WP11 – ANAC
Report on First Year

M. Biagini, on behalf of WP11 Task leaders

1° EuCARD Annual Meeting, RAL, March 14-16 2010

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**

Executive summary

- Task 2:
  - Subtask 1: work is proceeding at high speed and the Deliverable will probably be completed ahead of schedule
  - Subtask 2: CERN is having difficulty in recruiting personnel for the LHC upgraded Interaction Region. This needs to be solved urgently, or there will be a delay in Milestone 11.2.2. A possible solution is a post-doc from Valencia University (to be confirmed)
- Task 3:
  - A deviation from the original work plan has been encountered at STFC. There has been a request by STFC for the EC contribution being advanced, this was not possible. This is likely to affect subsequent milestones, but not the task Deliverable
  - It is in any case likely that the EMMA Deliverable will be completed ahead of schedule
- Task 4:
  - Beam parameters have been chosen for the beam emittance measurement
  - A meeting taken place at LNF to scrutinize methods for emittance measurement. A decision will be taken soon. Measurements expected to happen @ LOA in September 2010

1st year Milestones

- M11.3.1: Requirement for electron beam diagnostics, due M2, delivered M2.
- M11.1.1: Annual ANAC review meeting, due M11. Three meetings with Task Leaders have been scheduled, 2 done, 1 to happen.
- M11.2.1: DAΦNE beam parameters definition for KLOE, due M12, delivered (a Note has been prepared and has been published in the EuCARD Publications Database)
- No Deliverables due for first year

Next year Milestones

- 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, September 2010
- M11.3.3: Commissioning of EMMA completed, STFC, M20, November 2010
- M11.1.2: 2nd annual ANAC review meeting, INFN, M24, March 2011

Task 11.1 - Management

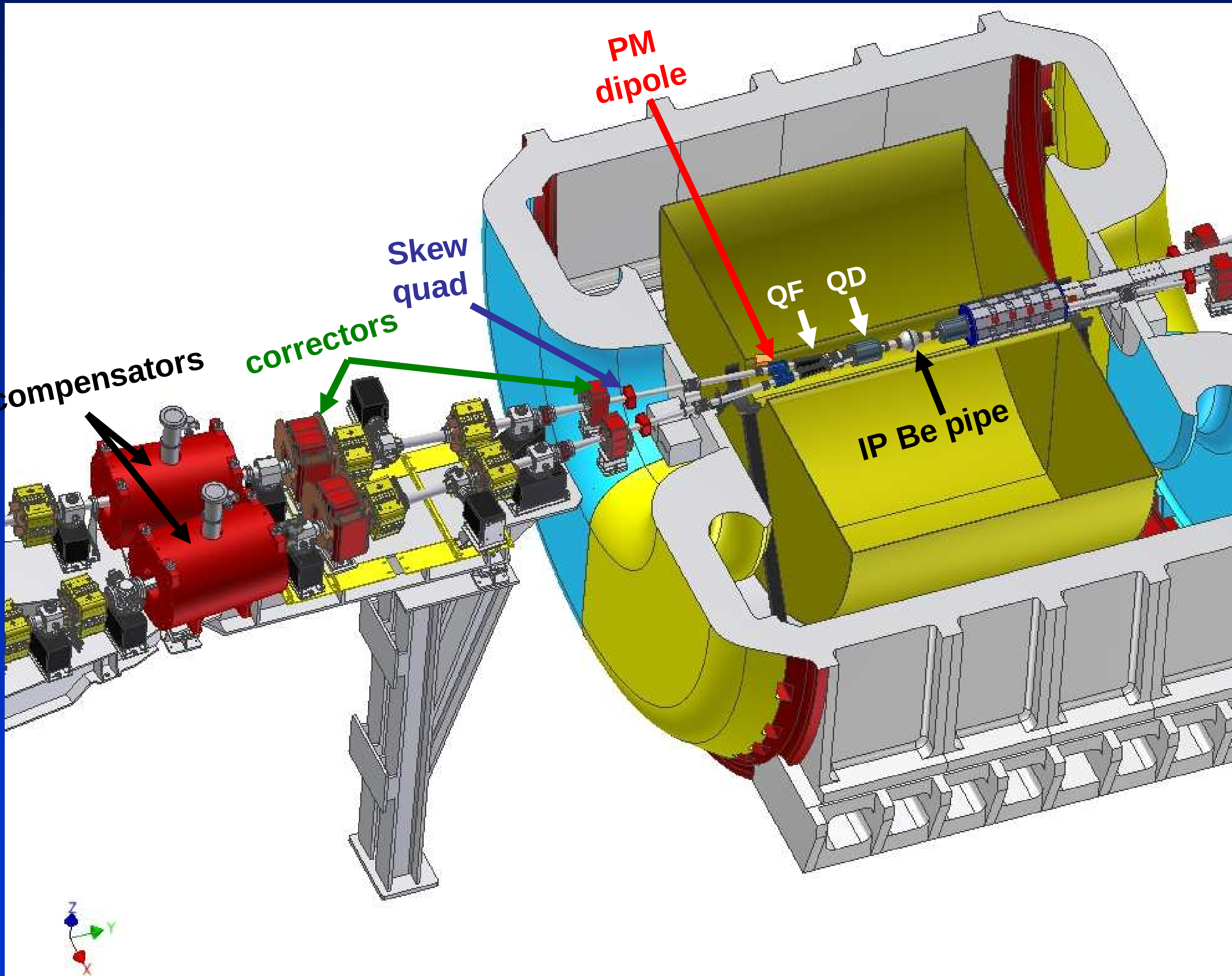
- A web page dedicated to the description of the WP11 for the EuCARD participant has been prepared in the framework of the overall EuCARD web page. In this page there are announcements of events, publication of reports, meetings organized and other useful scientific information (https://espace.cern.ch/EuCARD/WP11/default.aspx). The page is still in progress and will be updated regularly
- Work on a public web page is in progress
- A collaboration meeting for Task 2 has been organized between INFN-LNF and BINP at LNF in September 2009
- Organization of the 3° SC meeting at LNF in November 2009
- A collaboration meeting for Task 4 has been organized between INFN-LNF and CNRS-LOA at LNF in March 2010
- No Deliverable were due this year

