WP11 – ANAC

M. Biagini, on behalf of WP11 Task leaders

EuCARD 3rd Annual Meeting

Warsaw, April 25-27th, 2012

WP11 - Tasks

- **Task 11.1. ANAC Coordination and Communication** *(Coordinator M. Biagini, LNF - INFN)*
  - **Coordination and scheduling of the WP tasks**
  - **Monitoring the work, informing the project management and participants within the JRA**
  - **WP budget follow-up**
- **Task 11.2. Design of Interaction Regions for high luminosity colliders** *(Coordinator C. Milardi, LNF - INFN)*
  - **Feasibility study of a new IR based on the Crab Waist concept for the upgraded KLOE experiment at DAΦNE.**
  - **Study the possible integration of the Crab Waist collision scheme into the LHC collider upgrade**
- **Task 11.3. Upgrade of the EMMA FFAG Ring** *(Coordinator T.R. Edgecock, STFC)*
  - **Design, build and test the external diagnostics systems for EMMA**
  - **Commission EMMA using the diagnostics and perform the necessary experiments to evaluate non-scaling optics for a variety of applications.**
- **Task 11.4. Instrumentations for novel accelerators** *(Coordinator V. Malka, LOA - CNRS)*
  - **Design, build and test of detectors for emittance measurements of electron beams delivered by laser plasma accelerators**

Task 11.2.1 DAΦNE IR

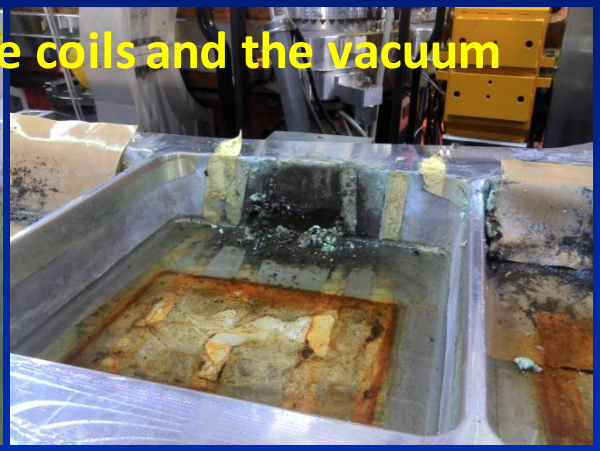
- This Subtask has accomplished all its Milestones and Deliverables
- Commissioning of the rings is not part of EuCARD scopes but the progresses are summarized here
- The commissioning of the collider for the KLOE experiment has had some delay due to several hardware faults (cooling system, power supplies, control system, water leakage from some magnets and a hole in one MRp wiggler)
- A vibration at the IP doublet has also been detected, measured and cured

Wiggler faults in the MRe

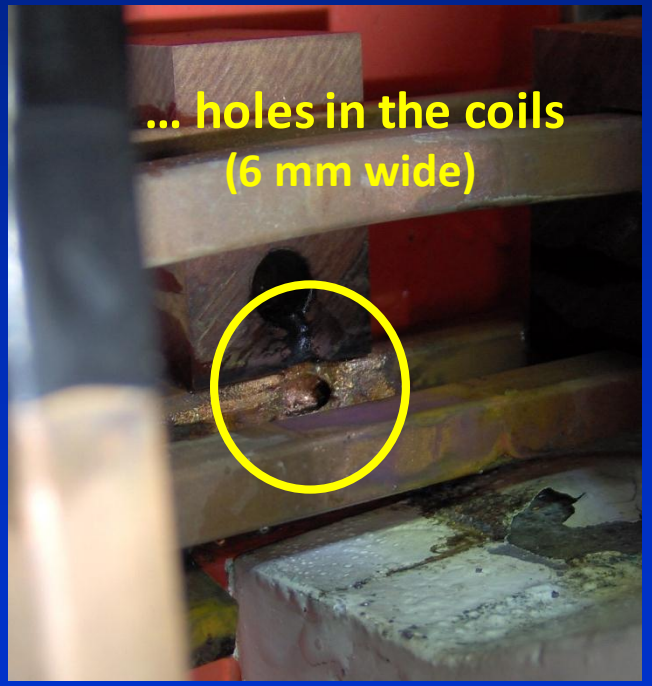
(March 25th 2012)

Three out of four wigglers installed in the e^- ring got seriously damaged due to a long term water leakage not detected due to a concomitant fault in the power supply board supervising ground fault occurrence.

…. discharge between the coils and the vacuum chamber



… calcareous concretions



… holes in the coils
(6 mm wide)

