EuCARD

The R&D program on Emerging Accelerator Concepts (ANAC, Assessment of Novel Accelerator Concepts, WP11)

M. Biagini (INFN-LNF), T.R. Edgecock (STFC)

on behalf of the ANAC Task Coordinators

EuCARD Kick-off meeting, CERN, Dec. 5th 2008

Science & Technology Facilities Council

CERN

INFN Istituto Nazionale di Fisica Nucleare

cnrs dépasser les frontières

ANAC objectives

- This WP regroups important topics regarding novel accelerator concepts in three different fields: high luminosity colliders, technologies required by neutrino facilities and plasma wave accelerator techniques:
  - a new collision scheme characterized by an innovative correction of higher order optics aberrations combined with large angle beam crossing holds the promise of increasing the luminosity far beyond the current achieved state-of-the-art in colliders
  - the planned instrumentation for the world's first non-scaling FFAG (Fixed Field Alternate Gradient) (EMMA, STFC) shall allow a better knowledge of the beam dynamics, with possible application to neutrino facilities and medicine. The accelerator neutrino community network is closely linked to the muon cooling facility MICE and to this topic
  - the measurement of ultra-short electron beams is instrumental to the assessment of laser plasma acceleration

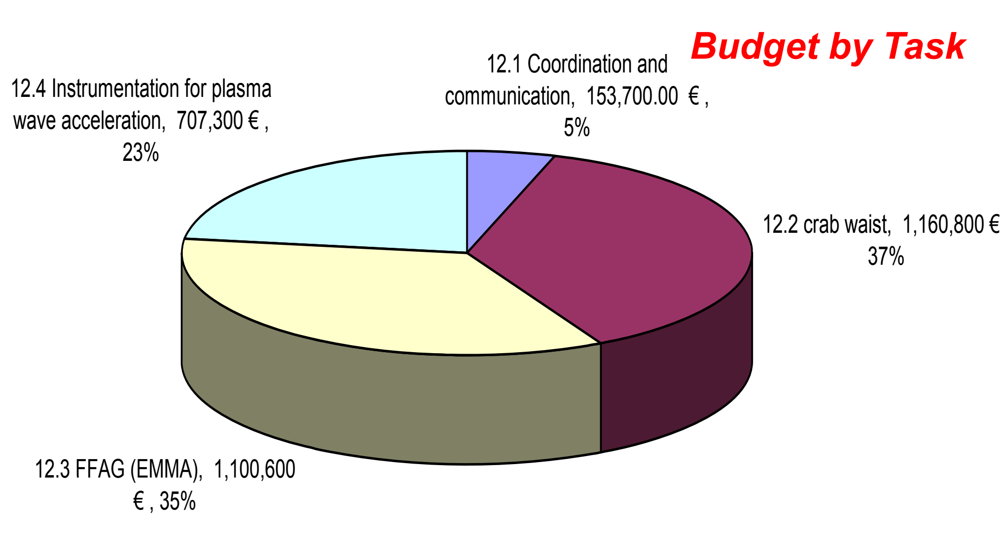
Tasks

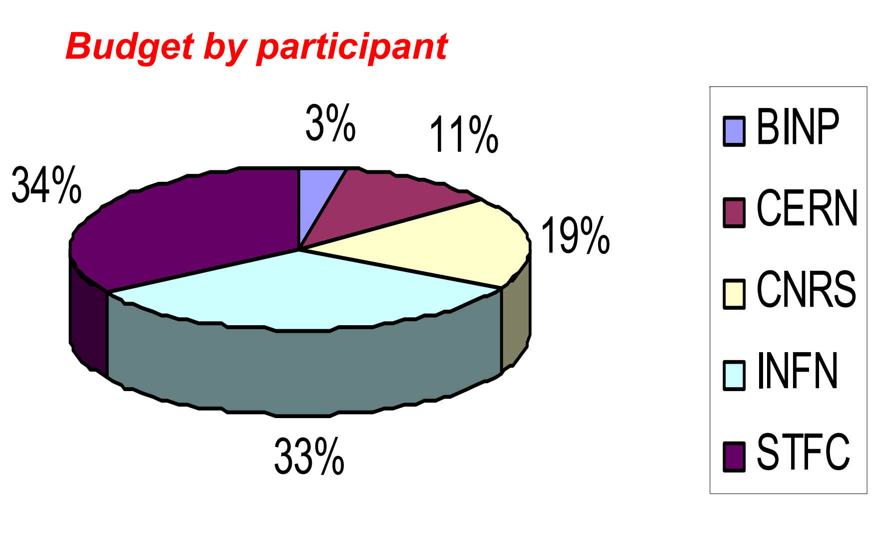
- **Task 11.1. ANAC Coordination and Communication**
  (Coordinator M. Biagini, LNF - INFN)
  - Coordination and scheduling of the WP tasks
  - Monitoring the work, informing the project management and participants within the JRA
  - WP budget follow-up
- **Task 11.2. Design of Interaction Regions for 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

Existing infrastructures used

- DAΦNE e^+e^- storage ring, INFN, Frascati National Laboratories, Italy
- LHC collider, CERN, Switzerland
- EMMA FFAG Ring, STFC, Daresbury Laboratories, UK
- SPARC Lab, INFN, Frascati National Laboratories, Italy
- LOA, CNRS, France

Statistics





3 years duration

Work package number	WP11		**Start date or starting event:**				M1
Work Package title	ANAC						
Activity type	RTD						
Participant id	**INFN**	**BINP**	**CERN**	**CNRS**	**STFC**		
Person-months per beneficiary	110	15	32	50	46		

Deliverables & Milestones

Deliverables of tasks	Description/title	Nature	Delivery month
11.1.1	ANAC web-site linked to the technical and administrative databases	O	M36
11.2.1	DAΦNE IR design for the upgraded KLOE detector	R	M24
11.2.2	Study of an IR design for LHC upgrade	R	M36
11.3.1	Results from the operation of EMMA using the new diagnostics	R	M36
11.4.1	Preliminary electron beam emittance measurement report	R	M36

Mile-stone	task	Description/title	Nature	Delivery month	Comment
11.1.1	11.1	1st annual ANAC review meeting	O	M12	
11.1.2	11.1	2nd annual ANAC review meeting	O	M24	
11.1.3	11.1	3rd annual ANAC review meeting	O	M36	
11.1.4	11.1	Final ANAC review meeting	O	M48	
11.2.1	11.2	DAΦNE beam parameters definition for KLOE	O	M12	Preparatory for IR study
11.2.2	11.2	Compatibility of new IR scheme and LHC	O	M18	Preparatory for IR study
11.3.1	11.3	Requirements for electron beam diagnostics	R	M2	
11.3.2	11.3	Construction of the electron beam diagnostics completed	R	M14	
11.3.3	11.3	Commissioning of EMMA completed	R	M20	
11.4.1	11.4	Electron beam emittance meter finished	P	M24	Alignment and pre test

Detailed budget for Task

1

Beneficiary short name (all costs in €)	Person-Months	Personnel direct costs	Personnel indirect costs	Sub-contracting cost	Consumable and prototype direct costs	Travel direct costs	Material and travel indirect costs	Total direct costs	Total indirect costs	Total costs (direct +indirect)	EC requested funding[1]
BINP	1	2,080	790	0		5,000	1,900	7,080	2,690	9,770	2,931
CERN	1	6,200	3,720	0		8,000	4,800	14,200	8,520	22,720	6,816
CNRS	1	5,200	3,120	0		5,000	3,000	10,200	6,120	16,320	4,896
INFN	4	20,800	12,480	0	4,970	16,000	12,582	41,770	25,062	66,832	20,050
STFC	1	7,000	7,350	0		10,000	0	17,000	7,350	24,350	7,305
Totals:	**8**	**41,280**	**27,460**	**0**	**4,970**	44,000	22,282	90,250	**49,742**	**139,992**	**41,998**