Task 11.2.1 – Design of IR for high luminosity

- Design and implementation of a high luminosity IR at DAΦNE collider for a new run of the upgraded KLOE experiment (KLOE2). The KLOE detector itself has been upgraded in order to cope with the higher acquisition rates expected from the improved collision scheme
- In April 2009 a 3 years contract has been awarded to work on beam dynamics topics related to the implementation of the new collision scheme for the KLOE2 experiment: in particular on e-cloud simulations and remediation, and Intra Beam Scattering calculations
- Achievements during this year:
  - Design of IR optics
  - Definition of transverse coupling correction
  - Tracking studies to ensure compatibility of the new IR with the mechanical layout of the ring arcs
  - IR technical design and construction completed: components are being installed
  - Kicker and power amplifier for the positron horizontal feedback are ready to be installed (needed to stabilize e^+ beam against e-cloud instability)
  - Stripline electrodes to avoid e-cloud formation in the e^+ ring already installed in the vacuum chamber of wigglers and in bending magnets

- No Deliverable were due this year

New KLOE2 IR



PM
dipole
Skew
quad
correctors
compensators
QF
QD
IP Be pipe

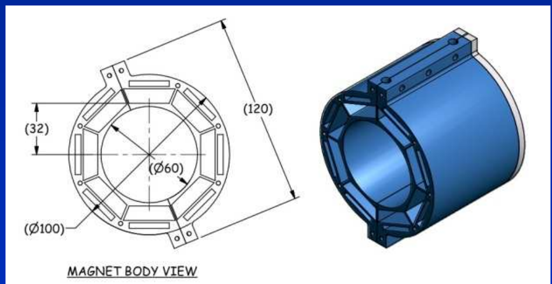
New KLOE IR (1)

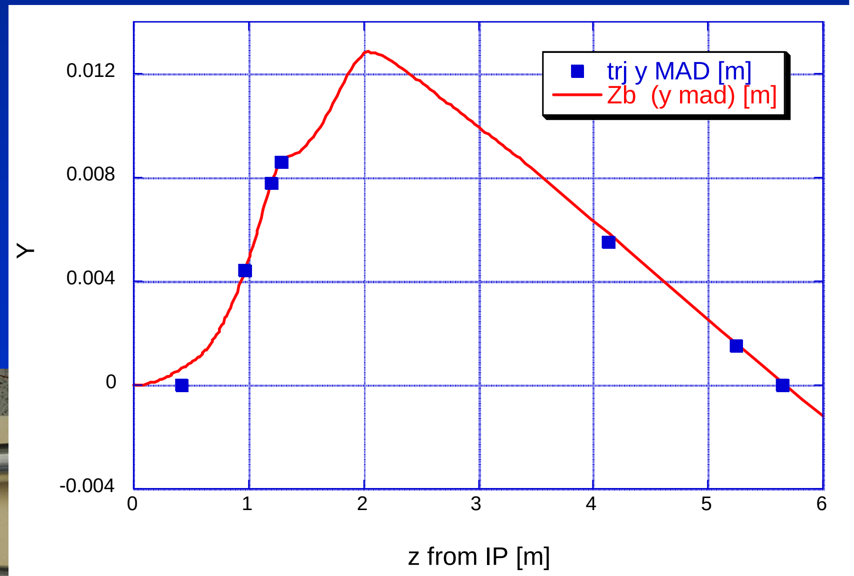
- IR design complete and several components of the new hardware already acquired and/or in construction

- Main improvements of the present optics w.r.t. old KLOE one are:
  - ➢ increased beam stay clear
  - ➢ better shielding → less backgrounds
  - ➢ additional skew quad added across PM QF1
  - ➢ independent pair of compensating solenoids for each beam
  - ➢ skew quad placed at the crab-sextupole location → detector solenoid coupling correction can be better than for KLOE (was achieved 0.2-0.3%) → no need of rotating quads for fine adjustment

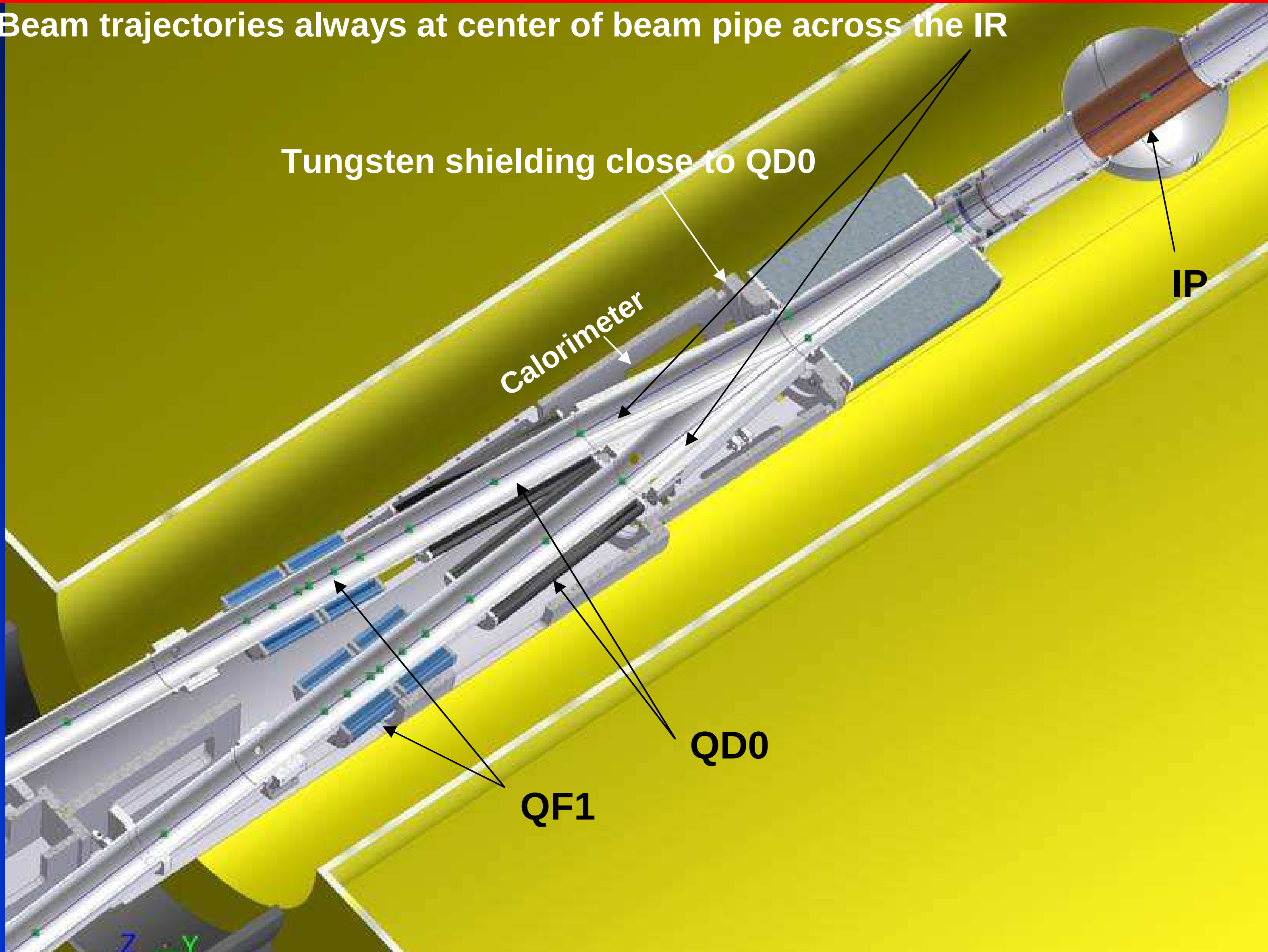
New KLOE IR (2)