DAΦNE Maximum Peak Luminosity so far …

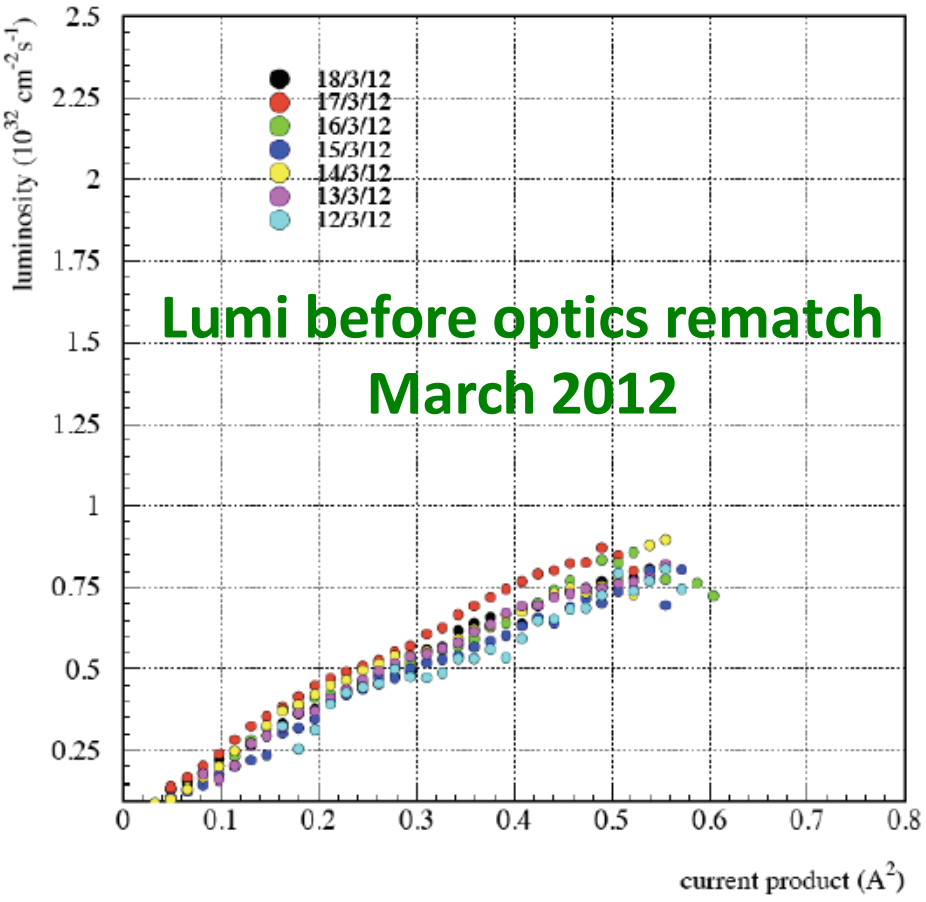
Same peak luminosity as in 2005, but

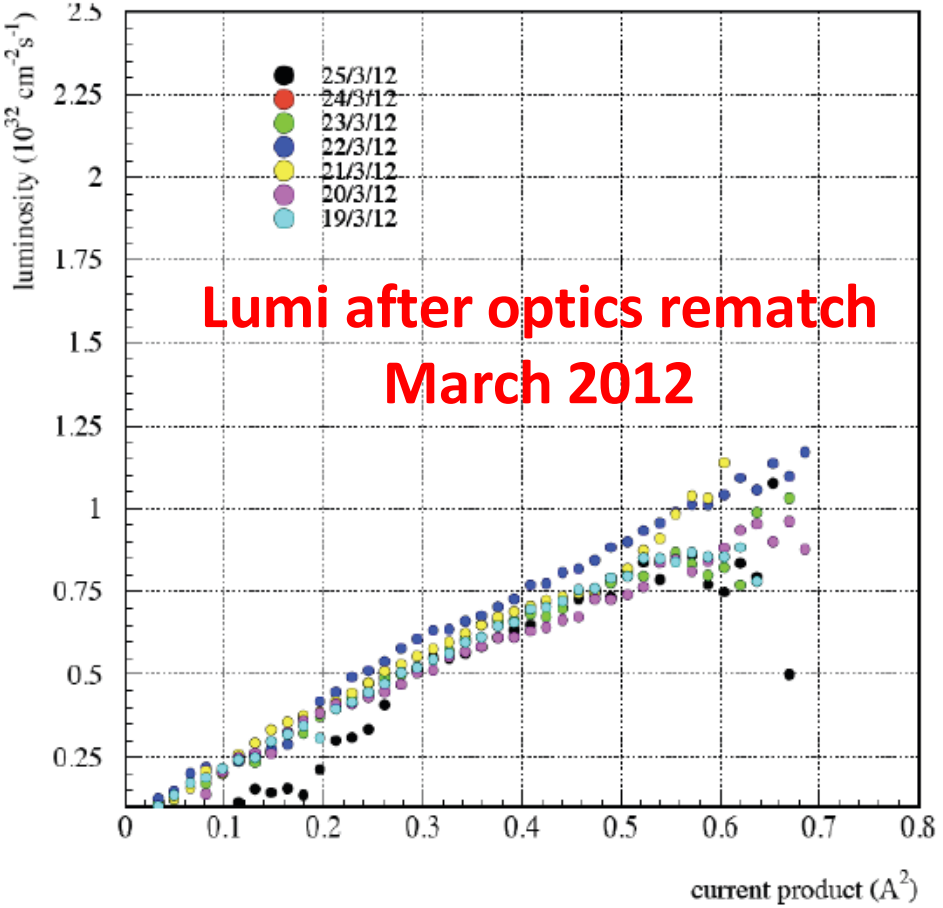
- **less bunches in collision (100)**
- **lower currents**

	DAΦNE upgrade SIDDHARTA (2009)	DAΦNE KLOE (2005)
L_{peak} [$cm^{-2}s^{-1}$]	$4.53 \cdot 10^{32}$ ($5.0 \cdot 10^{32}$)	$1.53 \cdot 10^{32}$
$L_{\int day}$ [pb^{-1}]	14.98	9.8
$L_{\int 1\ hour}$ [pb^{-1}]	1.033	0.44
I^{-}_{MAX} in collision [A]	1.52	1.4
I^{+}_{MAX} in collision [A]	1.0	1.2
$N_{bunches}$	105	111
ξ_y	0.044	0.025

Optics rematching

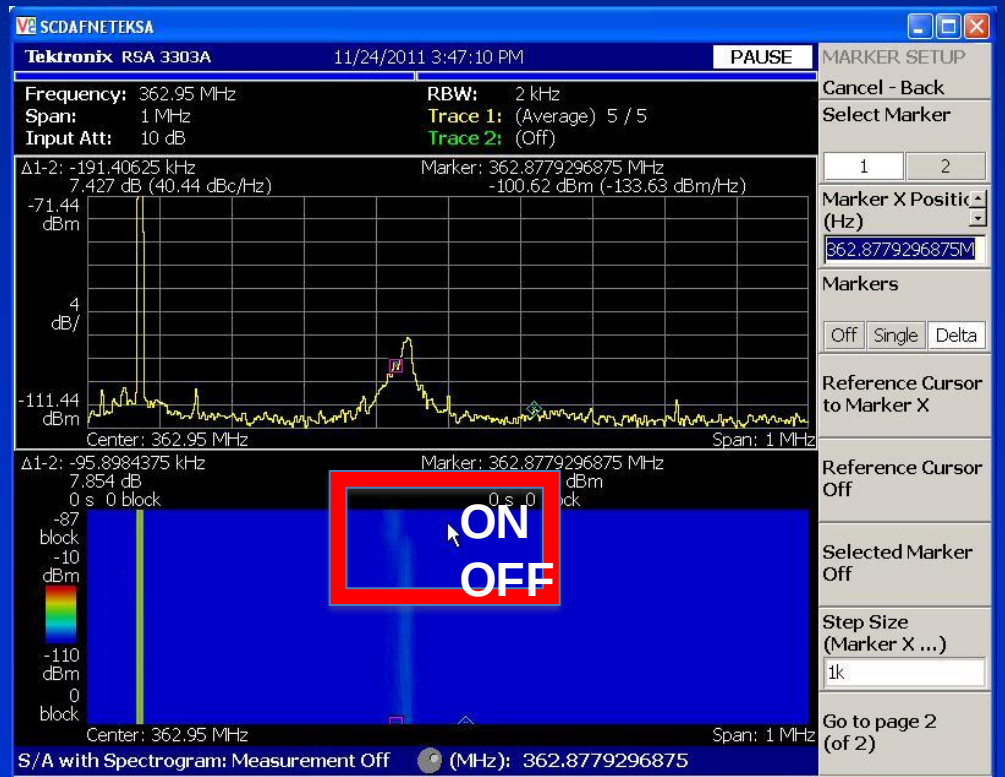
- Main Rings optics has been re-matched. As a consequence :
  - smoother injection with higher efficiency and lower radiation level
  - reduced beam blow-up with the main and the opposite beam current