2

Beneficiary short name (all costs in €)	Person-Months	Personnel direct costs	Personnel indirect costs	Sub-contracting cost	Consumable and prototype direct costs	Travel direct costs	Material and travel indirect costs	Total direct costs	Toal indirect costs	Total costs (direct +indirect)	EC requested funding[1]
BINP	14	29,120	11,066	0	30,000	9,000	14,820	68,120	25,886	94,006	28,202
CERN	31	192,200	115,320	0		9,000	5,400	201,200	120,720	321,920	96,576
CNRS	9	46,800	28,080	0		8,000	4,800	54,800	32,880	87,680	26,304
INFN	78	405,600	243,360	0		9,350	5,610	414,950	248,970	663,920	199,176
Totals:	**132**	**673,720**	**397,826**	**0**	**30,000**	35,350	30,630	739,070	**428,456**	**1,167,526**	**350,258**

3

Beneficiary short name (all costs in €)	Person-Months	Personnel direct costs	Personnel indirect costs	Sub-contracting cost	Consumable and prototype direct costs	Travel direct costs	Material and travel indirect costs	Total direct costs	Toal indirect costs	Total costs (direct +indirect)	EC requested funding[1]
CNRS	5	26,000	15,600	0		15,000	9,000	41,000	24,600	65,600	19,680
STFC	45	315,000	330,750	0	384,000	13,000	0	712,000	330,750	1,042,750	312,825
Totals:	**50**	**341,000**	**346,350**	**0**	**384,000**	28,000	9,000	753,000	**355,350**	**1,108,350**	**332,505**

4

Beneficiary short name (all costs in €)	Person-Months	Personnel direct costs	Personnel indirect costs	Sub-contracting cost	Consumable and prototype direct costs	Travel direct costs	Material and travel indirect costs	Total direct costs	Toal indirect costs	Total costs (direct +indirect)	EC requested funding[1]
CNRS	35	182,000	109,200	0	66,400	10,000	45,840	258,400	155,040	413,440	124,032
INFN	28	145,600	87,360	0	32,000	2,000	20,400	179,600	107,760	287,360	86,208
Totals:	**63**	**327,600**	**196,560**	**0**	**98,400**	12,000	66,240	438,000	**262,800**	**700,800**	**210,240**

Total costs: 3.117 keuro, EU funding: 935 keuro

Task 11.2: Large Piwinski Angle and Crab-Waist collision scheme

Coordinator C. Milardi, LNF - INFN

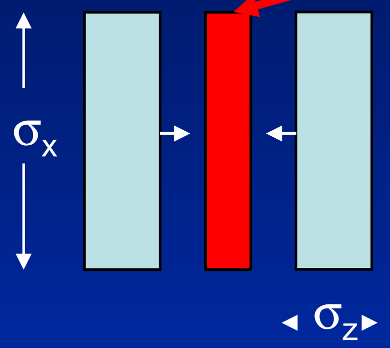
- Feasibility study of a new collision scheme for storage-ring colliders characterized by Large Piwinski Angle, low β^* and Crab Waist (LPA & CW).
- LPA & CW should provide a luminosity improvements far beyond the current state-of-the-art, without any significant increase in beam currents and without reducing the bunch length
- Tests are presently in progress at the INFN National Frascati Laboratory's Φ-Factory DAΦNE
- Task 2 is aimed at studying the LPA & CW implementation at:
  - DAΦNE collider upgrade in view of the KLOE2 experiment data-taking
  - Possible upgrade for one of the LHC interaction region
- Task Partners:
  - BINP, Russia
  - CERN, Switzerland
  - CNRS, France
  - INFN, Italy

Large Piwinski Angle, Crab-Waist

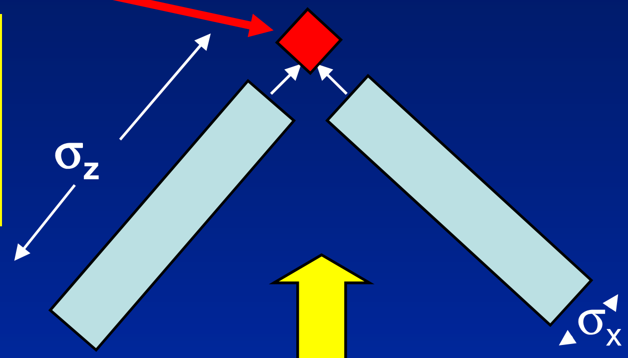
1) Head-on, Short bunches

Overlap region

2) Large crossing angle, long bunches

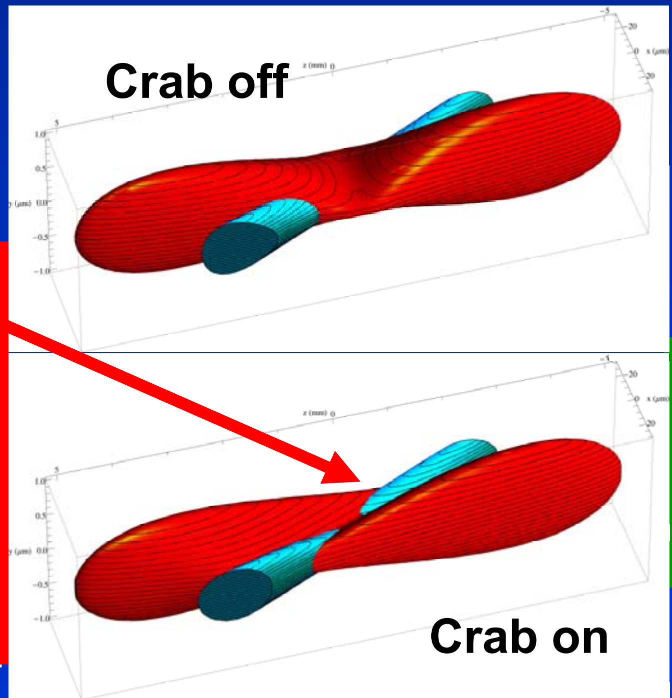


(1) and (2) have same Luminosity, but (2) has longer bunches and smaller σ_x



Large Piwinski angle:

$$\Phi = tg(\theta)\sigma_z/\sigma_x$$



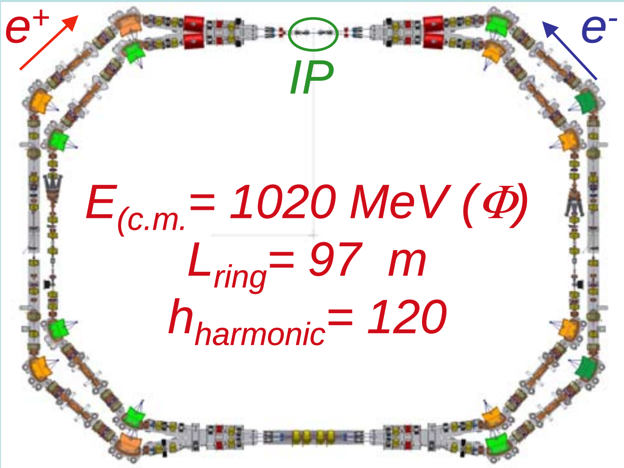
y waist can be moved along z with a sextupole on both sides of IP at proper phase

⇓

"Crab Waist"

All particles in both beams collide at the minimum β_y region (waist) with a net luminosity gain

LPA & CW at DAΦNE



Present rings layout

- *DAΦNE original configuration:*

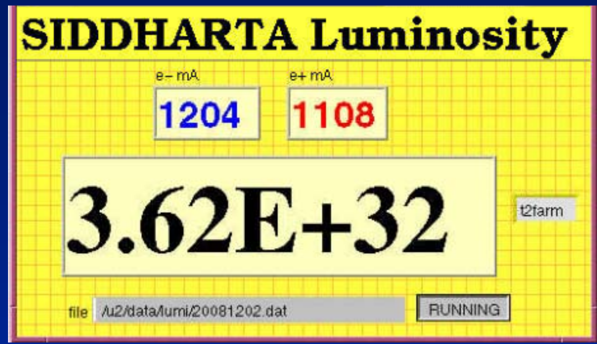
  L_{peak} ~ 1.6 10^{32} cm^{-2} s^{-1} (Apr 2007) maximum luminosity achievable due to:
  - β_y^* saturation, $\beta_y^* \geq \sigma_z$ to avoid the hourglass effect
  - Long-range beam-beam interactions (24 encounters in each of the two IRs) causing lifetimes reduction, limiting maximum currents and consequently L_{peak} and L_{int}.