- Due to the larger crossing angle, the vertical displacement of the beam in the IR is about 10 times w.r.t. the last KLOE run*:*
  - A permanent magnet dipole after QF1 is used to keep under control the vertical beam trajectory
  - PM designed, built, measured and ready to be installed
- KLOE2 IR design is flexible, allowing different detector solenoid field values (PM dipole can be split in two; QD0 rotation is zero)



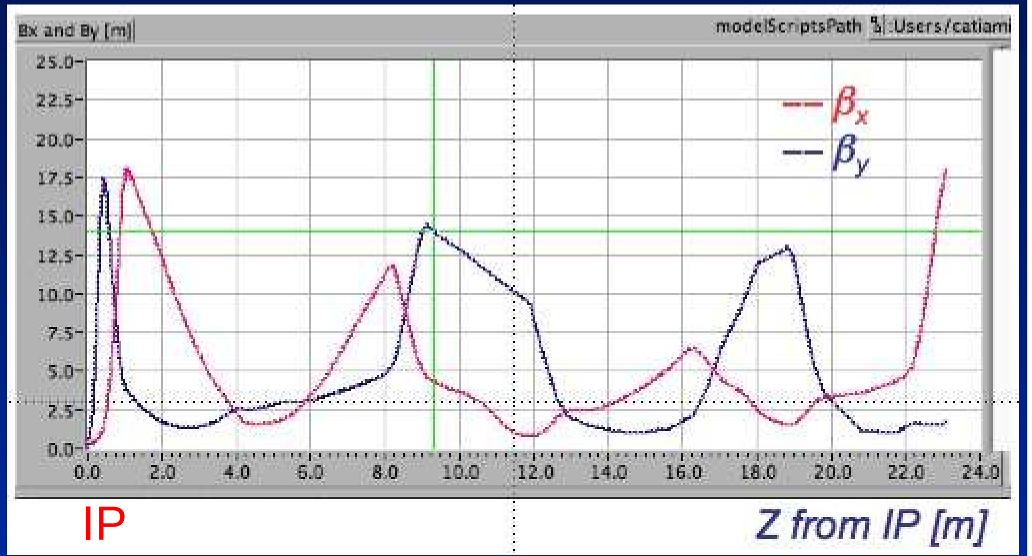


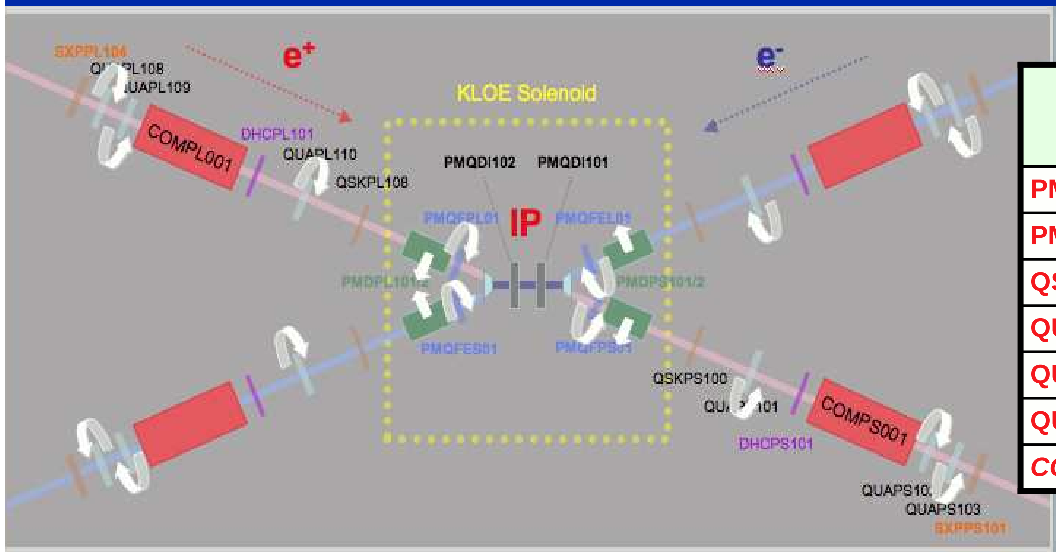
Close up IP chamber



KLOE2 IR optics

- ***Beam optics design criteria:***
  - β_x*= 26.5 cm
  - β_y* = 0.85 cm
  - Coupling matrix = 0 after QUAPS103
  - $\Delta\nu_x = \pi$
  - $\Delta\nu_y = \pi/2$
  - Highest β_y at the CW sextupole
  - PM QD0 not rotated