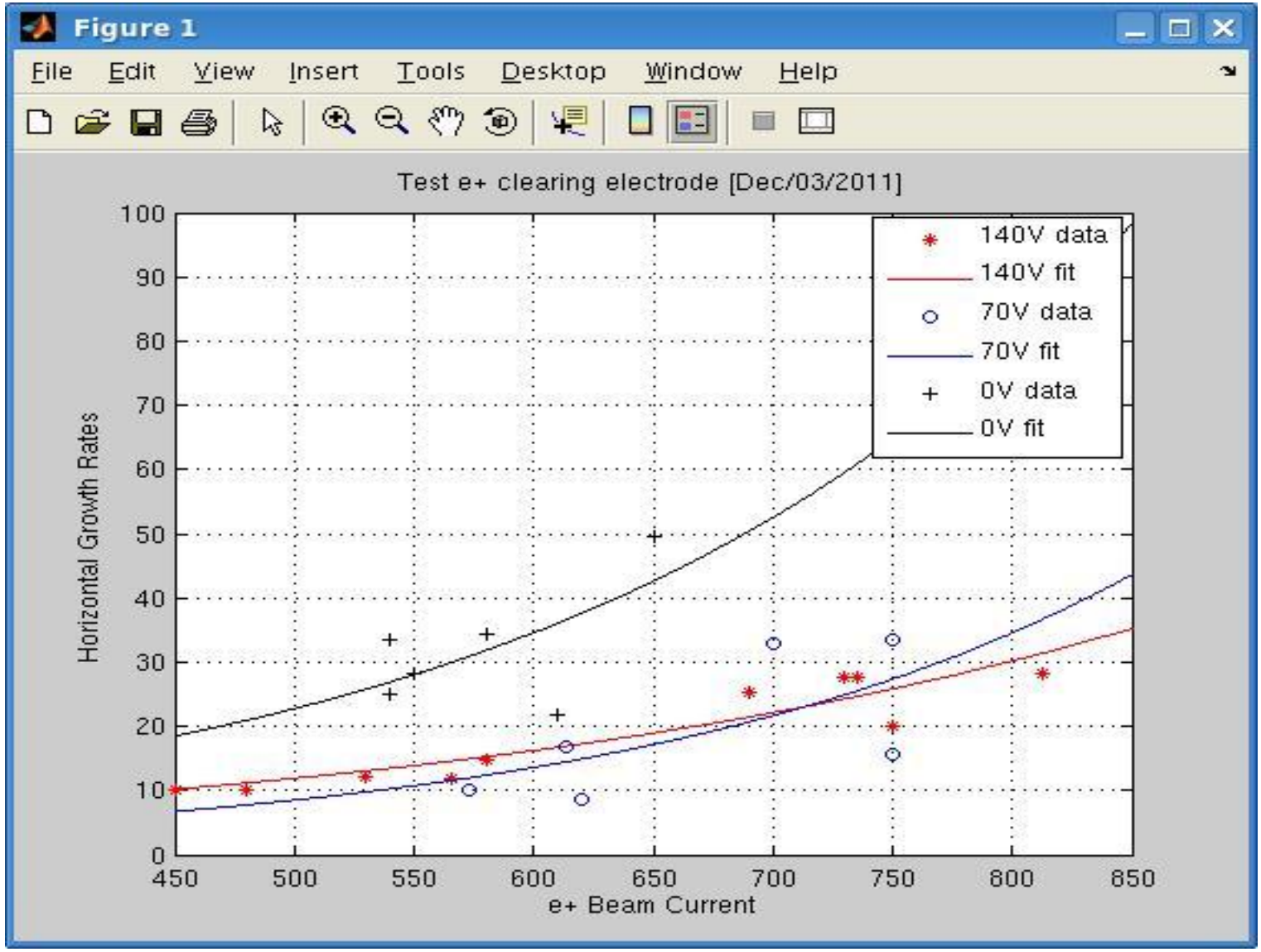
Clearing electrodes for e-cloud suppression

- *The electrodes are behaving as expected and are suppressing the e-cloud density in dipoles and wigglers. An even better effect is expected after replacing the electrodes power supplies*
- *Measurement of horizontal growth rates*
- *Increase in injected positron current (900 mA now)*

