WP11 – ANAC

M. Biagini, on behalf of WP11 Task leaders

2nd EuCARD Annual Meeting

Paris, May 11-13, 2011

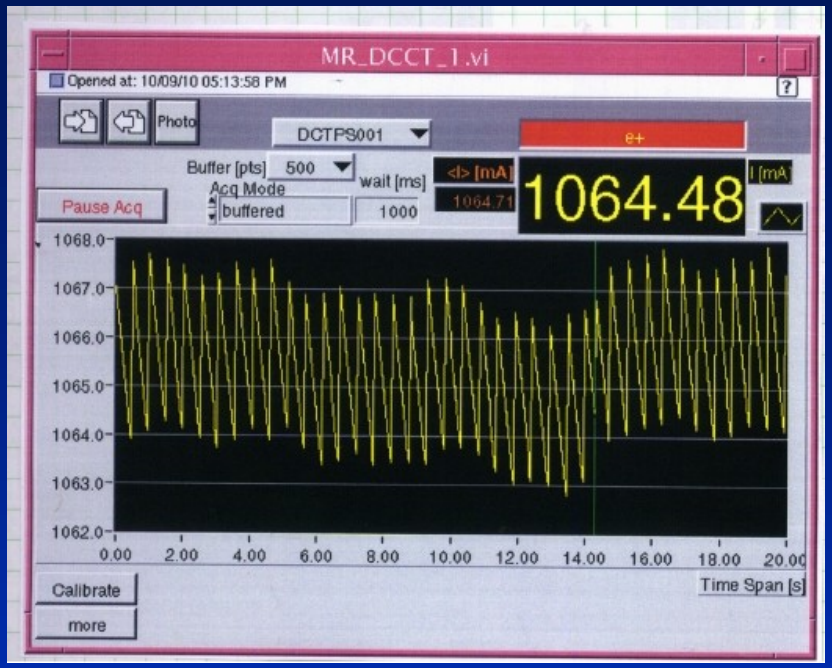
WP11 - Tasks

- **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

- Operations with the solenoid on started in November 2010
- The new kickers for the positron horizontal feedback behave as expected
- Stripline electrodes to avoid e-cloud formation are operative and their impact on beam dynamics is going to be studied extensively this year
- The luminosity monitor is routinely used for beam-beam scan and luminosity studies
- At the moment several problems, related to failure of other components of the DAΦNE complex, have slowed down the commissioning, resuming in these days
- A Report on e-cloud studies for DAΦNE has been published in April
- Deliverable 11.2.1 due March 2011 has been accomplished, a Report is ready, to be published soon

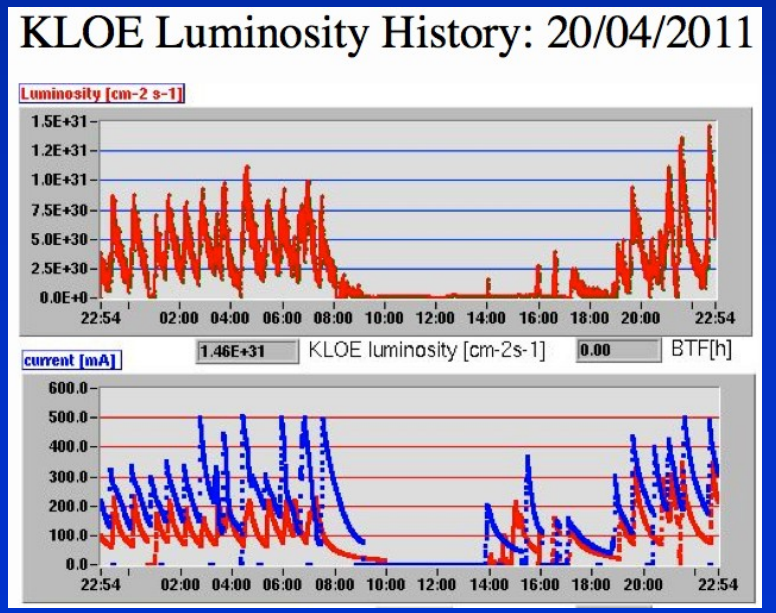
Machine tuning



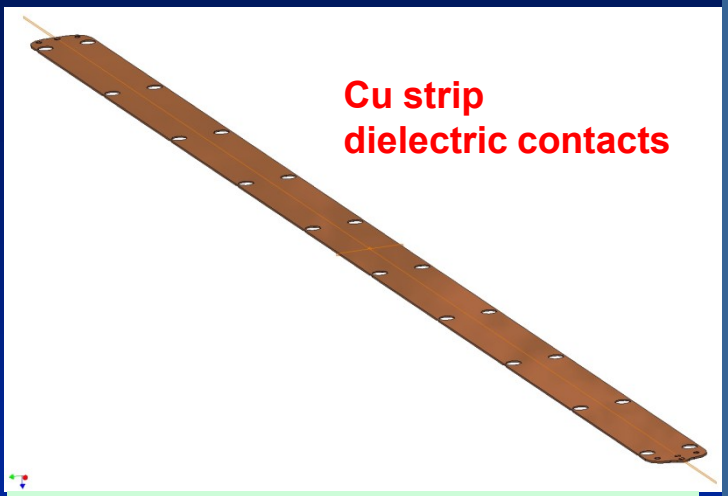
… thanks to the upgraded positron horizontal feedback:

- System power has been doubled (1 kW now)
- Feedback kicker has been replaced with a device with a double length stripline and reduced plate separation, providing larger shunt impedance at the low frequency typical of the positron horizontal unstable modes

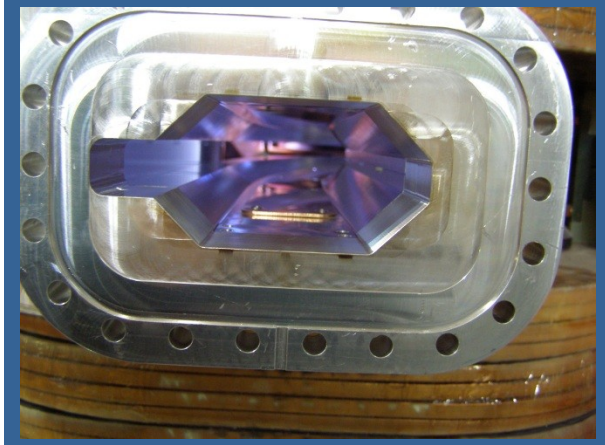
- Closed orbit minimization
- Quadrupole and sextupole beam based alignment
- Optics measurements and model optimization
- Transverse betatron coupling correction ($\kappa \sim 0.5\%$)
- Still rather low luminosity



Fighting e-cloud formation

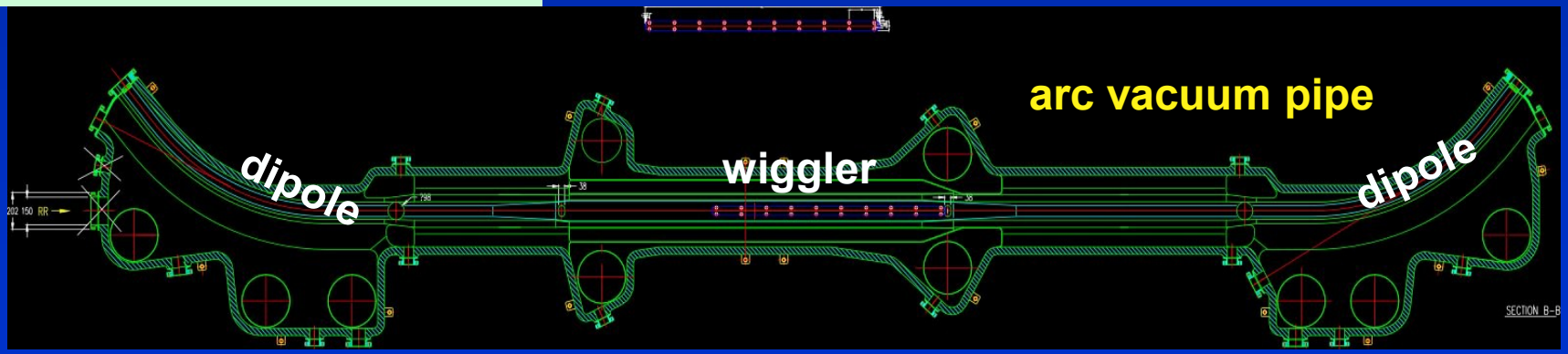


coupling impedance contribution, thermal and mechanical stresses have been evaluated



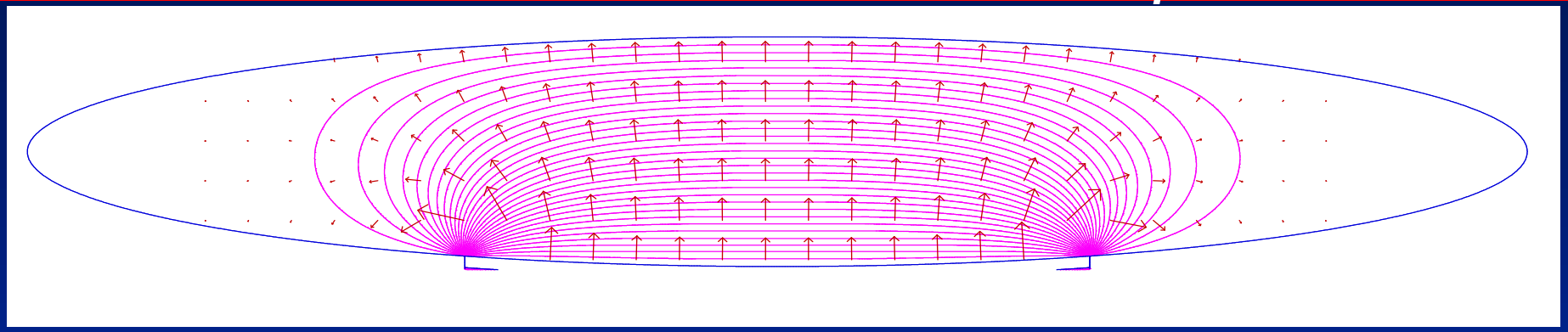
Clearing electrode installed in a wiggler →

Clearing electrode installed in dipole beam pipe, the strip shape is bent to follow the beam trajectory ←