	Z from the IP [m]	Quadrupole rotation angles [deg] *Anti-solenoid current [A]*
PMQDI101	0.415	0.0
PMQFPS01	0.963	-4.48
QSKPS100	2.634	used for fine tuning
QUAPS101	4.438	-13.73
QUAPS102	8.219	0.906
QUAPS103	8.981	-0.906
COMPS001	*6.963*	*72.48 (optimal value 86.7)*

Further hadware upgrades for high performances

- New kicker for horizontal feedback used for:
  - improved horizontal feedback in the e^+ ring (kick strength a factor ≈3 higher with same amplifier power)
  - beam dumper (less detector trips and radiation level)
- Stripline electrodes for e-cloud clearing:
  - e-cloud electrons in wigglers and dipoles can be removed with stripline electrodes at a moderate voltage
  - studies of coupling impedance contribution, thermal and mechanical stresses, insertion and extraction techniques

Double stripline length with reduced stripline separation in horizontal plane: 88 → 60 mm, new position with higher β

Cu strip dielectric contacts Installed in dipoles and wigglers

Task 11.2.2 – Design of IR for high luminosity

- CERN had difficulty in recruiting manpower (fellow with some experience)
- Note from F. Zimmermann: S. Fartoukh and R. de Maria are developing a flat beam optics with very small β_y^* for LHC, which was the first step of this Task proposal.
- They designed an optics with β_y^*~7 cm, and β_x^*~15 cm, which could be an excellent starting point for a crab-waist scheme

Task 11.3 - Upgrade of the EMMA FFAG ring

- EMMA = proof-of-principle non-scaling FFAG
- Presented in detail yesterday
- Schedule slightly delayed w.r.t. EuCARD proposal because:
  - machine is 1st of its type
  - technically complex
  - very compact
  - injection/extraction particularly difficult:
    - 3π m mrad acceptance
    - inj/ext from 10 to 20MeV
    - 8 different lattices
    - 10cm space for kickers & septa
- Commissioning is starting

Task 11.3 - Upgrade of the EMMA FFAG ring

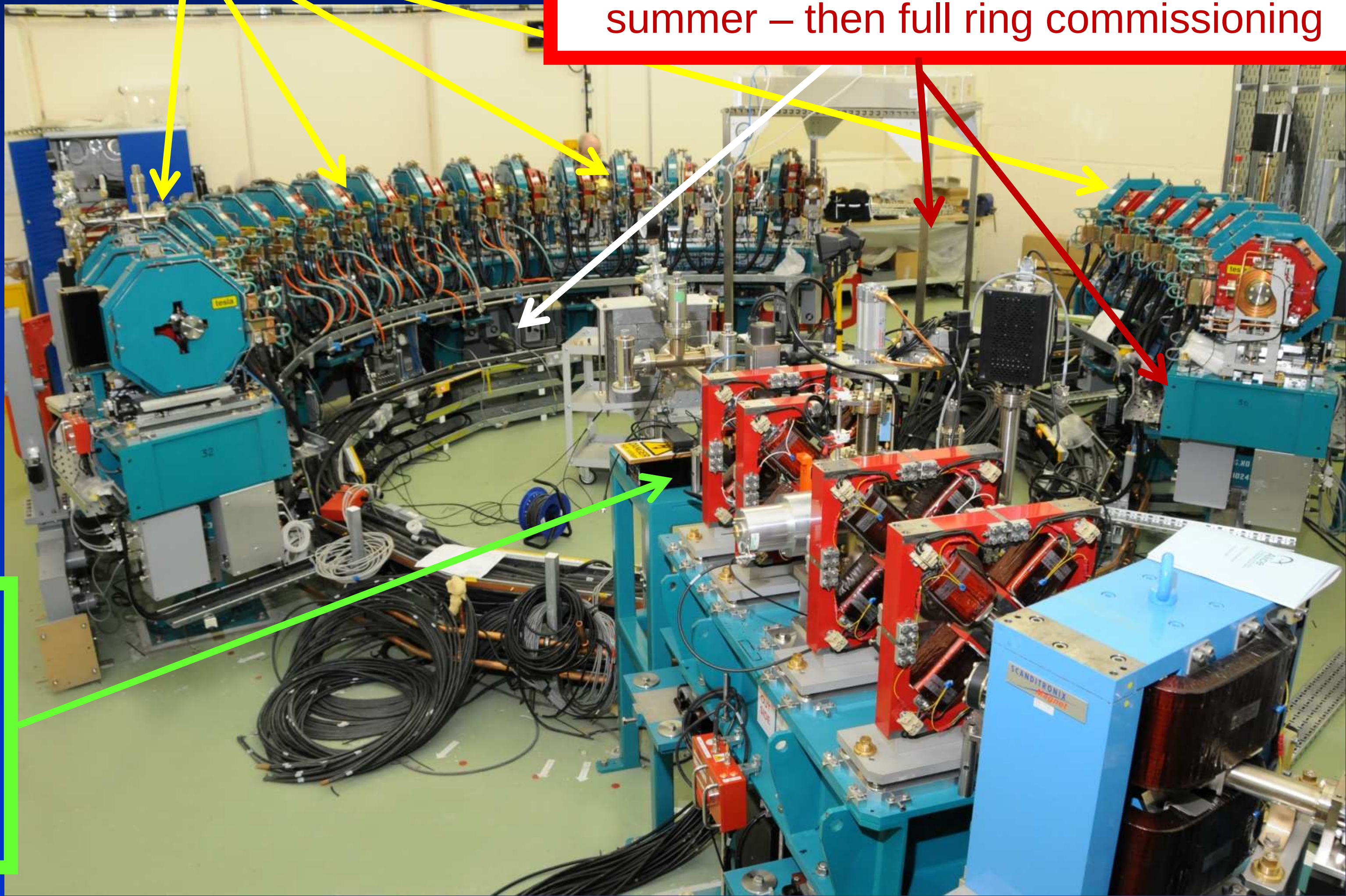
- The focus of the work has been on advancing construction as quickly as possible and starting commissioning
- The latter has now started, with relevant beam properties in the ALICE injector being measured and beam being passed down the injection line for the first time
- To stay on schedule, this task needed an advance of EC funds, as requested to the Governing Board. As this was not possible, a delay is inevitable. This is likely to affect subsequent Milestones, but not the task Deliverable
- There were no Milestones or Deliverables for this task during the second semester