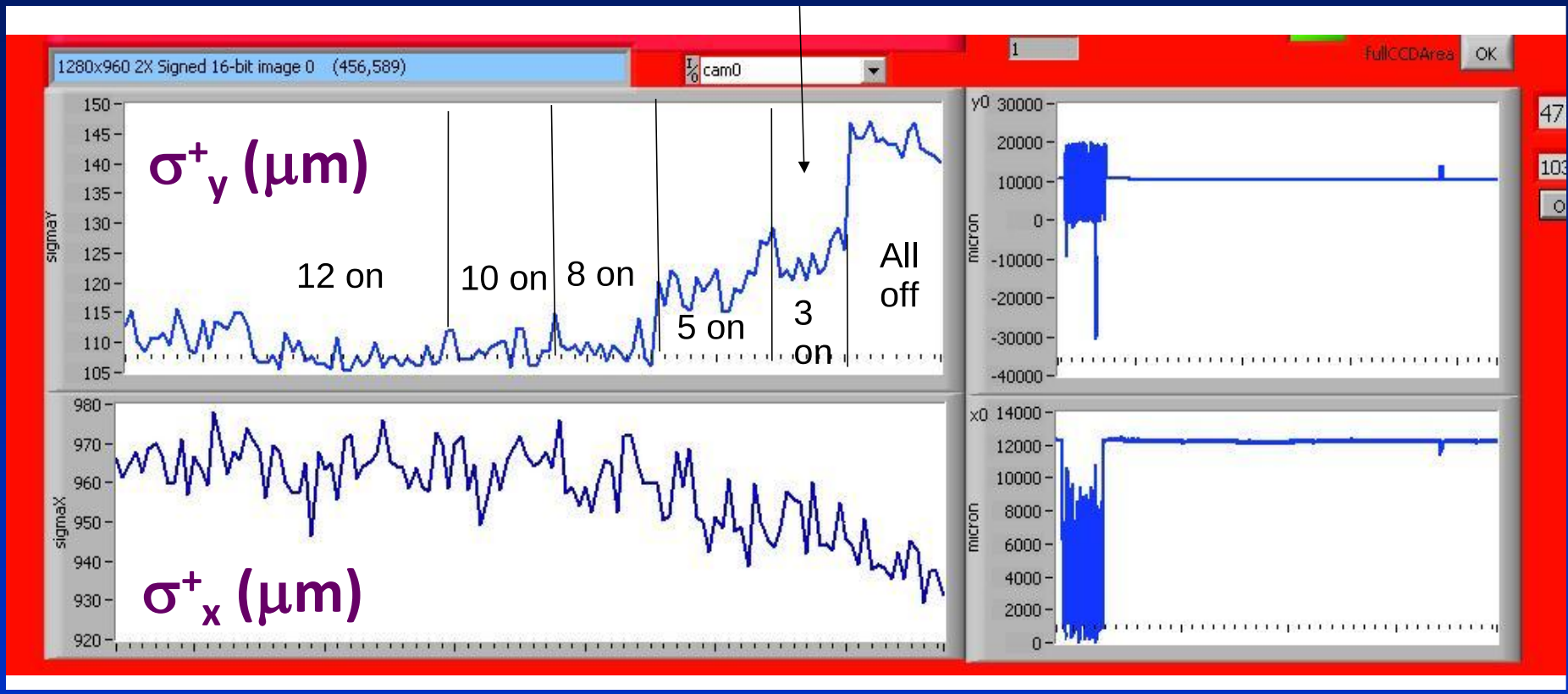


Horizontal tune-shift due to e-cloud

Horizontal growth rate measurements



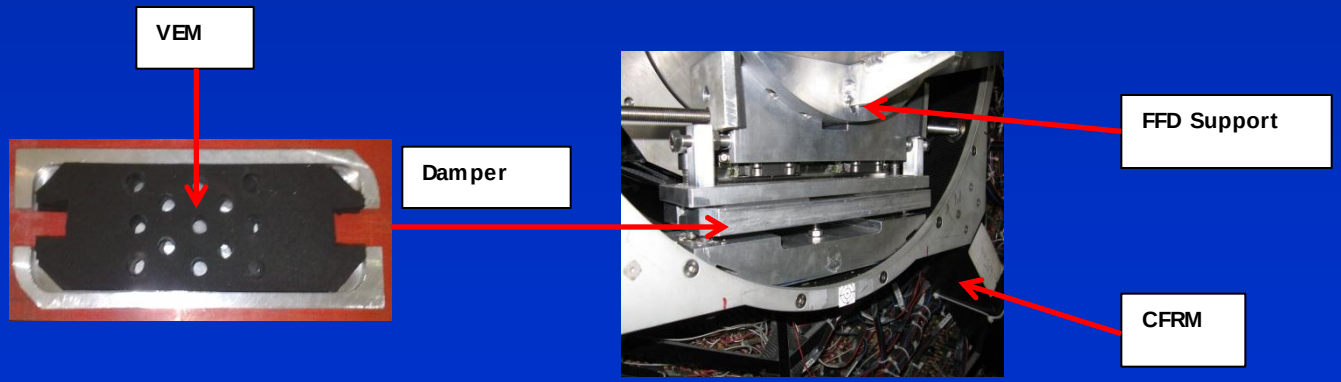
Turning off the electrodes the transverse vertical beam dimension increases



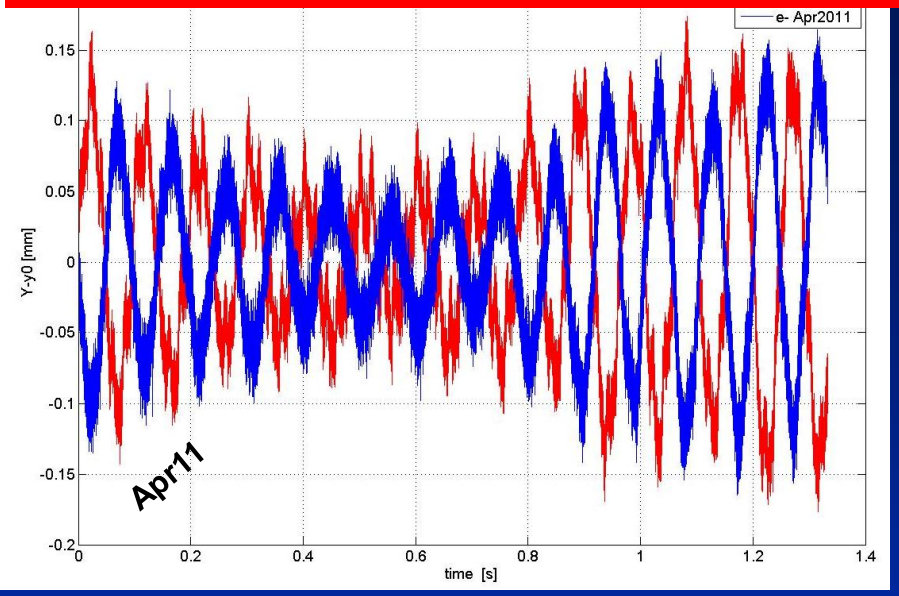
Power supplies must be replaced because their load impedance changes with the beam current

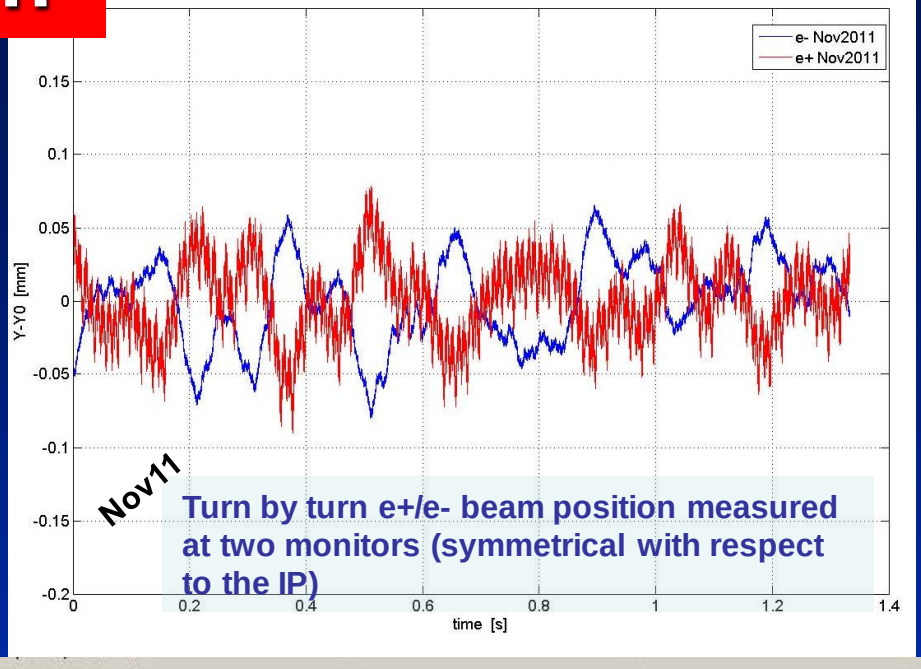
Vibrations at IP

- Lst year a random amplitude, 10.5 Hz vertical oscillation was detected on both beams, compatible with a vibration in the low-beta defocusing quadrupole → orbit deviation recorded by two BPMs installed in a symmetrical location with respect to the IP confirmed that the vibration source was $\pi/2$ in phase advance from the IP
- To overcome the effect four layers of viscous elastic material, total thickness 17 mm, have been inserted below the supports of the low-beta quadrupoles resulting in a ~50% reduction of the observed vibrations