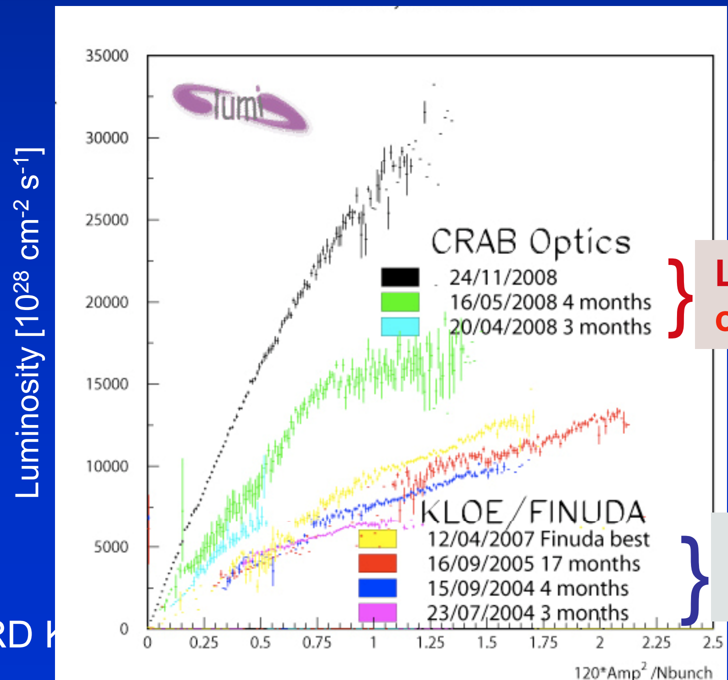
- *Collider upgrade for new collision scheme:*
  - new IR
  - new Ring Cross Region replacing former IR2
  - new injection kickers
  - new bellows
  - transverse and longitudinal feedback upgrade

DAΦNE achievements (Dec. 2008)

Operation restarted on Dec. 2007

- New collision scheme works and CW sextupoles effective in controlling transverse beam blow-up and increasing luminosity:
  - ***L_{peak} = 1.6 cm^{-2}s^{-1} , ∫ L_{day} = 10. pb^{-1} (KLOE 2003)***
  - ***L_{peak} = 3.6 cm^{-2}s^{-1} , ∫ L_{day} = 12.8 pb^{-1} (NOW)***
- In this context is reasonable to plan a further upgrade in view of the KLOE2 experiment run





Luminosity vs beam currents

LPA & CW collision scheme

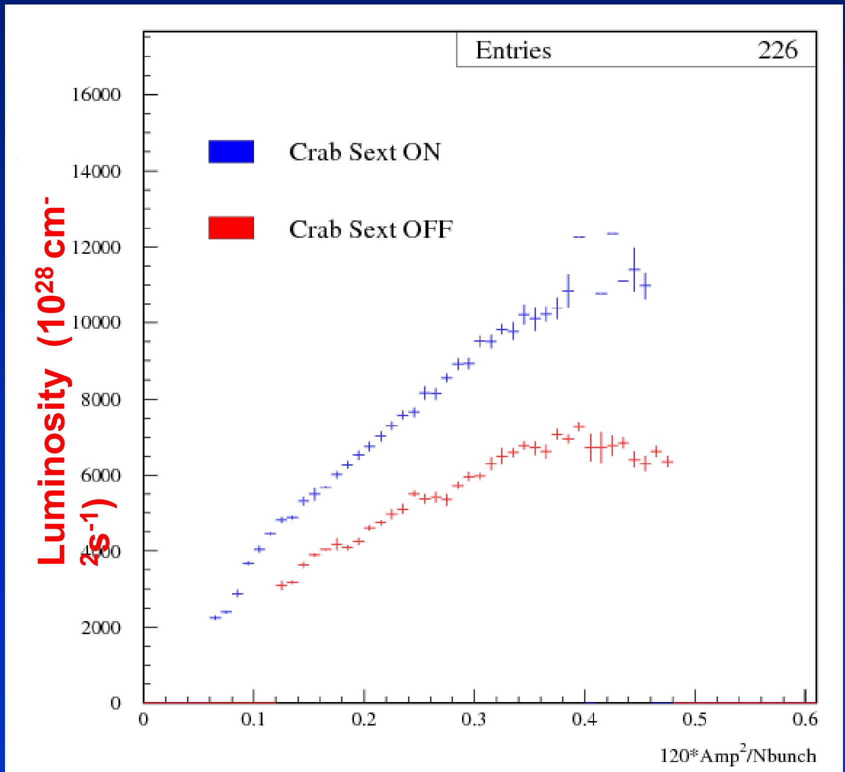
Original collision scheme

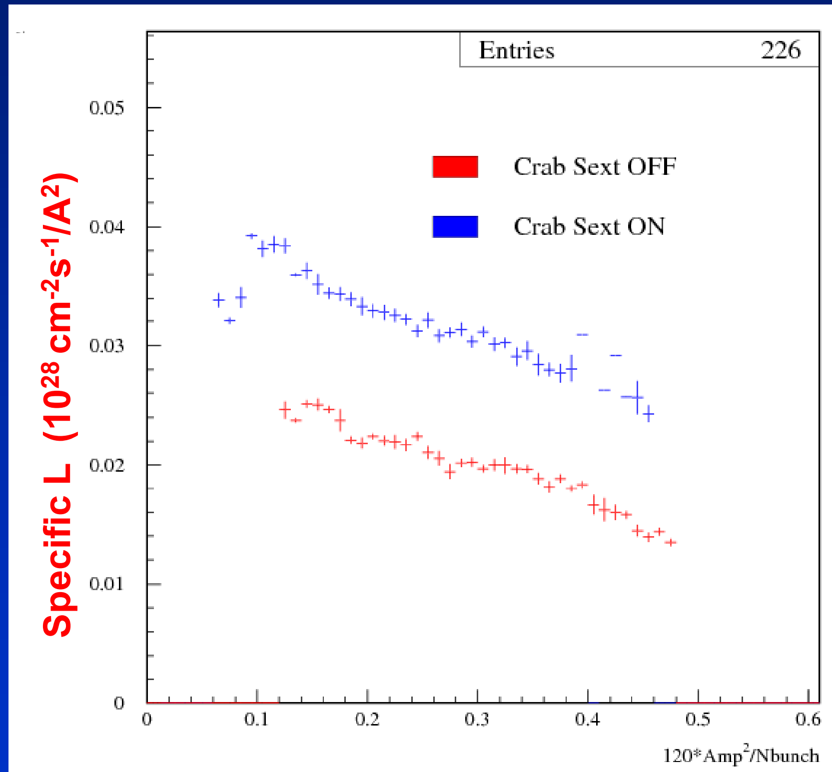
Luminosity, crab sextupoles ON/OFF

Luminosity

95 Bunches

Specific Luminosity





July 2008

$$L_{sp} = \frac{N_b\, L_{peak}}{I^+ I^-} \; [cm^{-2} s^{-1} / A^2]$$

Crab waist in LHC ?

