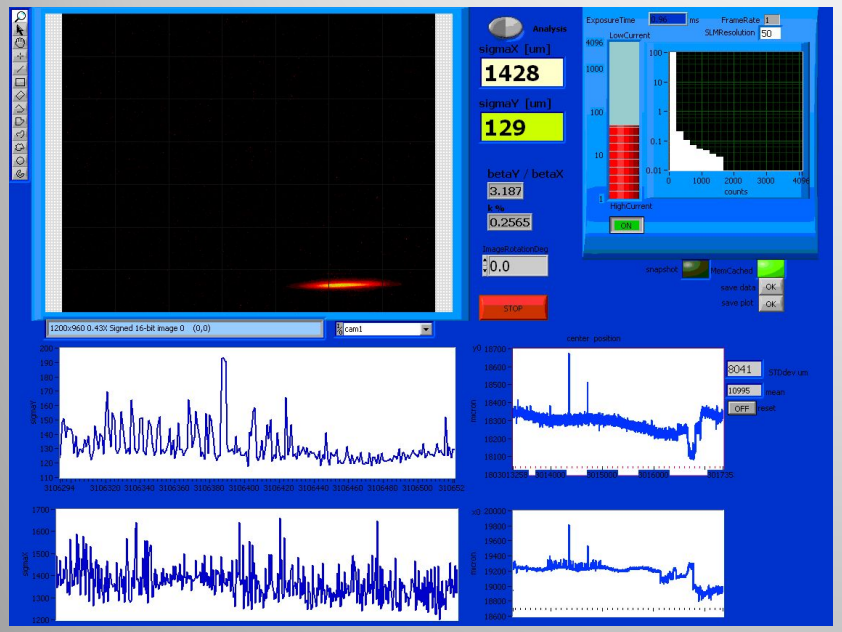


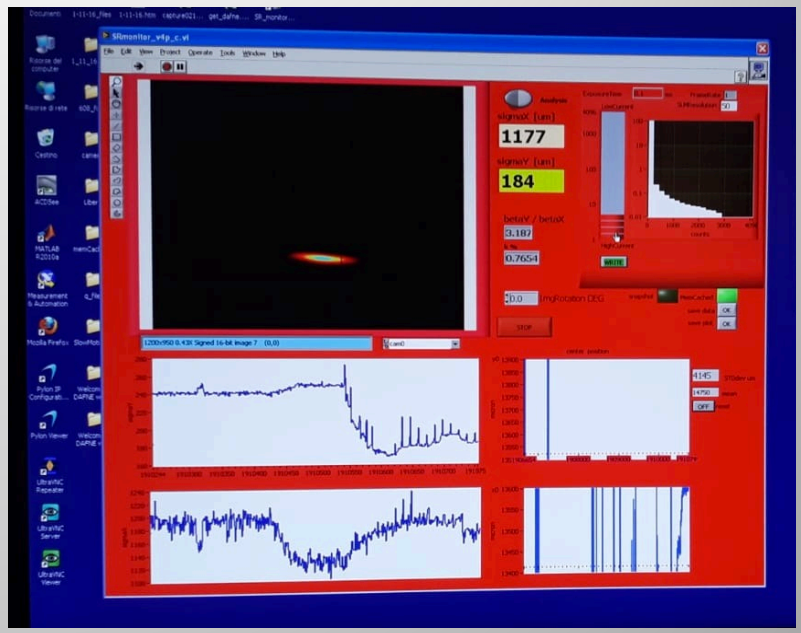
$$\Delta\nu_x = \pi \quad \Delta\nu_y = \frac{\pi}{2}$$