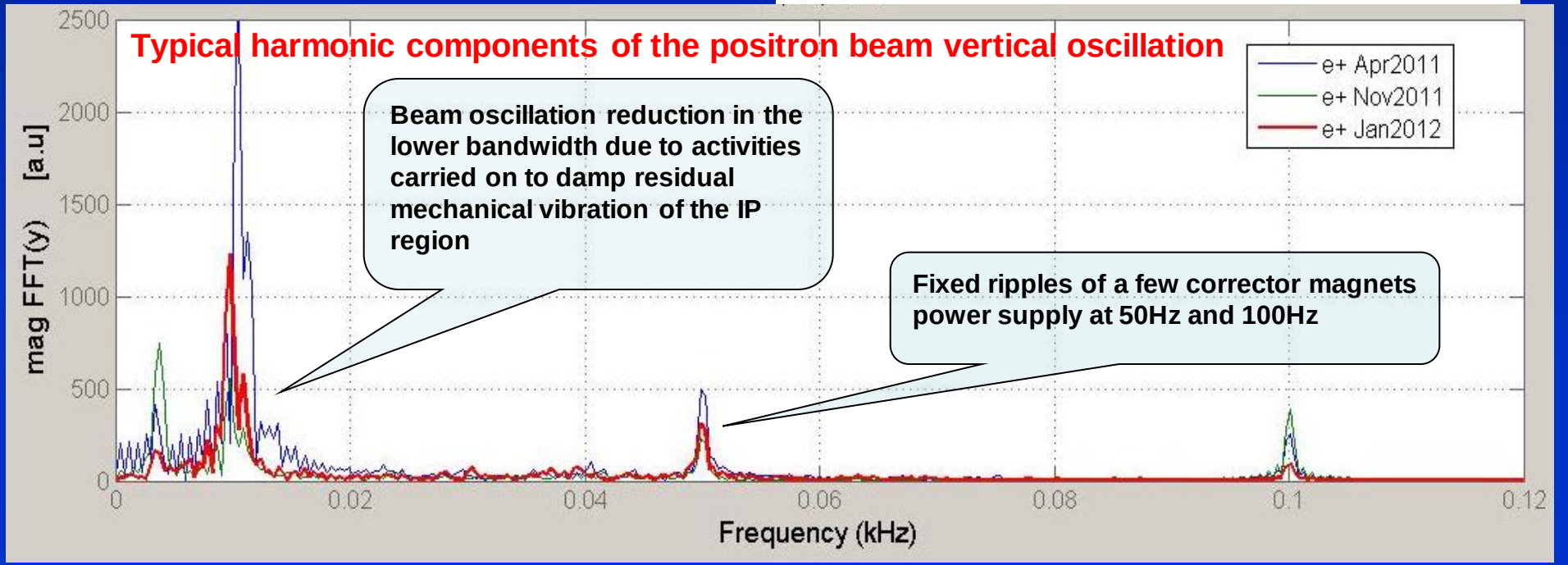
Vertical orbit oscillation





Turn by turn e+/e- beam position measured at two monitors (symmetrical with respect to the IP)

Typical harmonic components of the positron beam vertical oscillation



Beam oscillation reduction in the lower bandwidth due to activities carried on to damp residual mechanical vibration of the IP region

Fixed ripples of a few corrector magnets power supply at 50Hz and 100Hz

Conclusions on DAΦNE commissioning

- Peak luminosity now comparable with the maximum achieved at the end of the KLOE run in 2005
- At low currents the highest L_{spec} achieved exceeds by 3 times the best value measured during the past KLOE runs
- Maximum currents stored so far in collision are:
  - $I^- \sim 1.3$ A
  - $I^+ \sim 0.9$ A
- Clearing electrodes are effective in keeping under control the e-cloud driven instabilities in the positron ring
- Vibrations at IP have been damped by 50%

Subtask 11.2.2 - Crab Waist for the LHC

- Initial delay due to difficulty of recruiting a fellow at CERN
- Two mitigations:
  - ➢ contributions by external experts
    - Dmitry Shatilov (BINP) visiting Mikhail Zobov at INFN-LNF twice , in fall 2010 and winter 2011
    - Kazuhito Ohmi (KEK) visiting Frank Zimmermann at CERN twice, in summer 2010 and winter 2011
  - ➢ recruitment of doctoral student instead of fellow
    - Jose Abelleira started at CERN in November 2010

- **D11.2.2: Study of an IR design for LHC upgrade, CERN, M36, March 2012 will be delayed to M48**

Beam-beam studies

- Previous studies have shown that the Crab-Waist scheme becomes much less effective for round beams with respect to flat beams → bb simulations for flat beam option in LHC
- A special IR with beta function's ratio of 100 (β_x/β_y = 1.36 m/1.36 cm) at the IP and a local chromaticity correction is under study at CERN. A luminosity increase by a factor of 5-10 with respect to the nominal LHC luminosity can be achieved depending on the chosen beam crossing angle θ (see Table next slide)
- Numerical simulations and frequency map analysis (FMA) of bb interactions performed for all cases: switching ON crab waist sextupoles is very effective in suppression of the beam-beam resonances → smaller footprint area and a considerable beam-beam resonance strength reduction
- FMA plots in two planes: in the plane of betatron tunes (footprints, left) and normalized betatron amplitudes (right). Colors comply with the diffusion index: blue → stable motion, red → stochastic

(D. Shatilov, M. Zobov)

LHC luminosity vs Piwinski's angle

$\theta, mrad$	Φ	$1/\sqrt{1+\Phi^2}$	R	$L_0 R, 10^{34}$	ξ_x	ξ_y
1.0	1.8875	0.4682	0.2981	10.826	0.00792	0.00169
1.5	2.8312	0.3330	0.2417	8.7754	0.00406	0.00122
2.0	3.7749	0.2561	0.2019	7.3311	0.00242	0.00094
2.5	4.7187	0.2073	0.1728	6.2730	0.00159	0.00077
3.0	5.6624	0.1739	0.1506	5.4690	0.00113	0.00065