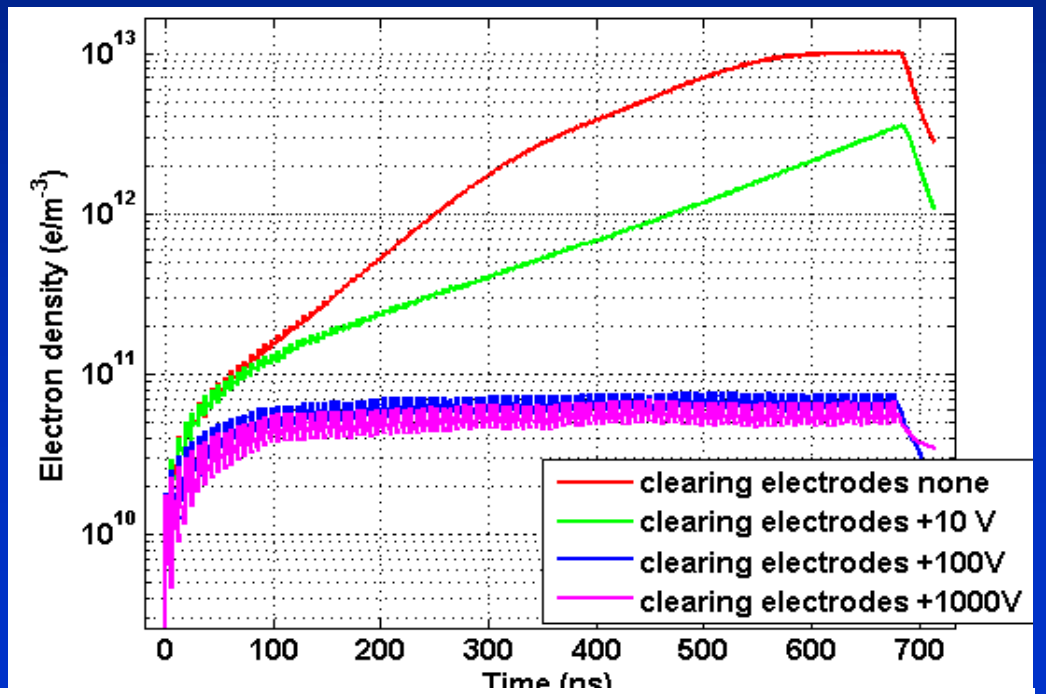
A Report by T. Demma (EuCARD contract) has been published in April

Clearing Electrodes field and e-cloud build-up



Simulations of electron cloud build-up and suppression with clearing electrodes

Bunch population	2.1×10^{10}
Bunch spacing L[m]	0.8
Bunch length σ_z [mm]	18
Primary electron rate	0.0088
Photon Reflectivity	100%
Max. SEY	1.9



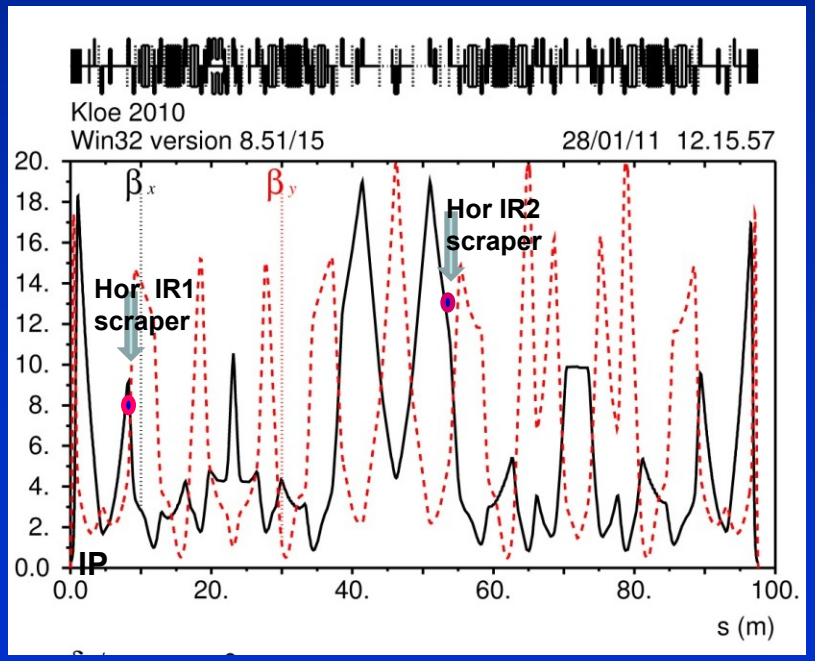
Effect of electron cloud clearing electrodes is going to be extensively studied by measuring the growth rate of the positron beam instability

Lifetime and background studies

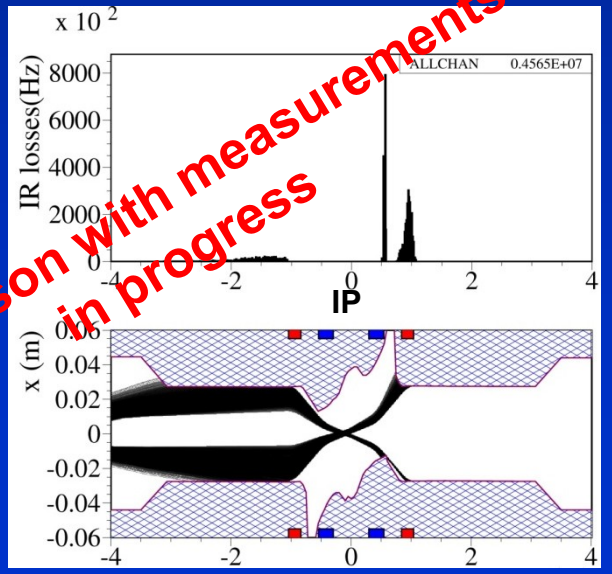
- Touschek lifetime in the Crab Waist scheme is shorter than before and also particle losses inducing backgrounds result higher, as verified during the CW scheme test with the SIDDHARTA run
- Remedies to counteract this effect need to be undertaken

parameters used in simulations

I_{bunch}(mA)	10
σ_z(cm)	1.45
ε_x(m rad)	$0.24 \cdot 10^{-6}$



with sextupoles and scrapers at optimal set	Tou. lifetime (s) (simulation)	Tou. IR losses (MHz/bunch) (simulation)
coupling = 0.4%	1020	4.56
coupling = 0.1%	510	9.1