IP1 – CW SXTs

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

Betatron Coupling in MRs





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

SXTs ON
CW SXTs ON
Few QSK ON

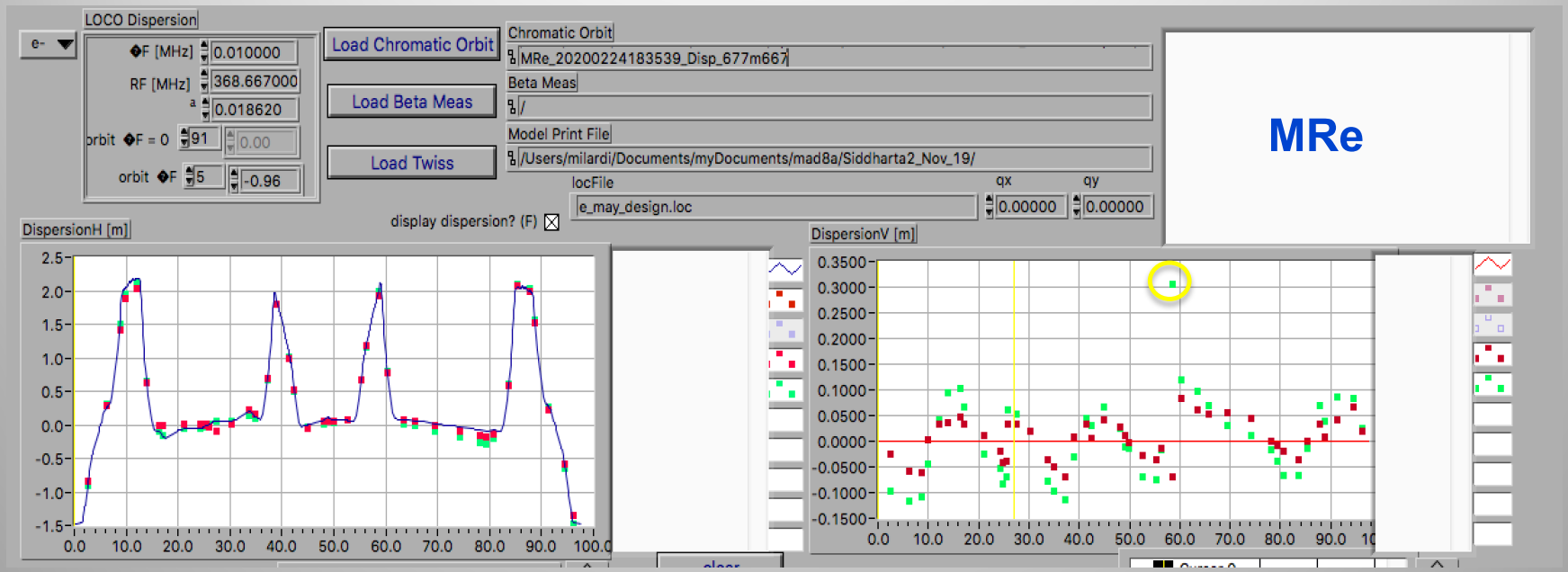
$\kappa \sim 0.7\ \%$ at SLM

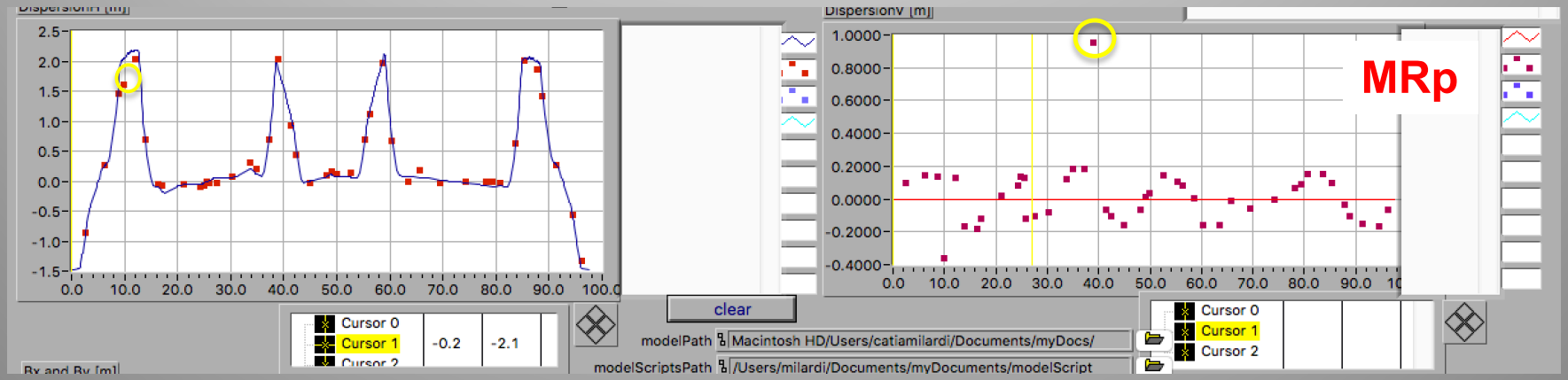
SXT ON (induce small beam tilt)
solenoids ON
QSK OFF