EMMA Status

4 (out of 7) ring girders:
complete and in place

Injection girder:
coming soon –
followed by 4/7th
commissioning

Extraction & wall current monitor girders:
summer – then full ring commissioning

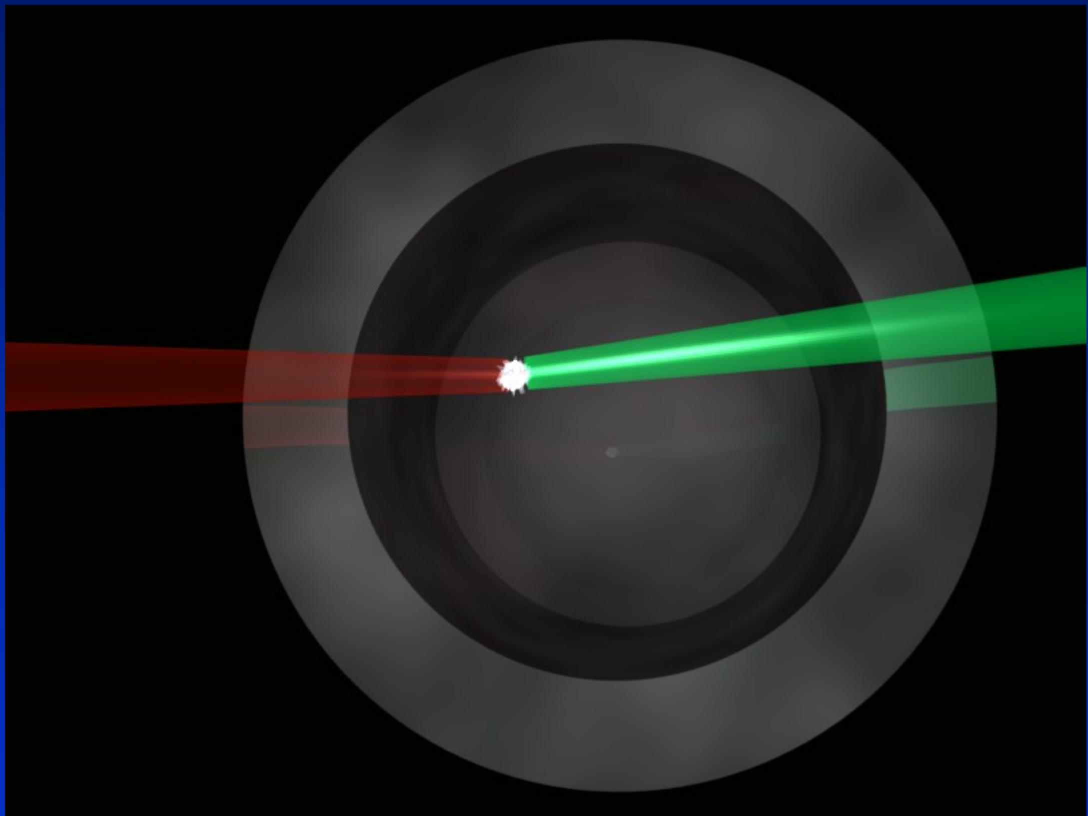


Injection line:
complete -
first beam
through on
26th March

Task 11.4 - Instrumentations for novel accelerators

- LOA/CNRS has defined the requirements for electron beam emittance diagnostic, summarized in a Report issued in May 2009. This includes the definition of the optimised electron beam parameter and the geometry for future measurement
- For emittance measurement a selection of one or two relevant techniques, knowing the parameters of the electron beam, will be done in collaboration with INFN-LNF (SPARC facility)
- To prepare this collaboration and start the study on the emittance-meter a meeting has been held in Frascati on March 8-9
- No Deliverables or Milestones due in the second semester