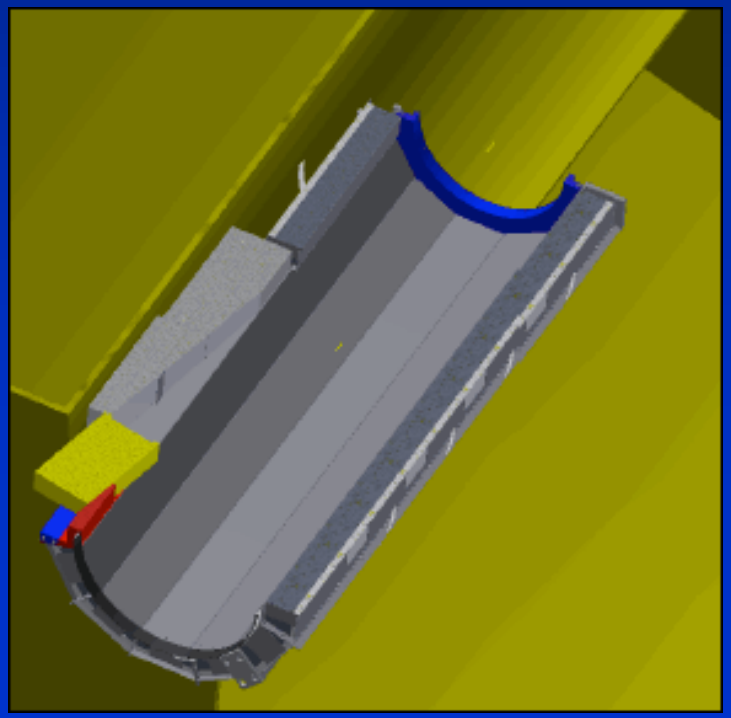


Comparison with measurements in progress

Distribution (upper) and trajectories (below) of Touschek particles lost at IR

Background optimization

- The new collimators installed in each one of the four IR branches have been conditioned with the beam. They proved to be very effective in reducing the background shower hitting the experimental apparatus, as predicted by numerical simulations
- In February 2011 an additional lead screen, 1 cm thick, has been added around the inner layer (QCAL) of the KLOE-2 detector. Preliminary measurements have shown a reduction of a factor 2 in the background hitting the experimental apparatus



Subtask 11.2.2 - Crab Waist for the LHC

- Initial delay due to difficulty / impossibility 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

Subtask 11.2.2 - Crab Waist for the LHC

- Weak-strong beam-beam studies by Shatilov & Zobov using Lifetrac code (Shatilov, Part.Accel.52:65-93,1996)

- Crab-waist (CW) application to "quasi-round" beams:
  - in terms of luminosity lifetime, resonance suppression and halo control, CW for HL-LHC efficient only when operating with rather flat beams of $\sigma_x/\sigma_y \geq 10$ [PRST-AB 14, 014001 (2011)]

- Luminosity gain from a longitudinally uniform or "trapezium" (as compared to Gaussian) profile for equal bunch charge and beam-beam tune shift, in the regime $\phi_w > 1$:
  - For $\phi_w = 2$: 10% gain from the flatter beam profile
  - For $\phi_w = 5$: 25% gain
  - For $\phi_w >> 1$: asymptotic gain of 41%