K. Ohmi (KEK)

One example:

CARE-HHH
mini-workshop
28 August '08

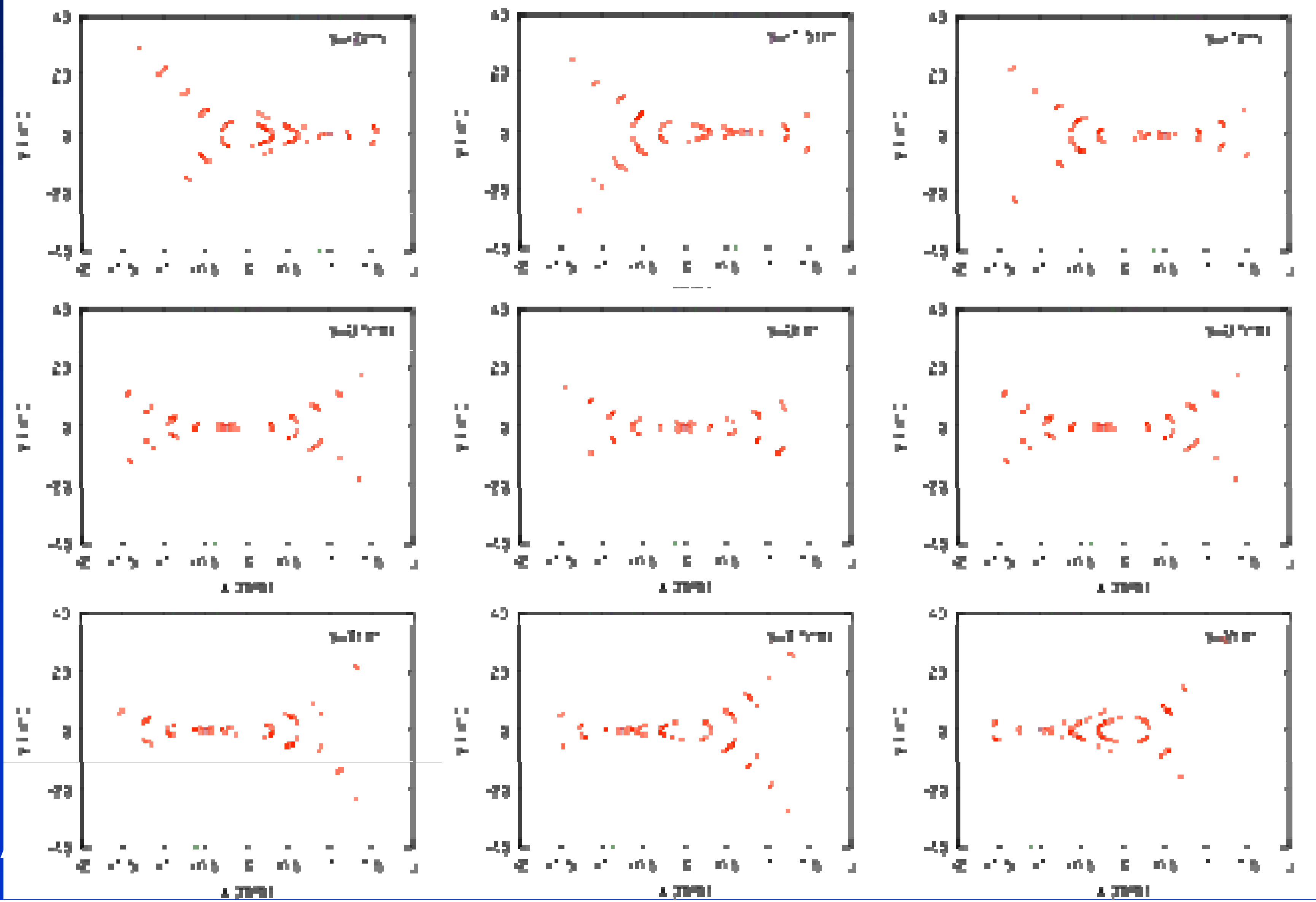
ϕ = 3.5 in LPA option
β_y squeezed to σ_x/ϕ=2.1cm (*extreme!*)

→ L increases $(14/2.1)^{1/2}$=2.6 times
→ ξ_y decreases and ξ_x is small for LPA

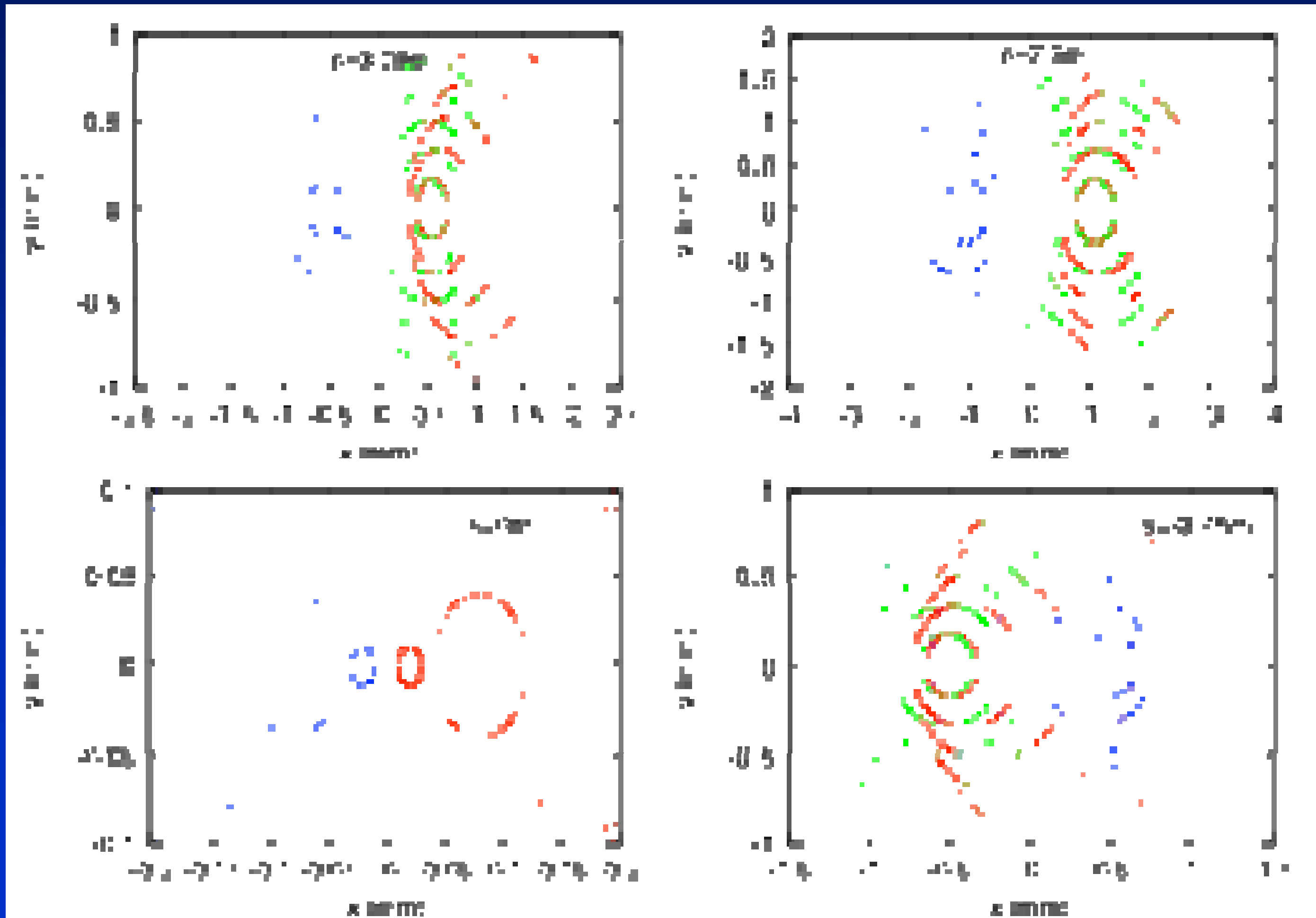
→ "crab waist has a chance to work!"