$$L = \frac{N^2 n_b f}{4\pi\sigma_x\sigma_y} \times R$$

$$R = \frac{L}{L_0} = \sqrt{\frac{2}{\pi}} a e^b K_0(b)$$

$$a = \frac{\beta_y^*}{\sqrt{2}\sigma_z}, \quad b = a^2\left(1+\Phi^2\right)$$

$$\Phi = \frac{\sigma_z \tan(\theta/2)}{\sigma_x}$$

$$\beta_x = 1.36m, \quad \beta_y = 1.36cm, \quad \varepsilon_n = 2.194\mu mrad$$

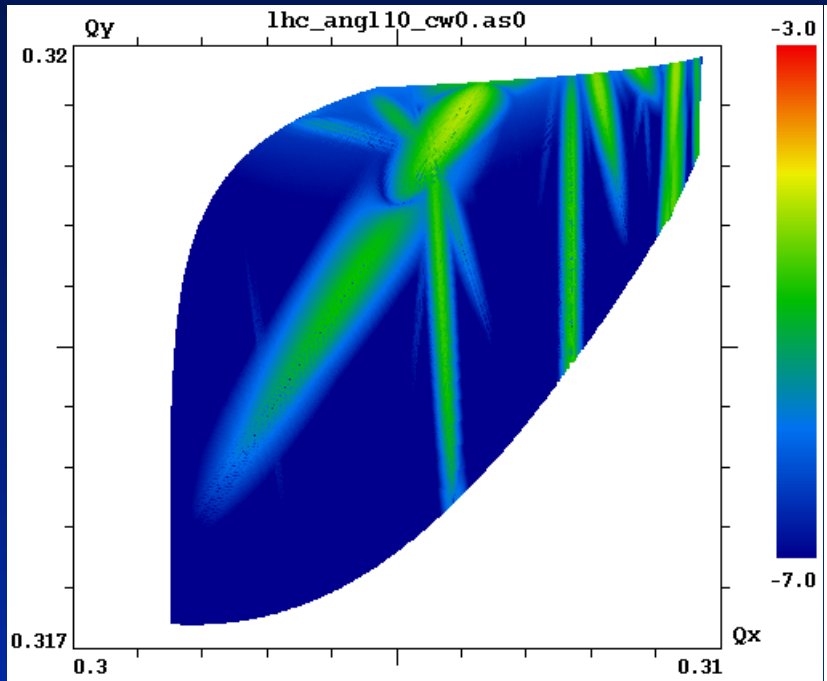
$$\sigma_x = 20\mu m, \quad \sigma_y = 2\mu m, \quad \sigma_z = 7.55cm$$

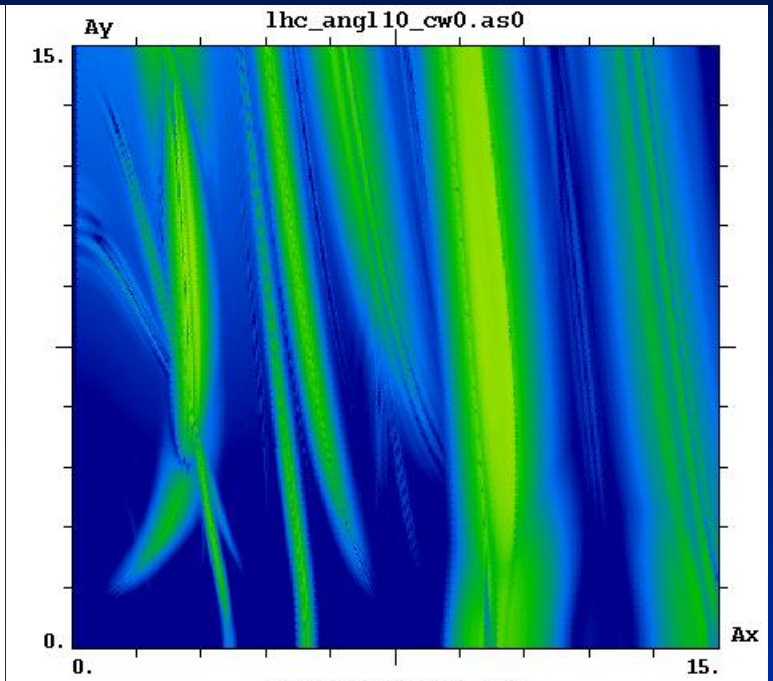
$$N = 3.4\times10^{11}, \quad n_b = 1404, \quad \gamma = 7461$$