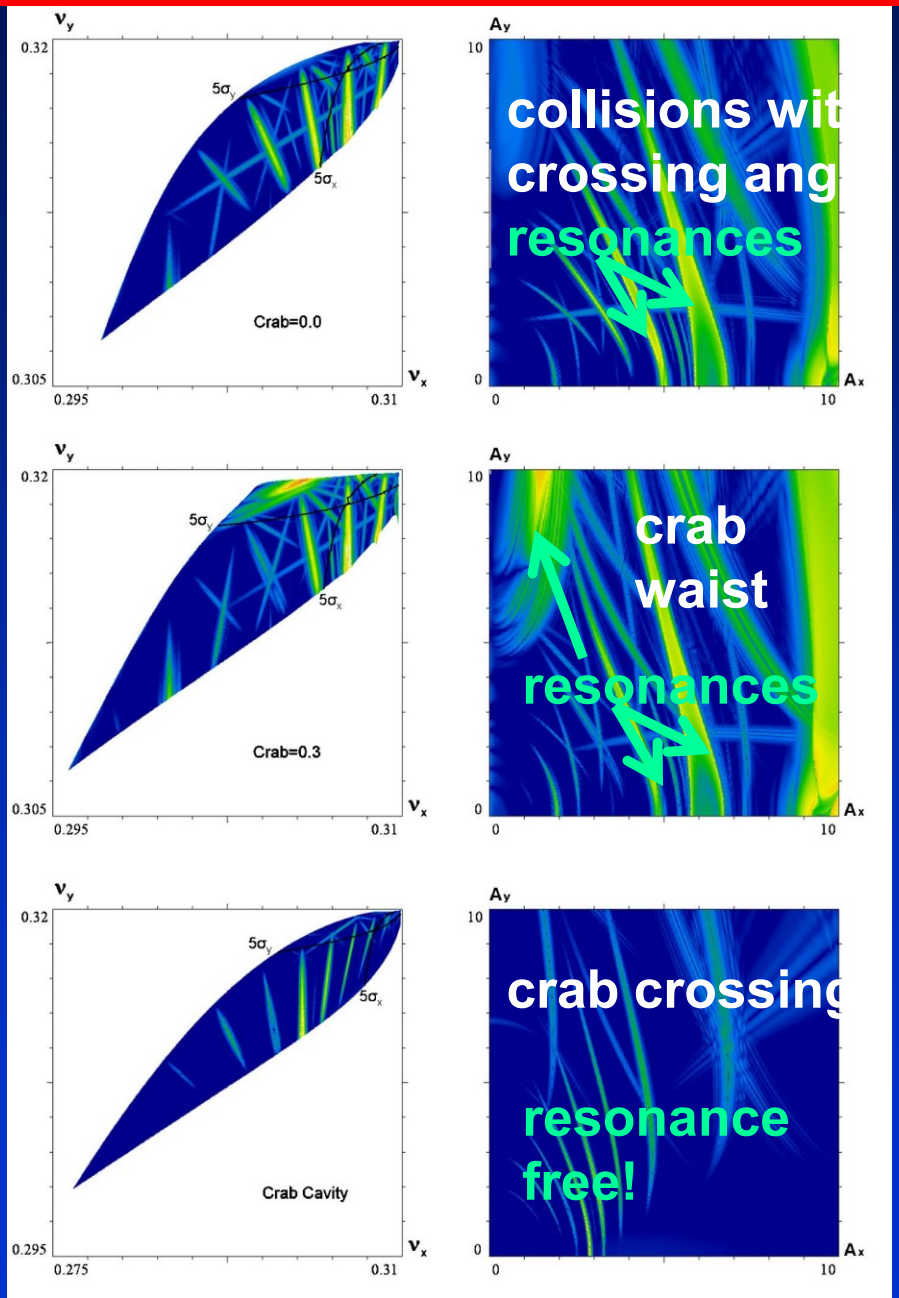
Subtask 11.2.2 - Crab Waist for the LHC

M. Zobov, D. Shatilov, et al,
PRST-AB 14, 014001 (2011)

Frequency-map analysis of Lifetrac simulation

assumed "LHC" parameters:

$\varepsilon_{x,y}$ =0.5 nm , E = 7 TeV
β_x = 30 cm, β_y = 7.5 cm,
σ_x/σ_y=2,
σ_z = 11.8 cm, θ_c= 315 μrad
(ϕ =1.5), N_b = 4.0x10^{11},
Q_s =0.002, $\Delta Q_{x,y}$ ~ -0.0065,
single IP



Subtask 11.2.2 - Crab Waist for the LHC

- Beam-beam & optics studies by K. Ohmi using BBSS code
- Strong-strong beam-beam simulations:
  - "various collision schemes (CC, CW) for HL-LHC have feasibility from the view of beam-beam; a beam-beam parameter ξ=0.03/IP is challengeable"
- Effect of kinematic term, quadrupole fringe fields, and nonlinear multipole errors on LHC dynamic aperture with crab waist:
  - LHC crab waist scheme requires local chromaticity correction and local nonlinearity corrections
  - effects of kinematic term & quadrupole fringe are weak