Non collinear geometry : choice made @ 135°



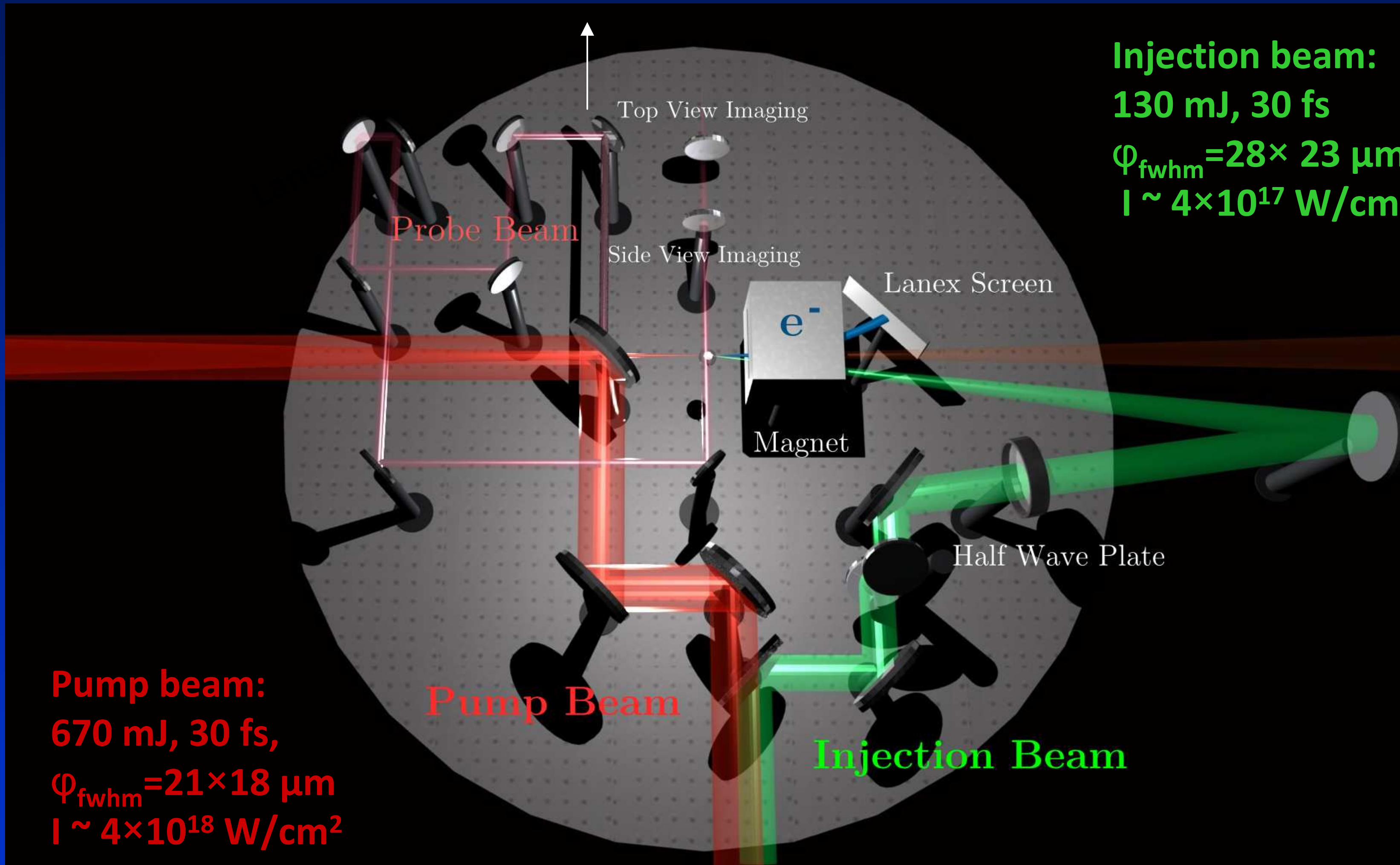
Advantages:

- No feedback (2 mJ of light scattered from the plasma)
- Easier access to use e-beams for applications or diagnostics

Drawbacks:

- Synchronization is more critical
- Tuning the energy is more difficult

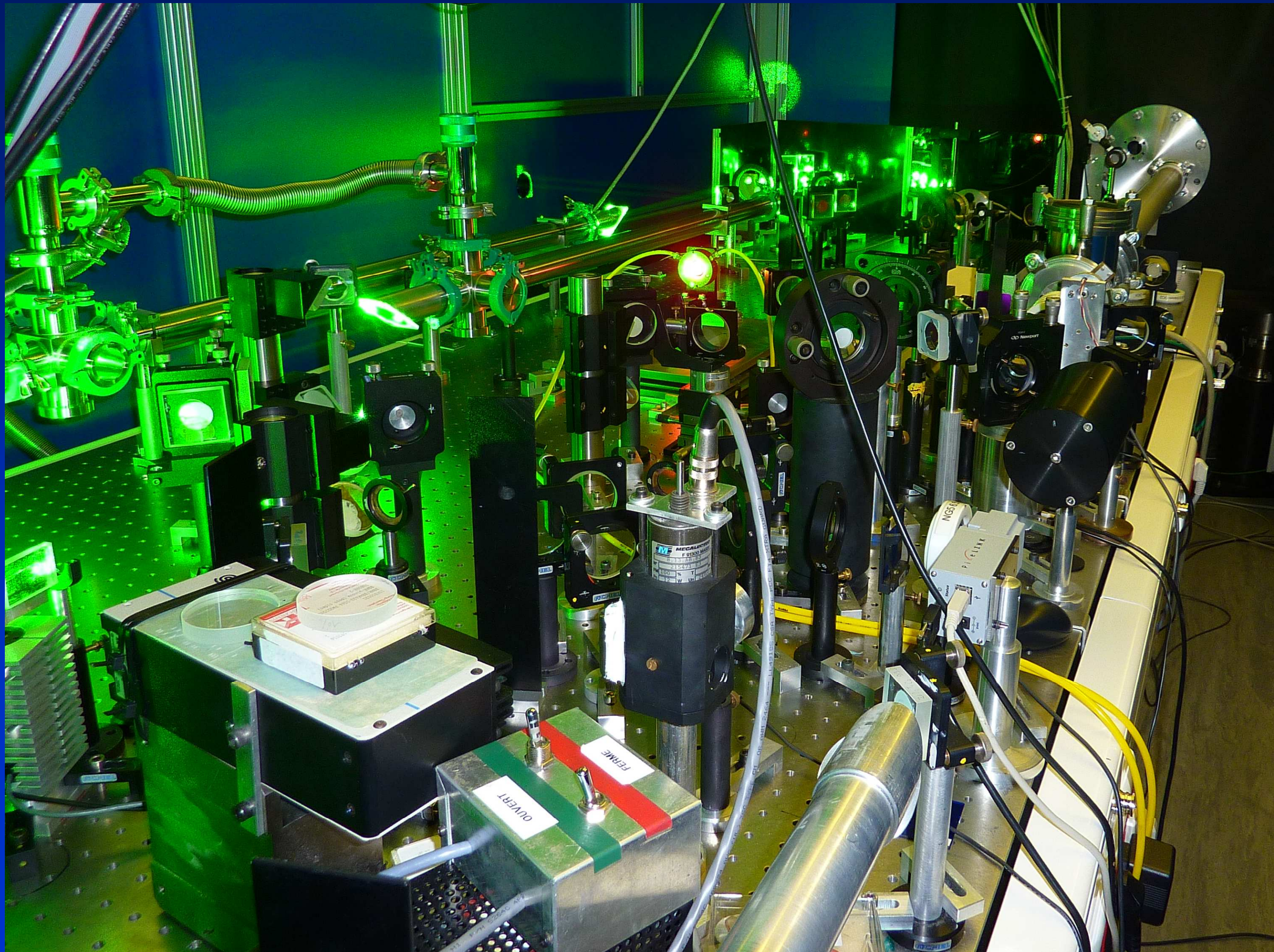
Experimental set up @ 135°



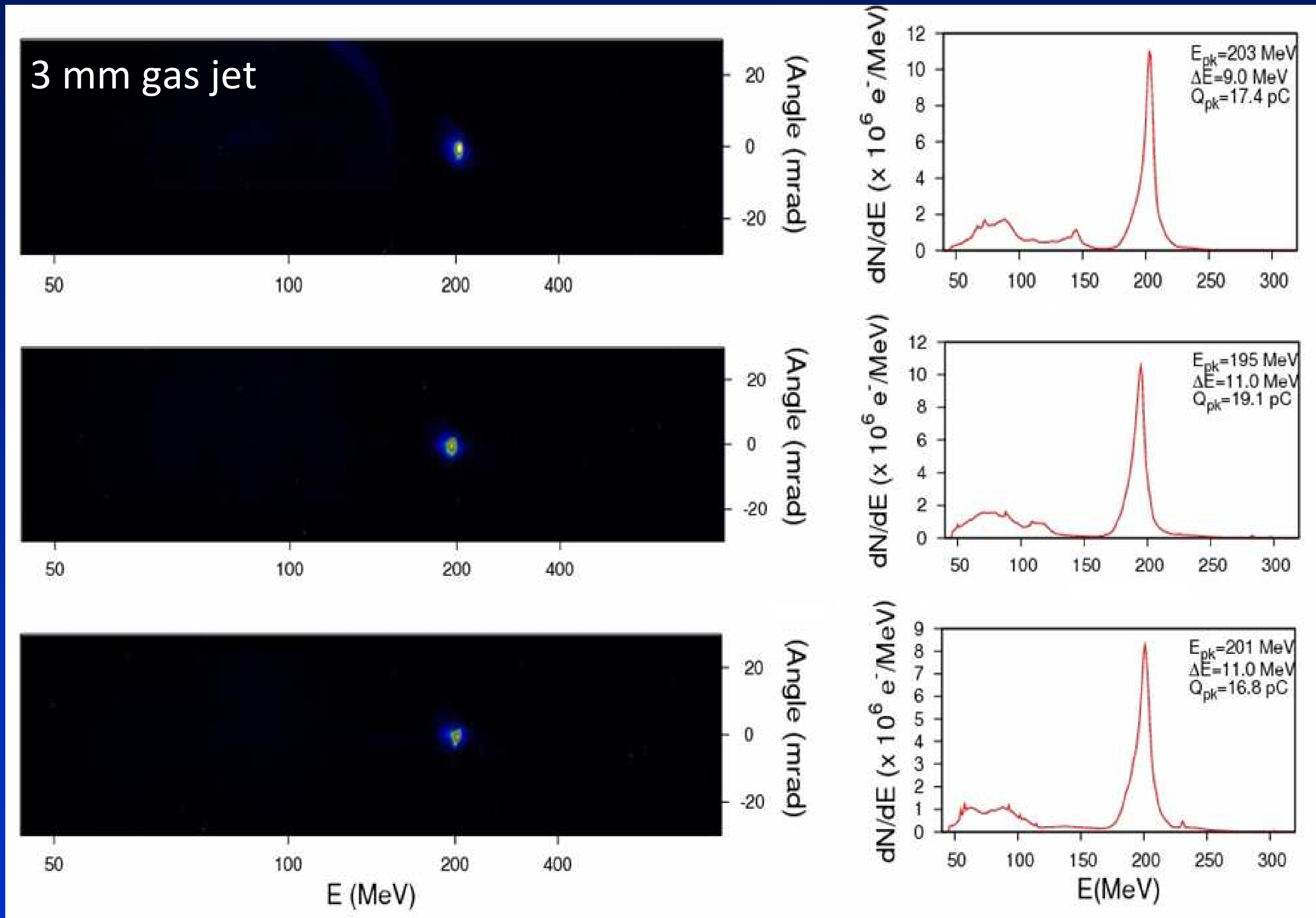
Injection beam:
130 mJ, 30 fs
φ_{fwhm}=28× 23 µm
I ~ 4×10^{17} W/cm^2

Pump beam:
670 mJ, 30 fs,
φ_{fwhm}=21×18 µm
I ~ 4×10^{18} W/cm^2

The actual set up @ LOA



Stable monoenergetic beams @200 MeV



Statistics (30 shots):

E = 206 +/- 11 MeV

Qpk = 16.5+/- 4.7 pC

δE = 14 +/- 3 MeV

δE/E = 6%

Very little electrons at low energy, δE/E=5% limited by spectrometer

Emittance measurements: Introduction

- In emittance measurements the transverse size and divergence are simultaneously measured either in different position with the multi-screens methods or for different quadrupoles field values in the quadrupole scan method
- If the particles phase space (x, x’) is filled up, separate measurements of size and divergence are permitted in order to define the emittance and for plasma photo-injectors this is certainly true because of the behavior of the particle in the plasma channel
- Separate measurement techniques of spot size at the plasma accelerator exit and of the divergence in the following drift space are under study