Crab-waist collisions (K. Ohmi,KEK)

Vertical focus moves through the beam horizontally



Another use of “crab-waist”: push beam halo away from opposing beam at LR collisions



K. Ohmi (KEK)

Detailed by work

- INFN:
  - ➢*New Interaction Region design for the KLOE2 experiment:*
    - *Optics design*
    - *Coupling correction & ring acceptance*
    - *Background*
    - *Beam dynamic*

    One postdoc for 3 years + travels

- CERN:
  - ➢*Evaluate the LPA & CW implementation for one of the LHC Interaction Region:*
    - *LHC flat beam and large-Piwinski angle scenarios with IR layouts and magnet parameters*
    - *Crab waist for primary and parasitic collisions*
    - *Crab waist for collimators*

    One fellow for 2.5 years + travels + invite experts to CERN

Detailed by work (2)

- BINP:
  - *Studies for the DAΦNE upgrade:*
    - *Beam-beam simulation*
    - *Dynamic aperture computation and optimization*
    - *Intra beam scattering and Touschek lifetime calculations*

  Computing resources + travels

- CNRS:
  - *Contribution to the DAΦNE upgrade:*
    - *Luminosity monitor design*
    - *Beam measurements*

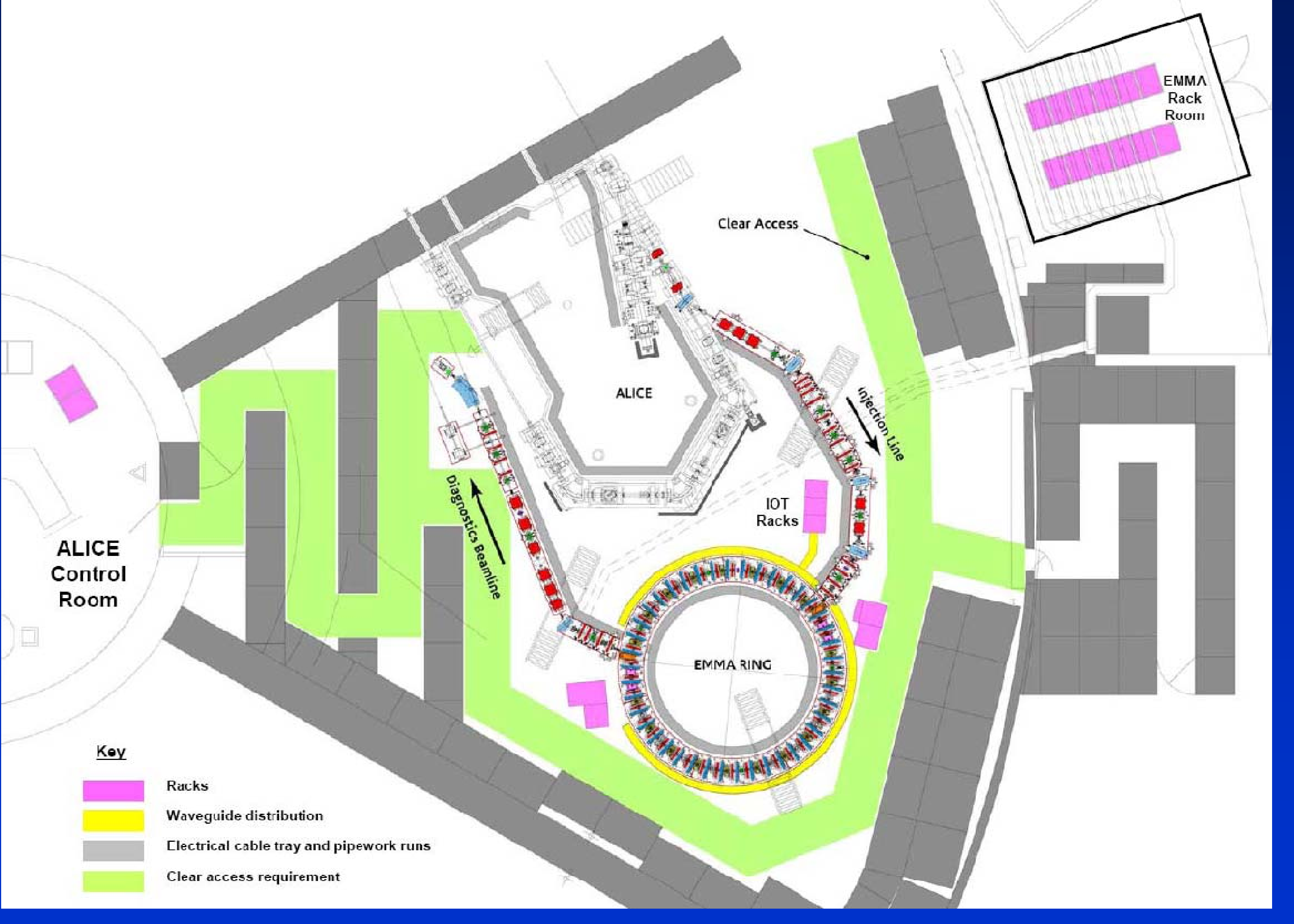
  One post-doc for 1 year

Task 11.3: Non scaling FFAG

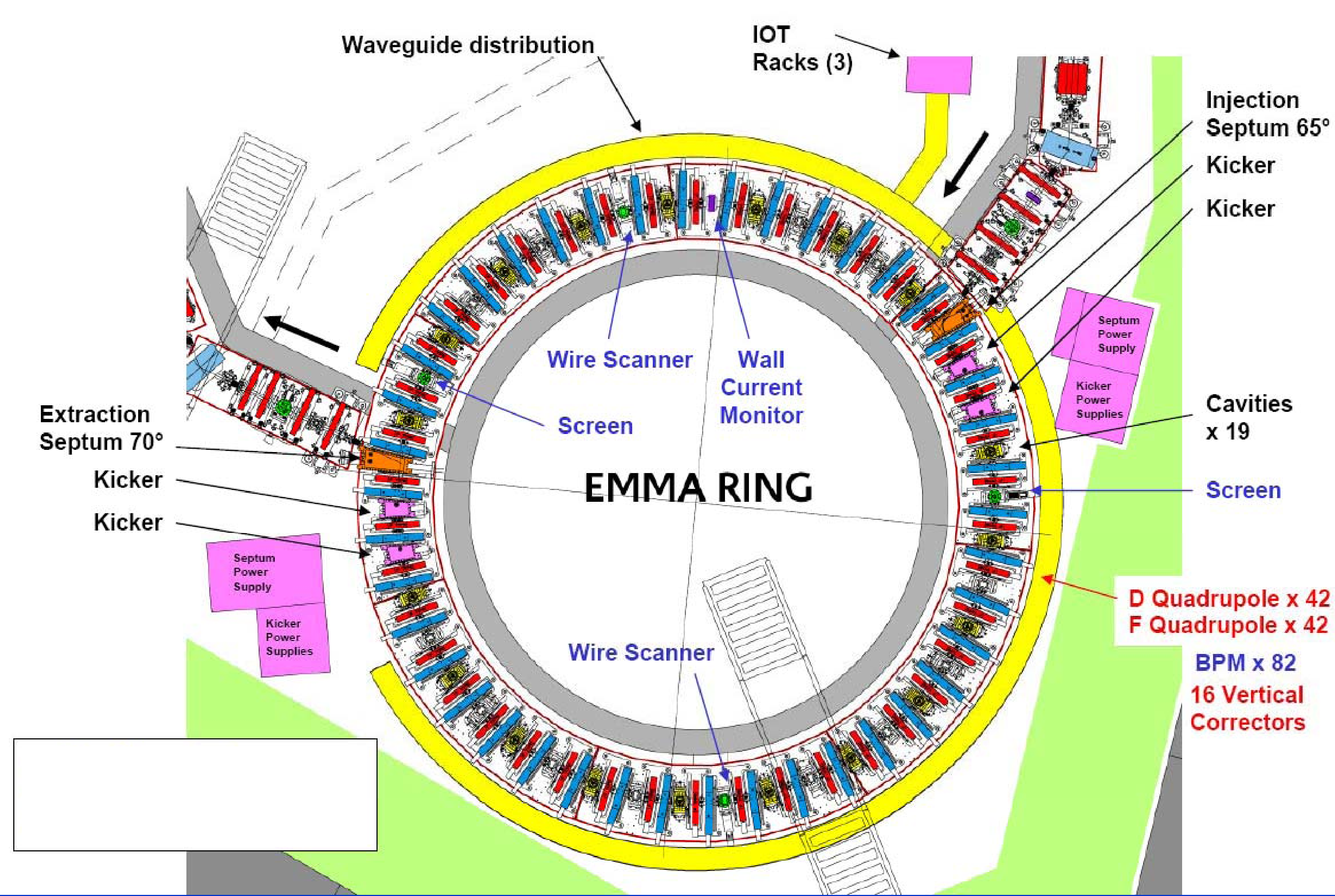
Coordinator T.R. Edgecock, STFC

- Non-scaling FFAGs under study for:
  - muon acceleration in a Neutrino Factory
  - proton & ion acceleration for cancer therapy
  - muon production for μSR
  - spallation neutron production and ADSR
- So far, only scaling FFAGs built
- EMMA → proof of principle ns-FFAG
  - being built at Daresbury Laboratory
  - electron acceleration from 10-20 MeV
  - uses ALICE (energy recovery linac prototype) as injector
  - diagnostics are very important