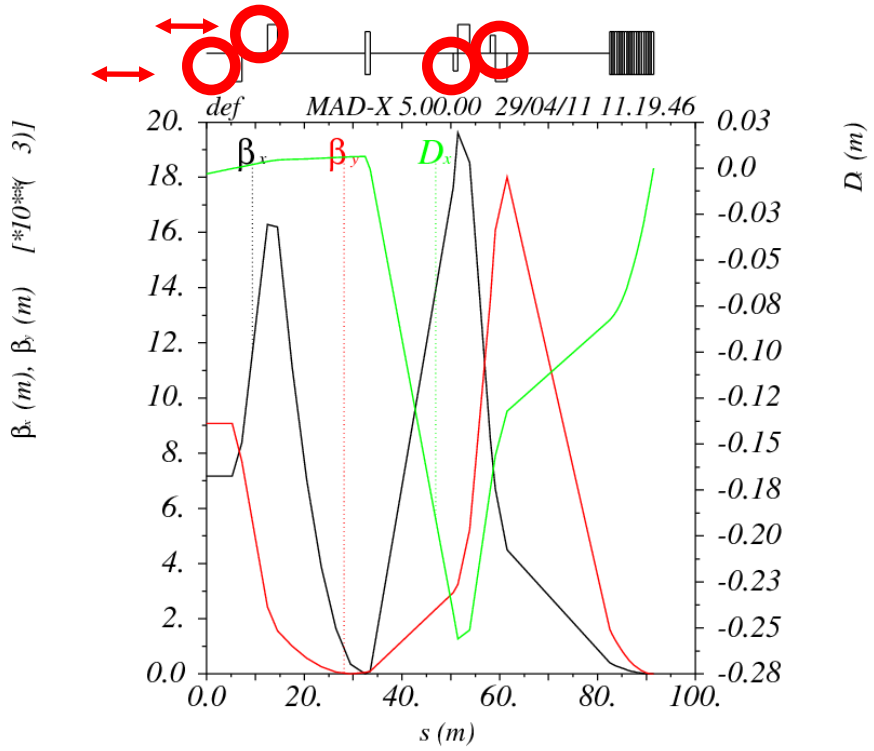
Subtask 11.2.2 - Crab Waist for the LHC

- WP11 doctoral student Jose Abelleira (EPFL Lausanne) started at CERN on 1 November 2010
- Thesis topic: study of a high-luminosity LHC upgrade based on large Piwinski angle, flat beams, and crab waist
- Achievements:
  - getting familiar with accelerator physics and with design concepts of final-focusing systems (LHC, LC, muon collider)
  - learning some important tools : MAD-X, PTC and MAPCLASS.
  - JUAS in January 2011
  - practicing with local chromatic correction of LHeC L-R e- final focus: momentum bandwidth without and with chromatic correction, and higher-order optimization of the sextupole positions and strengths with PTC and MAPCLASS
- Plan:
  - apply similar design concept to the much more complicated LHC high-luminosity upgrade, especially, as a next step, organize its chromaticity correction in view of a possible LHC crab waist scheme

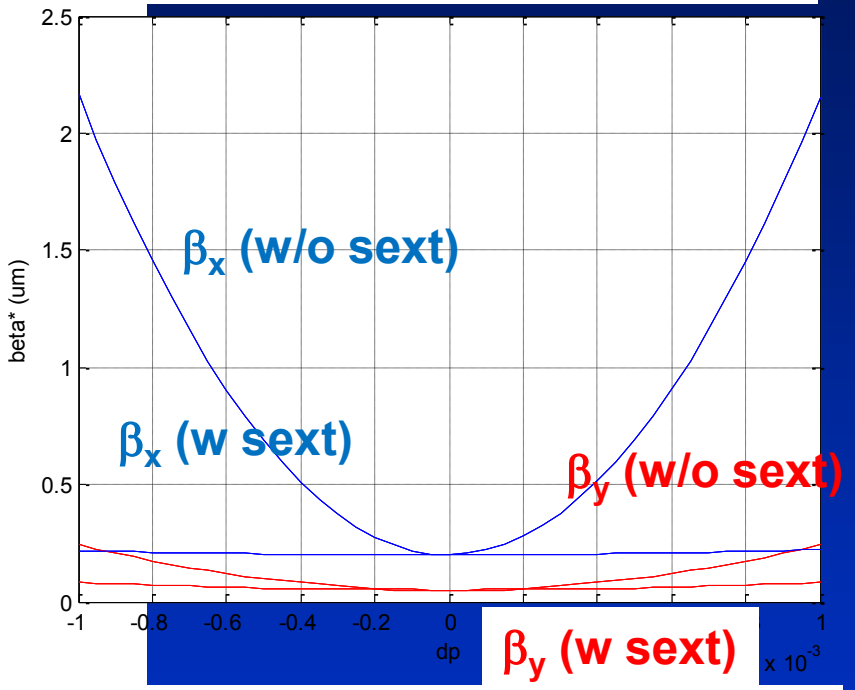
L-R LHeC e- beam FF model

J. Abelleira, R. Tomas, E. Marin

optics with location of 4 sextupoles



β momentum bandwidth without & with sextupoles



effect of higher-order aberrations with MAPCLASS – further optimization needed

order	1	2	3	4	5
σ_x [μm] (δ=0)	9.2	28.3	175.0	179.5	181.4
σ_y [μm] (δ=0)	4.6	8.5	85.4	87.5	88.2
σ_x [μm] (δ=3x10^{-4})	11.1	28.9	175.1	179.5	181.5
σ_y [μm] (δ=3x10^{-4})	4.6	8.5	85.4	87.5	88.2

Task 11.2 - Summary

- Subtask 2.1:
  - In the next months the efforts will be addressed to setup and optimize experimentally the DAΦNE main rings with the KLOE-2 detector, as well as to compare beam simulation studies on beam dynamics, beam-beam and backgrounds hitting the experimental detector with measurements
- Deliverable D11.2.1: DAΦNE IR design for the upgraded KLOE detector, INFN, due M24, has been delivered. A Report is ready to appear soon
- A Report on “e-cloud studies at DAFNE” has been published in April
- Subtask 2.2:
  - Beam-beam simulations and low-β_y* optics studies will be continued at CERN for the evaluation of the CW scheme possibility at LHC. Training of the student has started later than foreseen