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

η_x in MRs

Comparison between measurements (dots) and model (line)

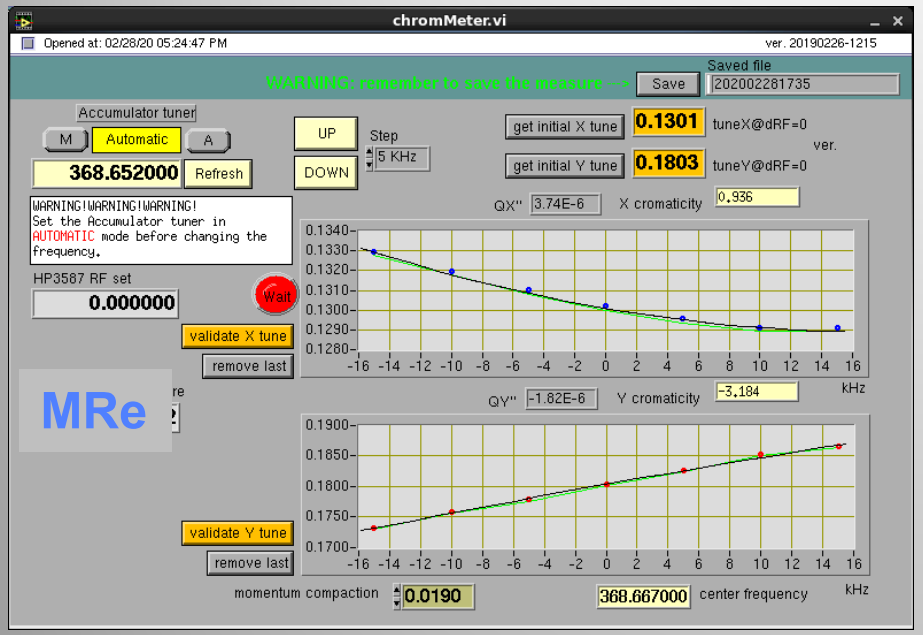


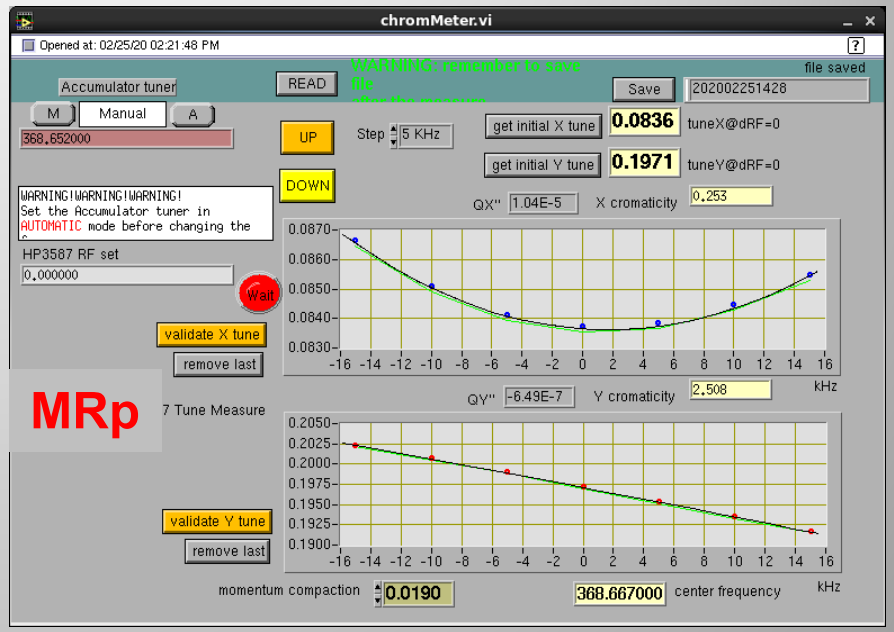


Saturated and/or disconnected BPMs

MRs Chromaticity

MRe CW SXTs at 200 A





- **ξ'' negligible**
- **Wide Energy Aperture**
  -0.7% DE/E $\leq A_E \leq$ 1.1% DE/E
- **SXTs setup**:
  has negligible impact on beam orbit
  does not affect σ_y
- **good lifetime**

much less time for optimization

Summary of *CW* Optics Activities

Feb 20th

PMQF moved longitudinally
New CW Optics applied

Feb 21st – Mar 2nd

Betatron Coupling optimized by rotating the PMQFs
Closed Orbit optimization
FBKs tuning
Localized Orbit bumps at CW SXTs closed and calibrated
Localized Orbit bumps at IP1 closed and calibrated, MRe only
Chromaticity measurements and chromatic SXTs optimized