EMMA Complex Layout

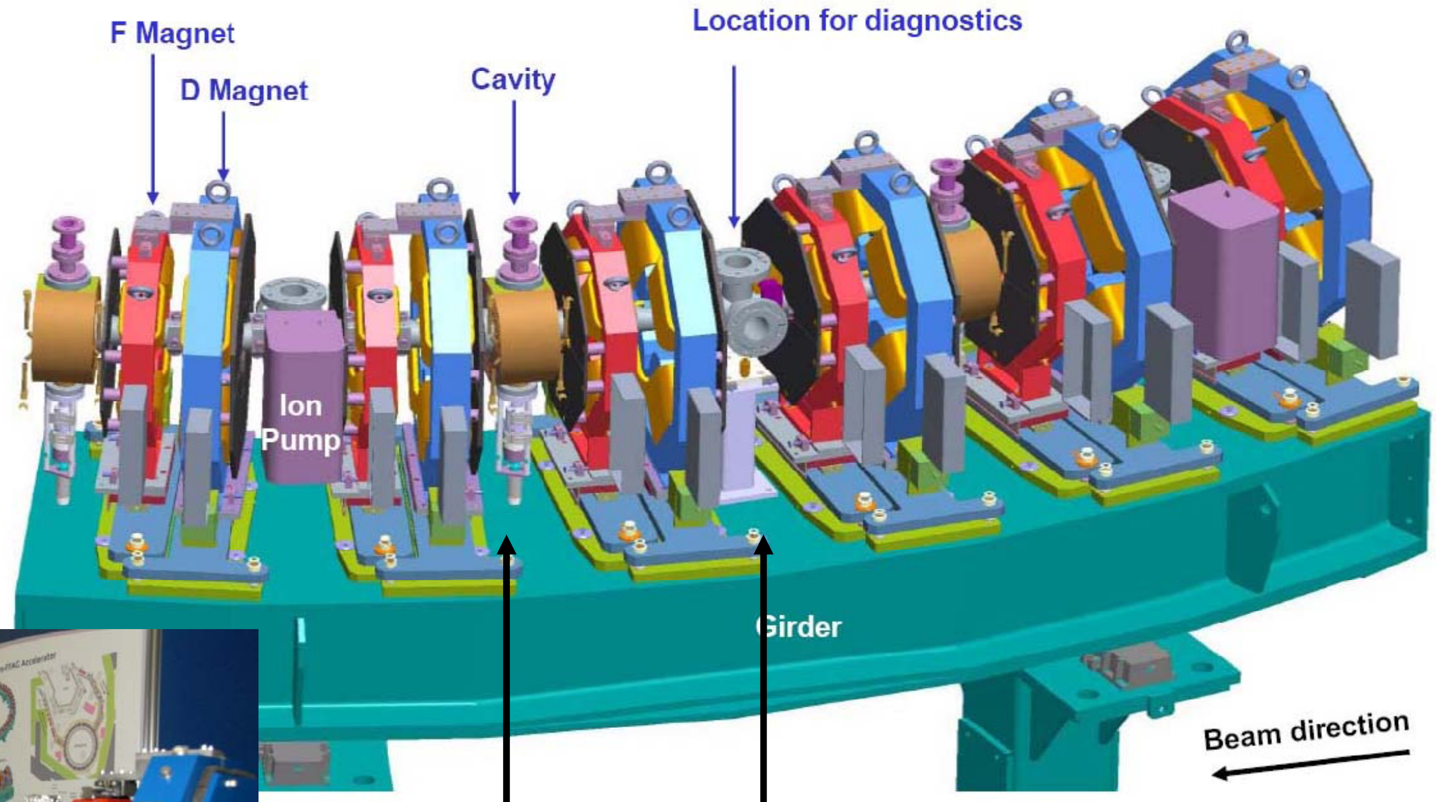


EMMA Ring



Waveguide distribution
IOT
Racks (3)
Injection
Septum 65°
Kicker
Kicker
Septum
Power
Supply
Kicker
Power
Supplies
Cavities
x 19
Screen
D Quadrupole x 42
F Quadrupole x 42
BPM x 82
16 Vertical
Correctors
Wire Scanner
Wall
Current
Monitor
Screen
EMMA RING
Extraction
Septum 70°
Kicker
Kicker
Septum
Power
Supply
Kicker
Power
Supplies
Wire Scanner

EMMA Girder



e.g. an EMMA cell gets a royal visitor

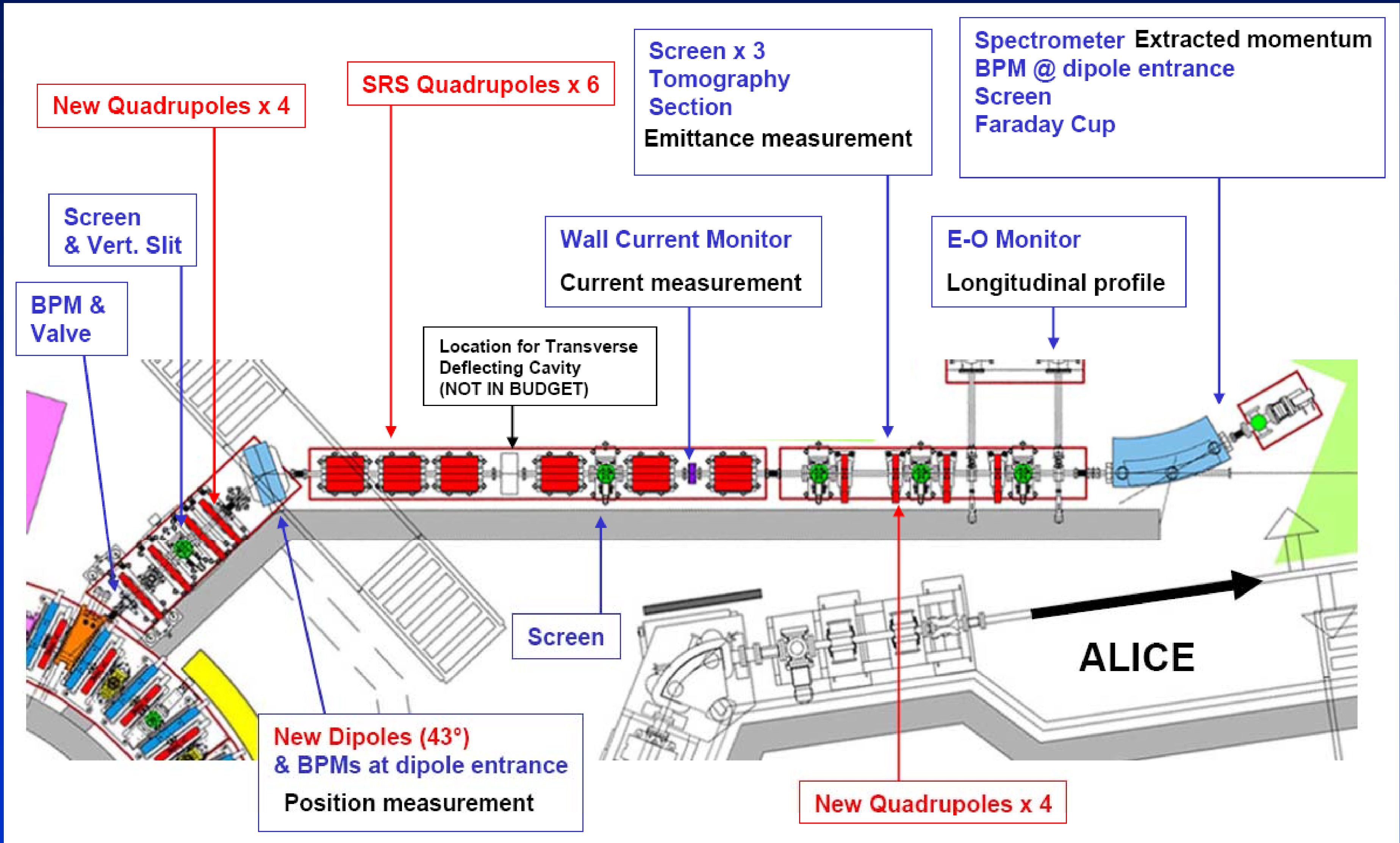
(Duke of Kent)