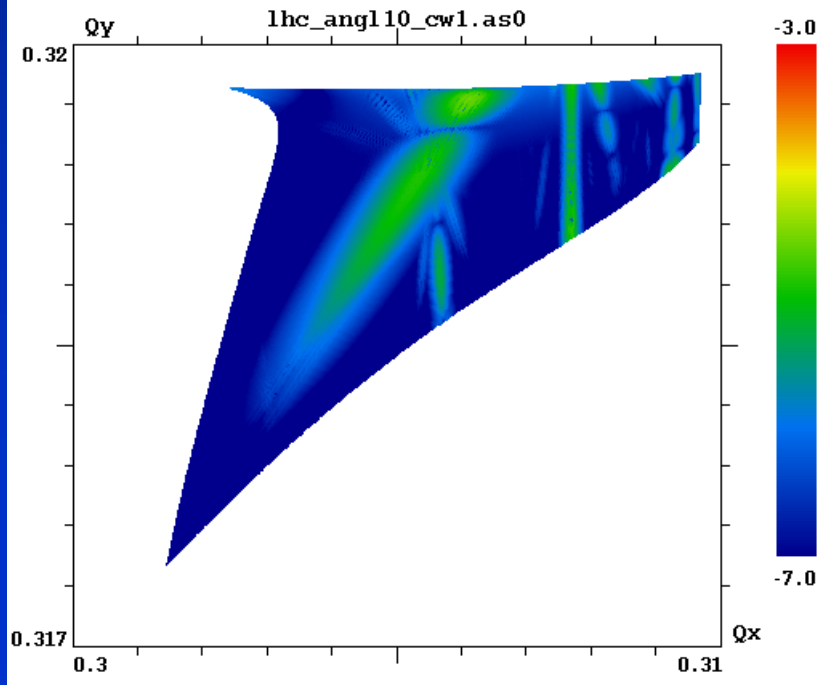
Angle = 1.0 mrad

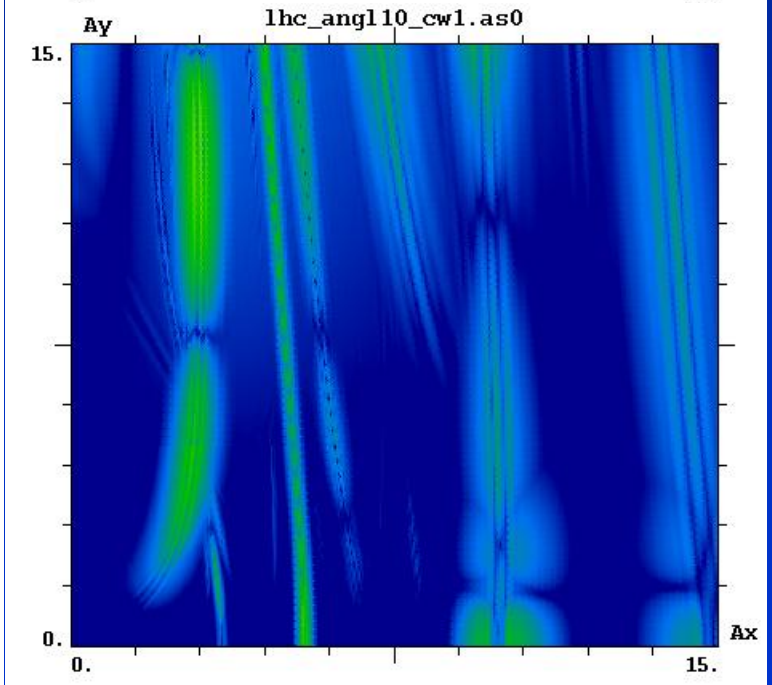
CW = 0

CW = 0.5





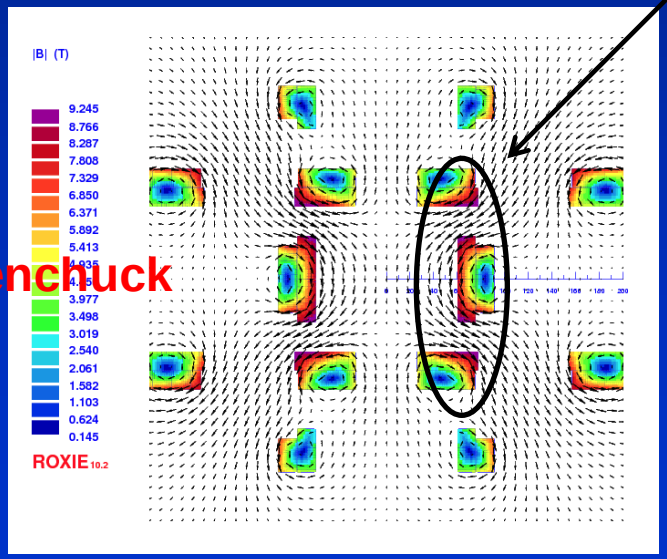




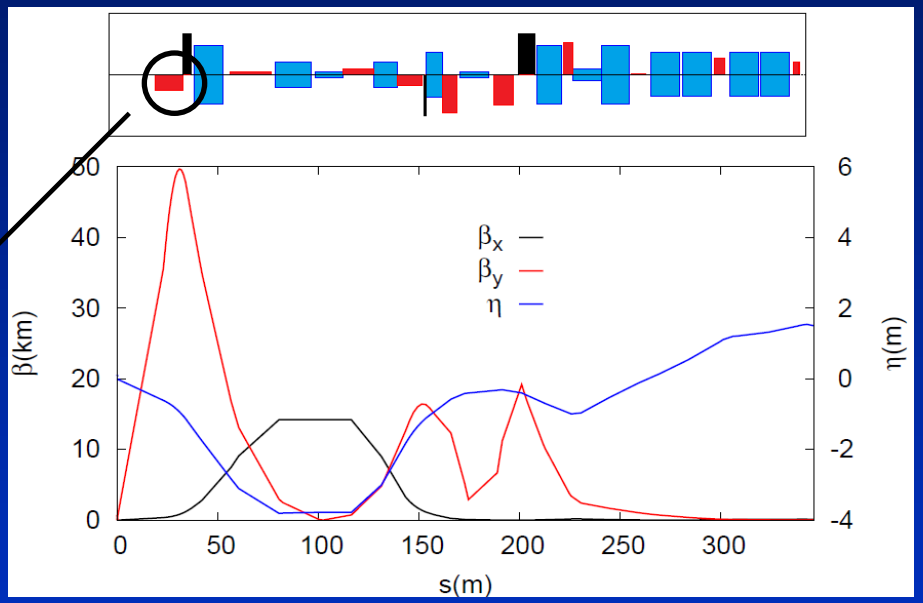
Study of crab waist optics for the LHC

A new optics is being developed for the LHC:
- large Piwinski angle, to allow for much lower β_y^* and higher brilliance
- extremely-flat beams β_x^*=1.5 m, β_y^*=1.5 cm
- local vertical chromatic correction
- crab-waist collisions

Opposite gradient in the same element: double half quadrupole



S.Russenchuck



Three sextupoles per side of IP for
- vertical chromatic correction & cancellation of aberrations
- crab-waist collisions

Details in WP11.2 talk "Towards an extremely-flat beam optics with large crossing angle for the LHC" by Jose Abelleira

Publications for Task 11.2.2

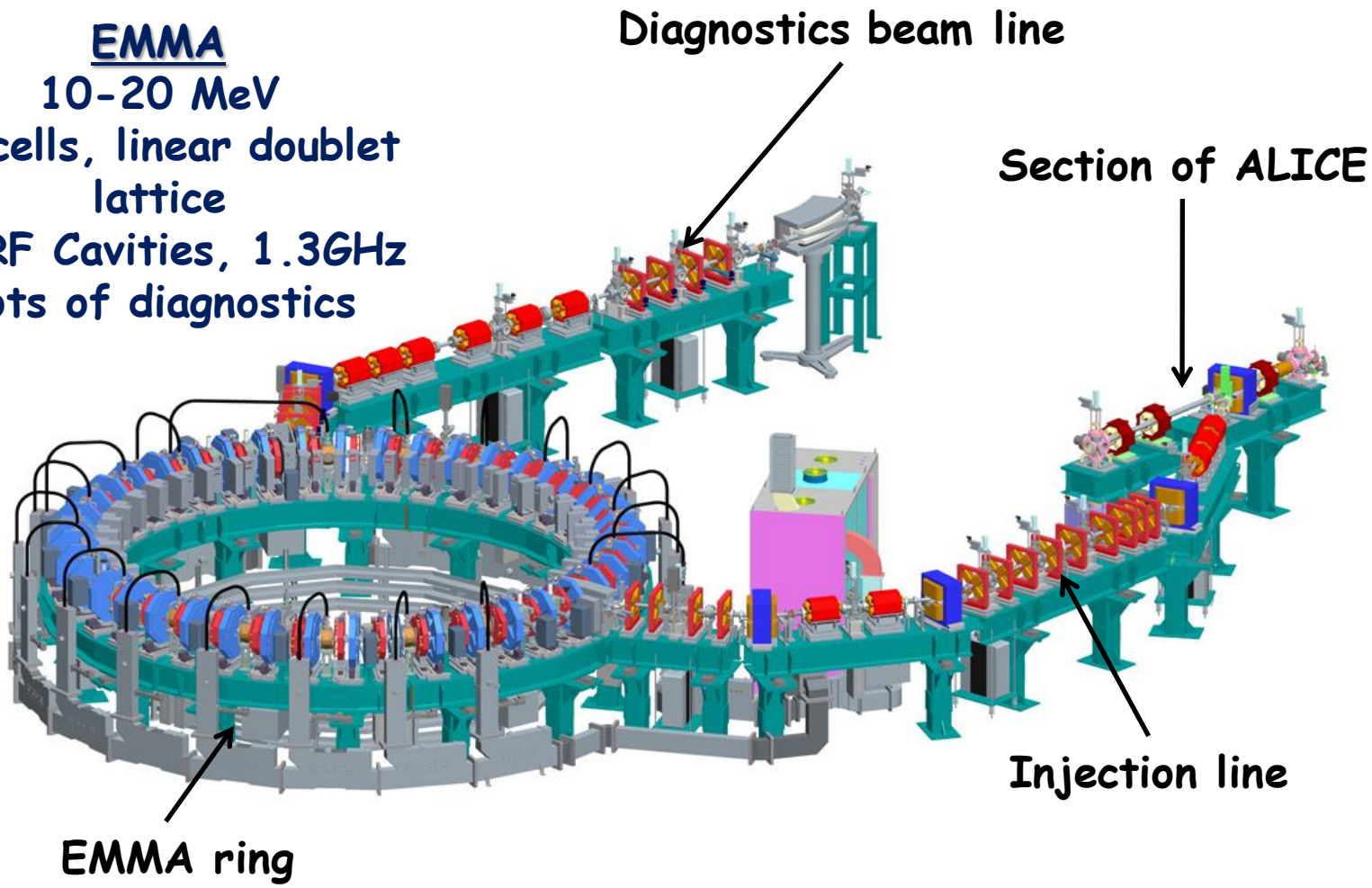
- *Design status of the LHeC linac-ring interaction region*. IPAC 2011
- *Local chromatic correction scheme and crab-waist collisions for an ultra-low beta* at the LHC*. IPAC 2012
- *Final-focus optics for the LHeC electron beam line*. IPAC 2012
- *Final Focus designs for the L-R Electron Beam Line*. LHeC note