2 – 6 Mar

***Crab-Waist* SXT beam based alignment, Mre only**
***Crab-Waist* SXTs ON, Mre only**

Optics tuned despite a quite high fault rate:

Feb 24th
Problems with LINAC, positron beam almost no longer available
Feb 27th
Vacuum vent in MRe
Mar 5th
Klystron of the Modulator C has been replaced again
Mar 12th
Machine shutdown

DAΦNE Plan

DAΦNE operations should, presumably, resume by the second half of October

In the meantime several activities have been planned starting after the required PADME installations.

Consolidation and Development Plan

Water leakage from Wiggler cooling system

Testing different kind of hoses and hose installation methods with the magnet on

Vacuum:

Replacement of the damaged flange in MRe, to be completed, at the latest, by the end of June.

Power Supplies:

- Repair several faulty components
- Preparatory work to install the new UFS PS in the LINAC

Mechanical & alignment

- Finalization of the PMQFs, magnetic characterization and tuning
- BPMs offsets measurement.

Consolidation and Development Plan

Control System:

- Replacement of obsolete hardware in the DAΦNE server
- Development of new, more efficient, tools for DAΦNE data logging
- Porting CS user applications to the new Linux consoles

Control System & Diagnostics

- Definition and acquisition of new hardware in order to start laboratory tests aimed at developing a new acquisition system for the MRs closed orbit measurement
- Fix hardware faults affecting a low pass VME board which is part of the MRs BPMs acquisition system

Consolidation and Development Plan

Luminosity Monitor improvements:

- Background evaluation (S)
- Cosmic Rays simulation and geometry description (S)
- Time synchronization/energy calibration (H/S)
- Energy response equalization (S/H)
- Full efficiency evaluation (H/S)
- MC validation (S)
- On-line luminosity deployment (S)

Consolidation and Development Plan

Main Rings Optics:

- Optimization of the RCR lattice
- Comprehensive non-linear optics studies
- Development of a lattice model for the new **PMQF**s, when magnetic measurements will be available
- Background simulations (following the Reviewers recommendation: *SIDDHART(A/INO) background conditions and their optimization should be anticipated*)

This program has to deal with the well known lack of dedicated manpower and it's not sure that all the items will be finalised.

Manpower

Concerning manpower: by the end of this month the person in charge of the DAFNE Feedback systems will retire.

The *DAΦNE Commissioning Team* will lose a person who has been following machine commissioning on daily bases, has been giving support in terms of operations and beam measurements, and a Run Coordinator.

Another researcher has been appointed to work on Feedback systems

Conclusions

Sources of betatron coupling in the MRs have been identified and fixed, while storing beams for vacuum conditioning.

Low-β optics has been completely characterized and the new model parameters have been used to compute the CW Optics.

First beam-beam vertical scan has produced results coherent with the nominal collision parameters.

CCAL-T luminosity monitor has been extensively characterized during dedicated operations, achieving a luminosity measurements in reasonable agreement with the theoretical predictions and with the SIDDHARTA-2 data.

CW Optics has been applied and optimized in terms of: coupling, orbit, chromaticity, and CW SXTs alignment, mainly for the e^- beam.