Status

All components designed

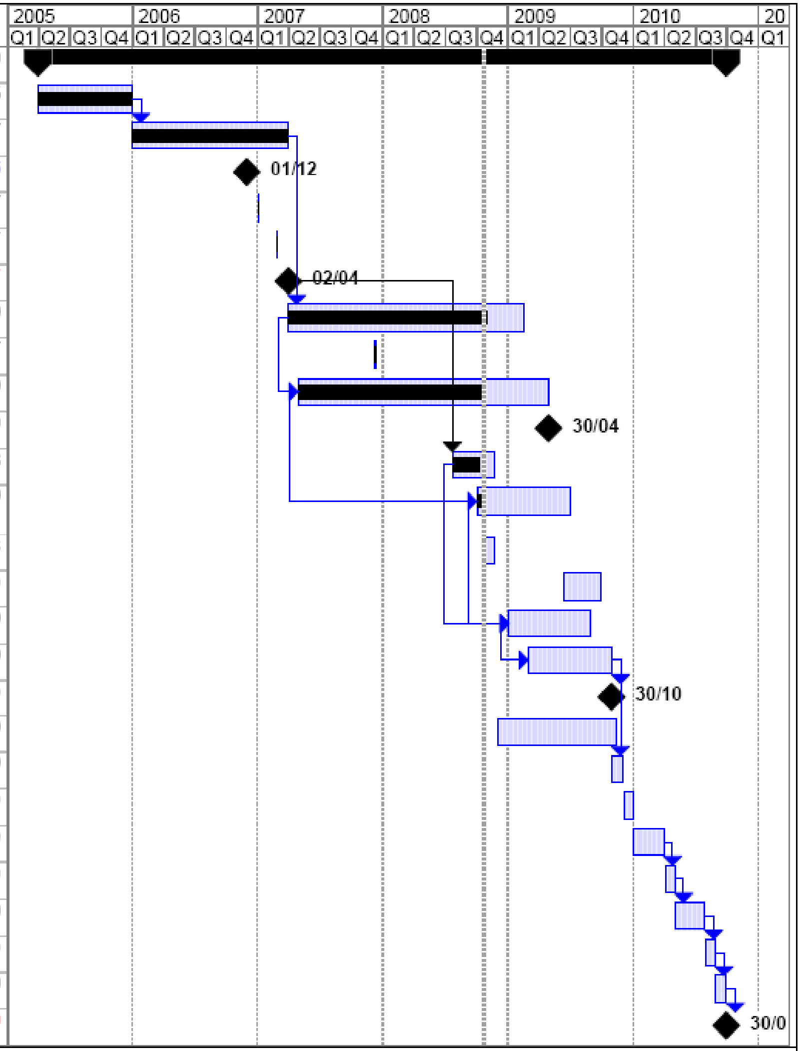
Construction of most well advanced

Diagnostics Line



EMMA schedule

ID		Task Name	Start	Finish
1		**EMMA Project Plan**	**Fri 01/04/05**	**Thu 30/09/10**
2	✓	Conception	Fri 01/04/05	Fri 30/12/05
3	✓	Feasibility Phase	Mon 02/01/06	Fri 30/03/07
4	✓	Project approval notified	Fri 01/12/06	Fri 01/12/06
5	✓	Design Review 1	Thu 04/01/07	Thu 04/01/07
6	✓	Design Review 2	Mon 26/02/07	Wed 28/02/07
7	✓	Funding available	Mon 02/04/07	Mon 02/04/07
8		Design	Mon 02/04/07	Mon 16/02/09
9	✓	Design review 3	Mon 10/12/07	Tue 11/12/07
10		Procurement	Mon 30/04/07	Tue 28/04/09
11		**All major components on site**	**Thu 30/04/09**	**Thu 30/04/09**
12		Infrastructure upgrade	Wed 23/07/08	Fri 21/11/08
13		Particle testing of vacuum chambers and off line assembly of modules	Fri 03/10/08	Tue 30/06/09
14		**ALICE Shutdown**	**Sat 25/10/08**	**Sat 22/11/08**
15		**ALICE Shutdown**	**Mon 15/06/09**	**Wed 30/09/09**
16		Installation in the ALICE Accelerator Hall	Mon 05/01/09	Mon 31/08/09
17		Test systems in the ALICE Accelerator Hall	Mon 02/03/09	Fri 30/10/09
18		**Injection line and ring complete**	**Fri 30/10/09**	**Fri 30/10/09**
19		Phase 1 Diagnostics Beamline Complete	Mon 01/12/08	Fri 13/11/09
20		Commission with electrons stage 1	Mon 02/11/09	Mon 30/11/09
21		**Alice Shutdown**	**Mon 07/12/09**	**Sun 03/01/10**
22		Commission with electrons stage 2	Mon 04/01/10	Wed 31/03/10
23		**Alice Shutdown**	**Tue 06/04/10**	**Sun 02/05/10**
24		Commission with electrons stage 3	Mon 03/05/10	Thu 29/07/10
25		**Alice Shutdown**	**Mon 02/08/10**	**Sat 28/08/10**
26		Commission with electrons stage 4	Mon 30/08/10	Thu 30/09/10
27		EMMA beam studies complete	Thu 30/09/10	Thu 30/09/10



Project: EMMA Summary Program V3
Date: Tue 21/10/08

Task		Milestone	◆	External Tasks	
Split		Summary		External Milestone	◆
Progress		Project Summary		Deadline	⇩

Within ANAC

- External diagnostics design, construction and testing.
- The requirements for the diagnostics will come from tracking studies performed by CNRS-Grenoble and STFC at the Daresbury Laboratory.
- The design, construction and testing of the devices will be undertaken by staff in STFC. The installation in the beam-lines will also be done by STFC staff
- Commissioning and experimental running. Commissioning of EMMA using diagnostics will be undertaken by staff from STFC and CNRS. The experimental measurements with these devices required to determine the applicability of non-scaling optics for the applications being studied will also be made by staff at STFC and CNRS
- Task Partners:
  - CNRS, France
  - STFC, UK