Task 11.3 - EMMA FFAG ring commissioning

- EMMA commissioning completed in April 2011:
  - First non-scaling FFAG
- First ever demonstration of serpentine acceleration!
- Several integer resonances crossed during acceleration
- No apparent degradation in beam quality
- NS-FFAGs work (at least for relativistic particles)
- Full experimental programme started last Summer

EMMA Layout

EMMA
10-20 MeV
42 cells, linear doublet lattice
19 RF Cavities, 1.3GHz
Lots of diagnostics



EMMA Time Line

2007-2011 - Construction

March 2010 - Injection line complete.
First beam on 26th March

18th June 2010 - Ring "complete"
i.e. all sectors in place, but one not connected.
4-sector commissioning

22nd June - Beam to end of 4-sectors

July 2010 - Ring construction complete

Aug-Oct 2010 - First commissioning period

Feb 2011 - Diagnostics line complete

Feb-April 2011 - Second commissioning period

Conclusions

- **EMMA is the proof-of-principle non-scaling FFAG**
- **Construction was a challenge**
  - **novel machine**
  - **very compact: "...everything takes 5 times longer in EMMA...", Neil Bliss, project manager**
- **Commissioning has been successful:**
  - **EMMA works!**
  - **Beam accelerated from 12 to 18 MeV/c in 6 turns**
  - **Small orbit excursion ~10 mm**
  - **Many resonances crossed, no observable growth in beam oscillation amplitude**
- **Long way to go: full experimental programme started**
- **Upgrades planned:**
  - **improve EMMA performance**
  - **learn more for applications**

Task 11.3 Status

- D11.3.1: Results from the operation of EMMA using the new diagnostics M36 Done
- Results published in Nature Physics in January 2012
- Also presented in various meetings and IPAC'11
- CNRS:
  - no longer part of task 3
  - work taken over by Huddersfield University (UK)

- **D11.3.1: Results from the operation of EMMA using the new diagnostics, STFC, M36, March 2012 DONE BEFORE DEADLINE**

Task 11.4 - Instrumentations for novel accelerators

- In Task 11.4 a special technique was developed for the measurements of highly divergent beams ("betatronic radiation")
- Theoretical work was needed to justify the choice of "betatronic radiation" to characterize this key parameter of the e-beam
- The beam emittance measurements were accomplished
- Published in "Controlled Betatron X-ray radiation from tunable optically injected electrons", S. Corde, K. Ta Phuoc, R. Fitour, J. Faure, A. Tafzi, J. P. Goddet, V. Malka, and A. Rousse, Phys. Rev. Lett. **107**, 255003 (2011).
- *More details in C. Thaury's talk*
- Deliverable 11.4.1 due M36 accomplished → Report written and submitted to Coordinator

WP11 Milestones & Deliverables

- M11.3.1: Requirements for electron beam diagnostics, LOA-CNRS, M2, May 2009 √
- M11.1.1: 1st annual ANAC review meeting, INFN, M12, March 2010 √
- M11.2.1: DAΦNE beam parameters definition for KLOE, INFN, M12, March 2010 √
- M11.3.2: Construction of the electron beam diagnostics completed, STFC, M14, May 2010 √
- M11.2.2: Compatibility of new IR scheme and LHC, CERN, M18, Sep. 2010 √
- M11.3.3: Commissioning of EMMA completed, STFC, M20, Nov. 2010 √
- M11.1.2: 2nd annual ANAC review meeting, INFN, M24, March 2011 √
- M11.4.1: Electron beam emittance meter finished, CNRS, M24, March 2011 √
- M11.1.3: 3rd annual ANAC review meeting, INFN, M36, March 2012 √
- M11.1.4: Final ANAC review meeting, INFN, M48, March 2013

- D11.2.1: DAΦNE IR design for the upgraded KLOE detector, INFN, M24, March 2011 √ Report
- D11.2.2: Study of an IR design for LHC upgrade, CERN, M36, March 2012 **delayed**
- D11.3.1: Results from the operation of EMMA using the new diagnostics, STFC, M36, March 2012 √ Report
- D11.4.1: Preliminary electron beam emittance measurement report, CNRS, M36, March 2012 √ Report
- D11.1.1: ANAC web-site linked to the technical and administrative databases, INFN, M48, March 2013

WP11 summary

- WP11 milestones and deliverables were all met on time or ahead of time, except for Subtask 11.2.2
- Task 11.1 has delivered D11.2.1 on time. Report published
- Subtask 11.2.2 had a delay due to missing recruitment of a fellowship, now solved. This work needs a further year so deliverable 11.2.2 was moved to end of the EuCARD project (March 2013)
- Task 11.3 has delivered D11.3.1 ahead of time (Summer 2011). Report published
- Task 11.4 has delivered D11.4.1 on time (March 2012). Report ready for publication
- All the informations from task leaders for P2 report are in my hands ☺