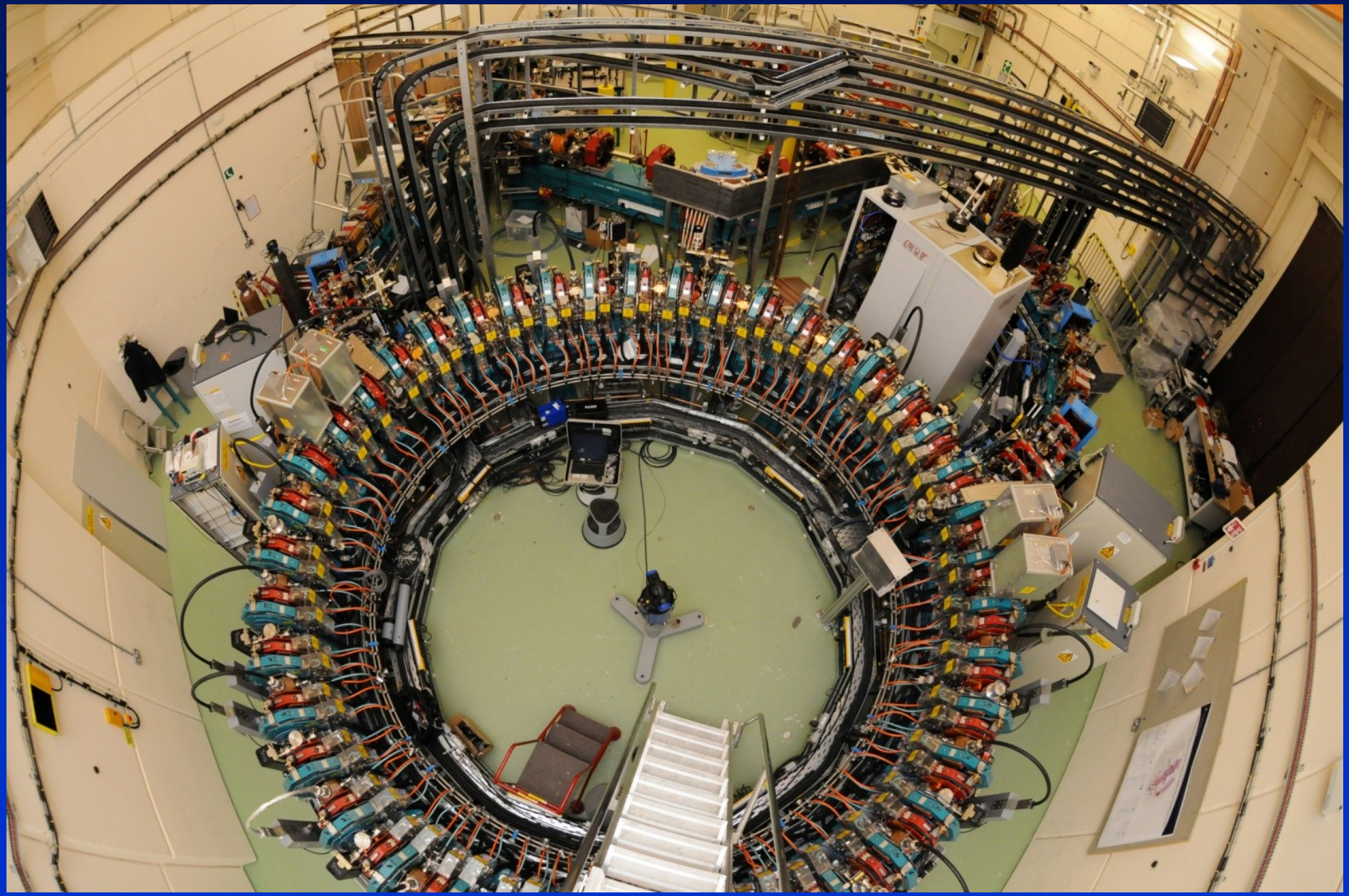
Task 11.3 - EMMA FFAG ring commissioning

- EMMA (Electron Model of Modern Accelerator) = proof-of-principle Non-Scaling FFAG (Fixed Field Alternating Gradient)
- EMMA consists of 42 magnetic cells mounted on seven girders, with six cells per girder. EMMA construction was completed at end of 2010
- Two commissioning periods:
  - August to October 2010
  - February to April 2011
- For both, not full time:
  - time shared with other projects (~4 days out of 10)
  - only 1 or 2 (8 hour) shifts per day
- A lot was learnt during first period
- After second:
  - Injection
  - Circulating beam
  - Acceleration
  - Extraction

Task 11.3 - EMMA accomplishments

- EMMA commissioning complete:
  - 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 starting soon
- **See highlight talk this morning**

EMMA in February 2011



Task 11.3 Status

- Partnership issue: CNRS (one person) is no longer partner of Task 11.3
- Contribution being transferred to Huddersfield University (UK) which is willing to open to research activity
- Milestone 11.3.3 – “EMMA commissioning complete” (due M20)
  - Delivered **M25**
  - Commissioning of an entirely novel accelerator exactly on time is difficult !
  - Main problem were large closed orbit distortions, the main source (misalignment of a number of magnets) was identified and fixed

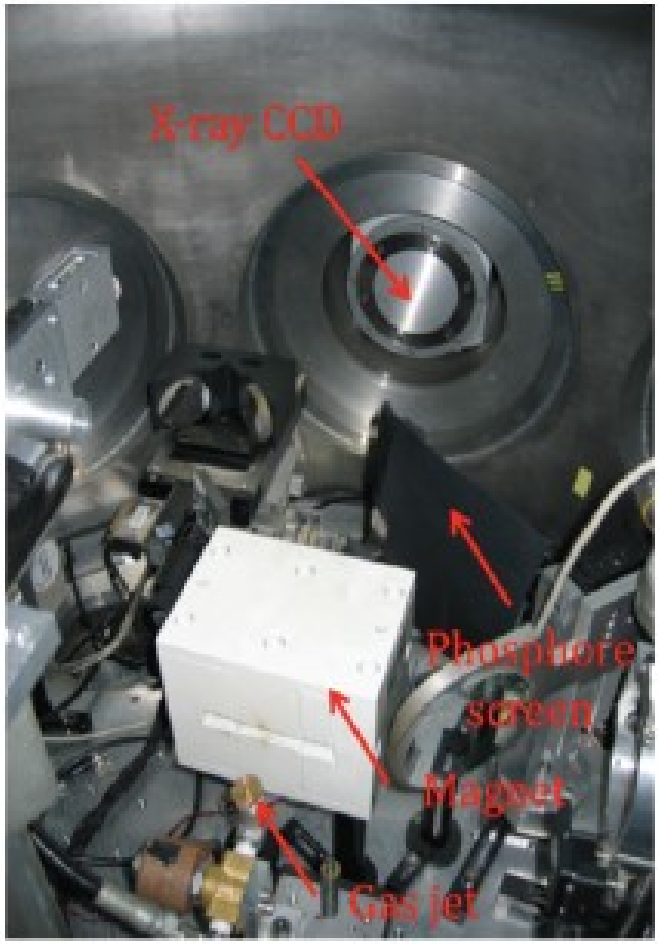
Task 11.4 - Instrumentations for novel accelerators