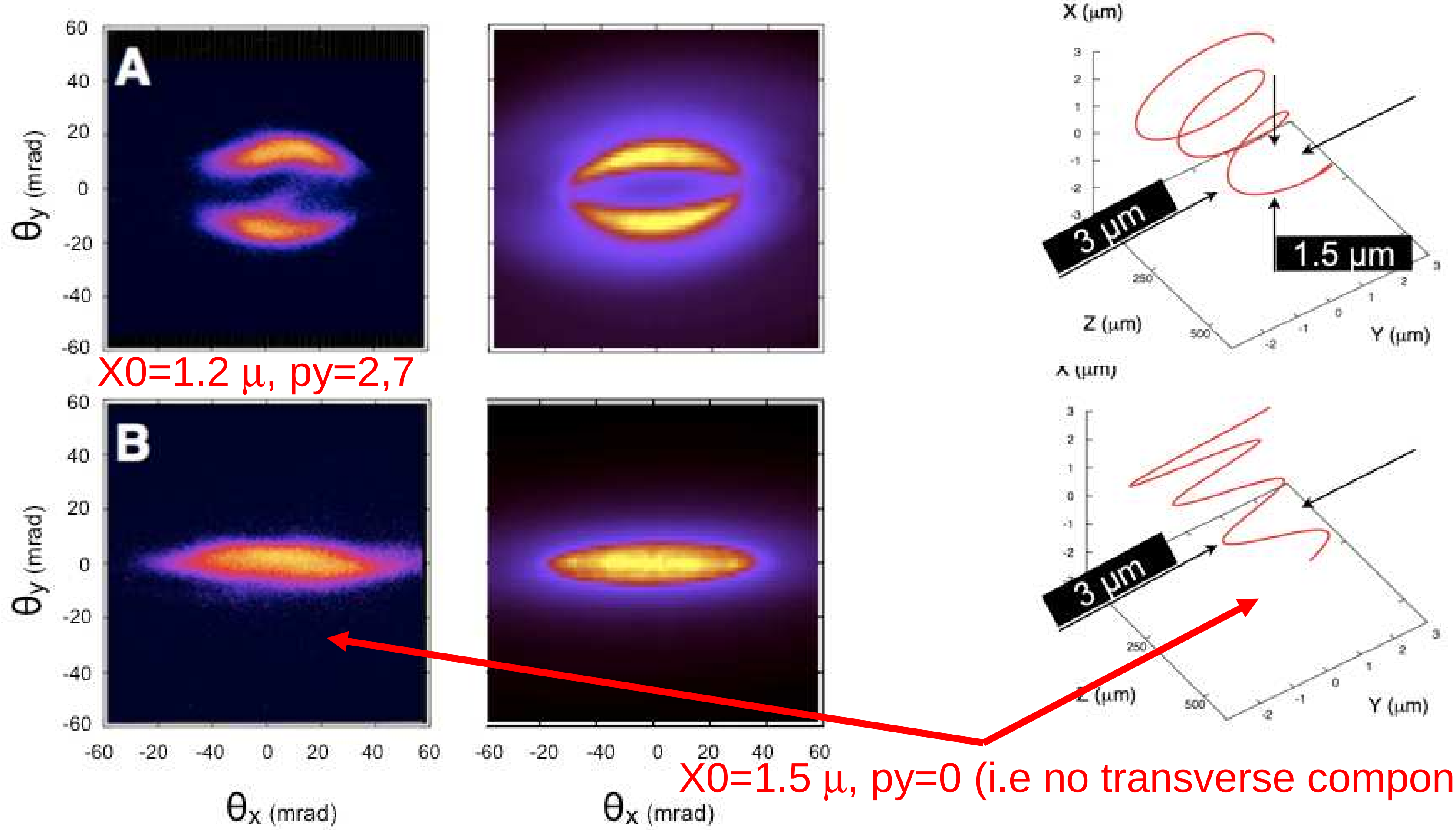
loa

Spot size and momentum measurements

- Betatron approach: X rays are produced by electrons oscillating in the transverse electric field. This radiation produces an X ray beam in the forward direction with energies up to few keV
- Measurements of X rays beam size AND electron distribution in energy and angle can be a powerful diagnostic of the emittance
- The X rays source size gives transverse size of the electron beam in the plasma bubble as well as with their transverse momentum
- The INFN emittance-meter, composed by a movable screen and slits system could be used in the LOA experiment

Results obtained in the bubble regime (on a X ray CCD for E>2keV)

Experimental and calculated profile Electron orbit



X0=1.2 µ, py=2,7

X0=1.5 µ, py=0 (i.e no transverse component)

"Imaging Electron Trajectories in a Laser-Wakefield Cavity Using Betatron X-Ray Radiation", K. Ta Phuoc et al., Phys. Rev. Lett. 2006

Emittance measurements

- Pepper pot method does seem feasible:
  - assuming a 1 μ transverse size and a divergence of 5 mrad
  - knowing that pepper pot cannot be closer than 20 cm from the source (laser damage)
  - beam diameter at this distance will be 1 mm: corresponding angular resolution will be of less than 5 μrad, difficult to achieve experimentally
  - because of the high beam energy is necessary to develop a thick pepper pot to avoid the image of the electron shower superimposed to the beam-lets on the screen
- Quad scan method:
  - well known quadrupole scan method can be used but the chromaticity of the system, with the high beam energy spread (>1%) of the e^- beam can dominate in the transverse size measurement
  - Achromatic solutions for different set of quadrupoles values is under study to avoid this effect

Task 4 Future plans

- Repeat the experiment in the colliding laser pulses scheme
  - Measure the electron and X ray energy distribution
  - Measure the electron and X ray angular distribution → emittance
  - The possible change of the electron beam divergence due its propagation in the decreasing plasma density region can as well be determined

WP11 future plans

- Task 11.1
  - Complete website, improve DCO, improve communications between WP and TL
- Task 11.2.1
  - Beam parameters evaluation and optimization including:
    - Dynamic aperture estimate and optimization *(BINP)*
    - Background simulations and beam lifetime evaluations *(INFN, BINP)*
    - Beam-beam simulations and working point definition *(INFN, BINP)*
    - e-cloud instability simulations and measurements in e^+ ring (INFN)
  - Luminosity monitors design *(INFN, CNRS)*
  - Analysis and minimization of the background hitting the detector (INFN, CNRS)
- Task 11.2.2
  - Start work on 11.2.2, LHC upgrade IR (CERN)
- Task 11.3
  - EMMA commissioning
- Task 11.4
  - Definition of techniques for emittance measurement (LOA, INFN)
  - Emittance measurement on electron beam at LOA with the SPARC emittance-meter

WP11 summary

- WP11 work is about on schedule in all Tasks
- Subtask 11.2.1 is ahead of time, while Subtask 11.2.2 has a delay due to missing recruitment of a fellowship
- Task 11.3 maybe a little delayed
- Task 11.4 is on track, but need to speed up the choice of emittance-meter techniques
- Two EuCARD Reports have been published by Tasks 2 and 4 (besides conferences and journals publications)