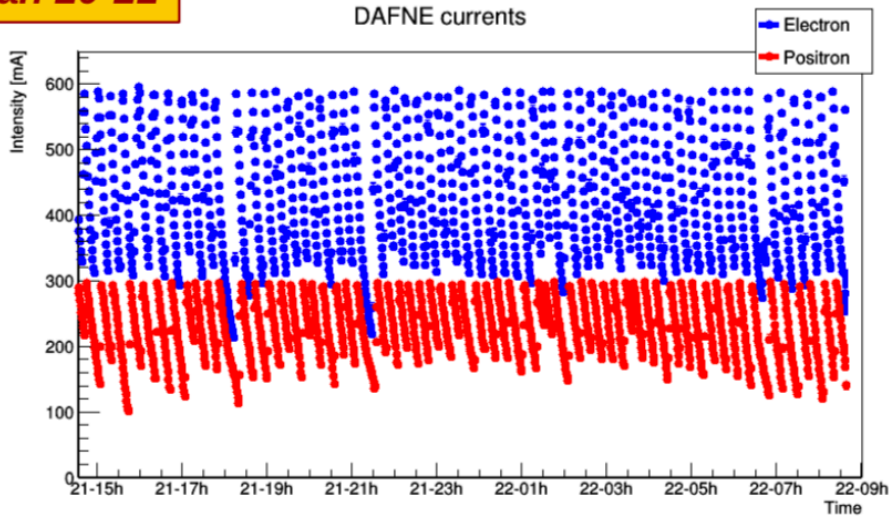
A minimal plan has been defined to efficiently resume DAΦNE operations according to the new LNF schedule imposed by the pandemic.