- The production of a self-injected high energy electron beam from laser-plasma interaction is one of the goals of the Task WP11.4. In order to perform the emittance measurement of such beam a complete set of simulations have been performed
- Electron beams produced by laser plasma accelerators have peculiar transverse dimension and large divergence. Their values are respectively in the μm and mrad ranges, corresponding to a typical transverse normalized emittance of π mm mrad or less
- It was proved in the framework of Task 11.4 that a conventional technique such as “pepper-pot” is not well adapted for such e-beam and a special technique was then developed for this purpose (“betatronic radiation”)

Task 11.4 - Definition of technique and test

- Theoretical work was needed to justify the choice of "betatronic radiation" to characterize this key parameter of the e-beam
- The diagnostics has been set-up and aligned during this last semester
- In addition few shots were done: this preliminary test was very successful and they are now confident that this prototype will allow in a year a single shot measurement of the emittance with a very accurate precision
- An EuCARD Report has been published in April
- Milestone 11.4.2 due M24 accomplished

Detector and first preliminary results



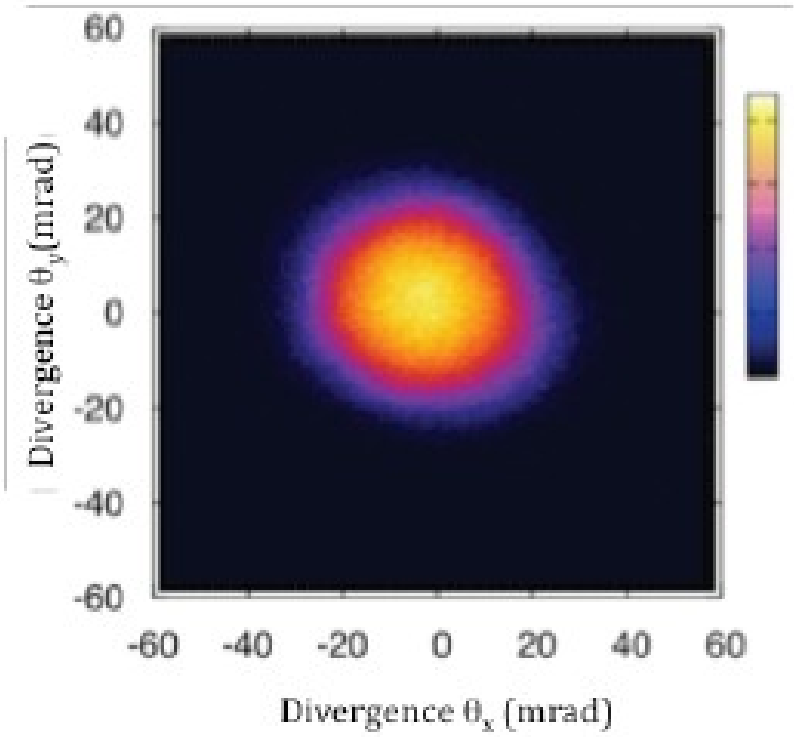


Figure 2: Left: the experimental set-up for the Betatron-based emittance measurement. It combines a X-ray angular profile measurement realized with a X-ray CCD located on axis, and an electron spectrometer composed of a magnet and a phosphor screen imaged onto a visible CCD camera. Right: an example of X-ray angular profile measured with this set-up.

Task 11.4 - Summary

- The prototype is working. X ray cooled CCD camera has been tested and used. Needed shielding in order to avoid noisy radiation produced by electrons interacting with target chamber wall has been implemented and tested
- A "betatron signal" is high enough to determine in a single shot the spectrum and divergence of the X-ray beam
- An experiment is planned this summer for the emittance measurement. In addition to a precise value of the emittance, a study on how the emittance evolves with the laser plasma accelerators parameters is planned
- This work has been described in a EuCARD Report published in April
- Milestone 11.4.2 was accomplished

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

WP11 summary

- WP11 work is now on schedule in all Tasks
- Subtask 11.2.1 is ahead of time, even if at the moment the luminosity is lower than expected
- The deliverable 11.2.1 due March 2011 has been accomplished, a report to appear soon
- Subtask 11.2.2 had a delay due to missing recruitment of a fellowship, now solved. Work has started at KEKB and BINP to study the possible applications of crb-waist to LHC, and training of the student has started
- Task 11.3 has been delayed (5 months) but now on track
- Task 11.3: issue with partner CNRS disappeared has been solved: contribution (35keuro) will be transferred to Huddersfield University (UK)
- Task 11.4 is on track, choice of emittance-meter techniques done, test and pre-alignment done
- Two EuCARD Reports have been published by Tasks 2 and 4 this last semester