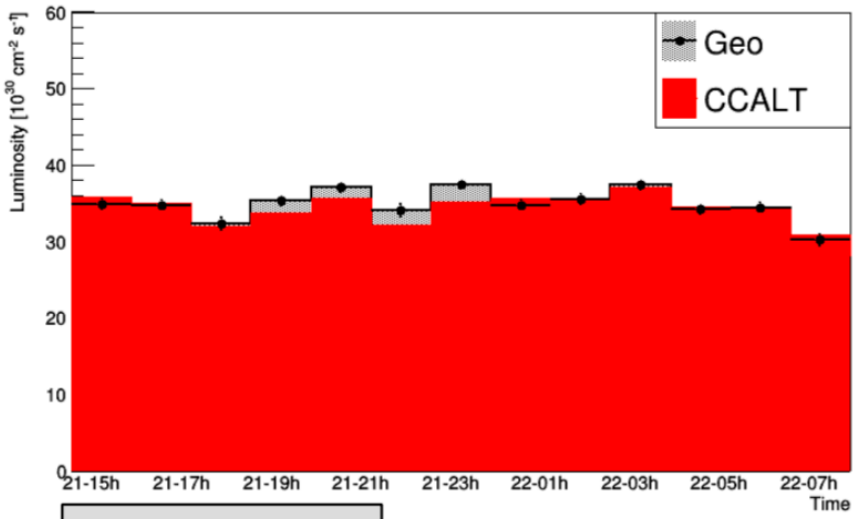
Thank you for your attention

Spare Slides

Luminosity measurements

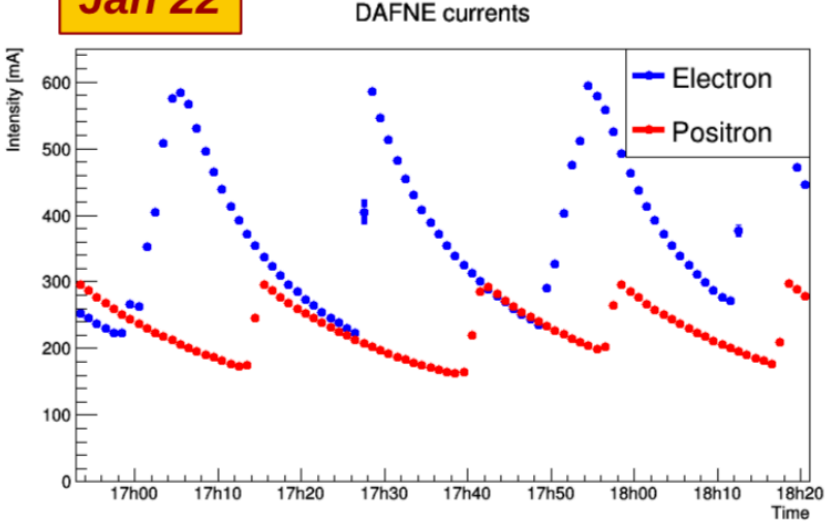
Jan 20-21

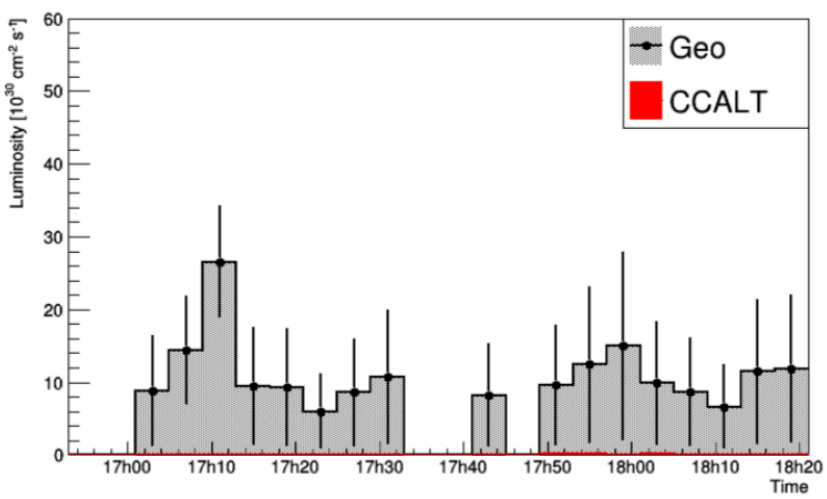




COLLISIONS

Jan 22

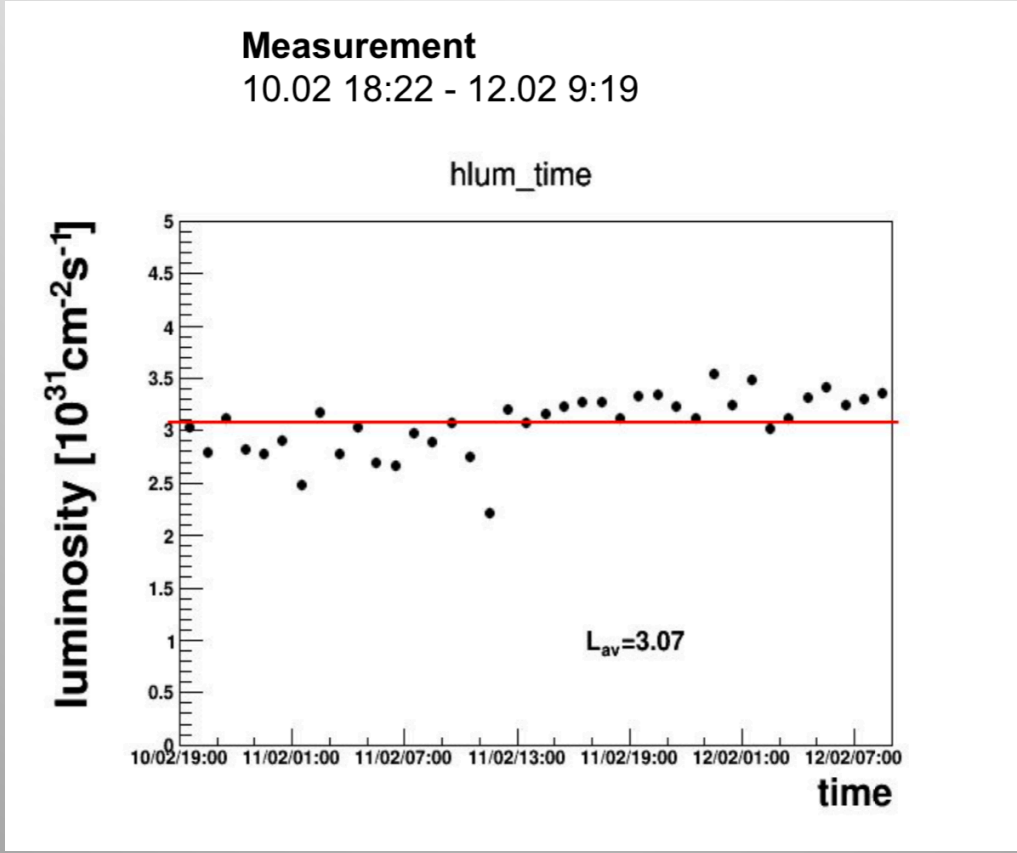




NO COLLISIONS

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

First SIDDHARTA-2 Luminosity Measurement



Geometrical luminosity