Budget for construction of “diagnostics” beamline

Task 11.4: Emittance measurements of laser-plasma accelerator

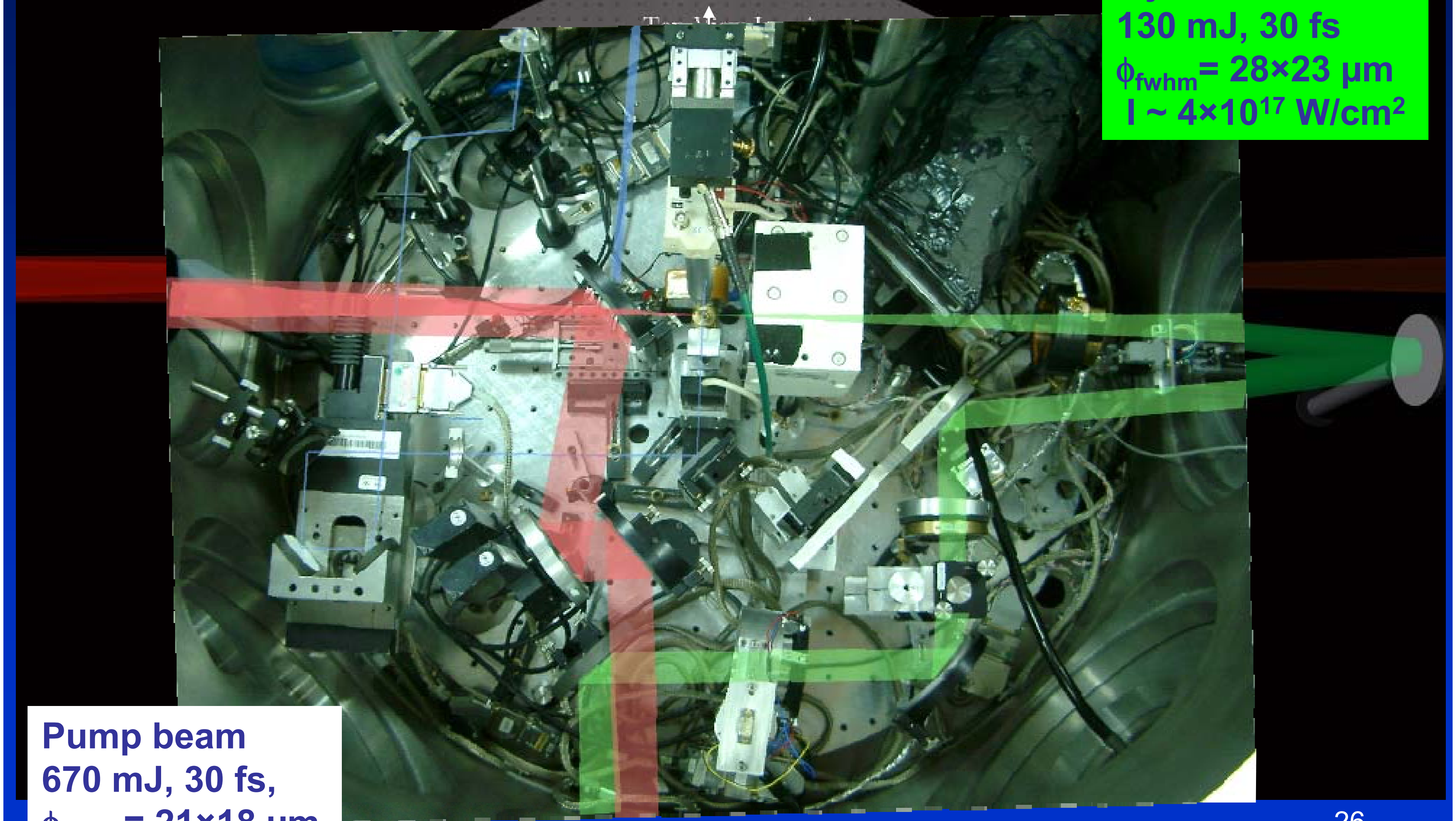
Coordinator V. Malka, CNRS

- The development of ultra short electron beams with low emittance, using RF or laser based accelerators, is crucial for the development of a two stage laser plasma accelerator, which should permit to reduce notably the relative energy spread of the electron beam
- The need of new instrumentation to diagnose parameters of the electron beam produced is extremely important. An experimental methodology is needed to investigate these parameters, such as emittance or relative energy spread, since they are not today produced with a very high shot to shot reproducibility as those produced using RF cavity based accelerators.
- It is proposed to study the different approaches for measuring emittance of these electron beam delivered by laser plasmas accelerators. These emittances are expected to be in the mm.mrad range.

Experimental set up at LOA

Laser plasma acceleration demonstrated (CARE)

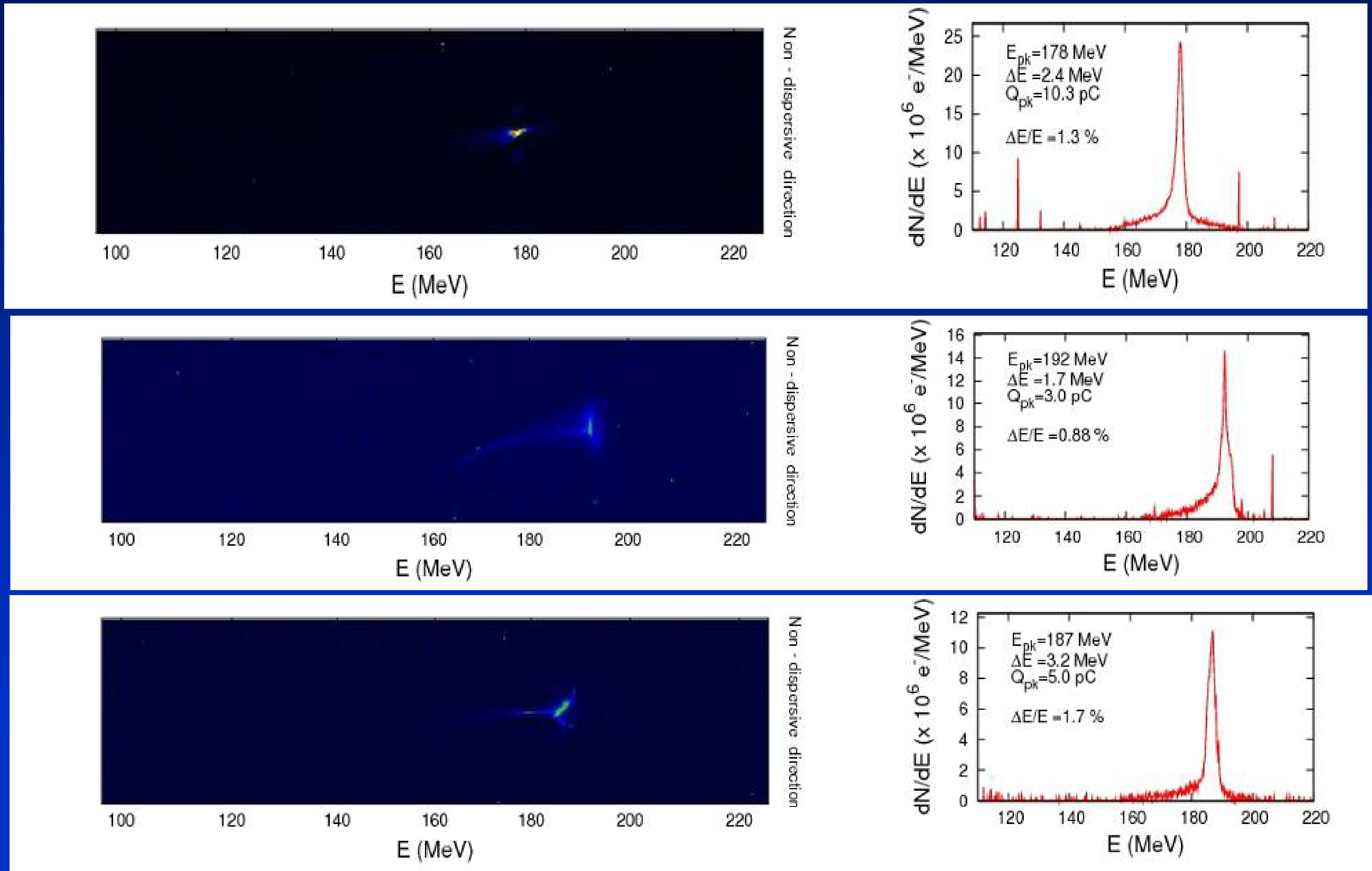
Injection beam
130 mJ, 30 fs
ϕ_{fwhm}= 28×23 μm
I ~ 4×10^{17} W/cm^2



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

1% energy spread beams measured

CARE collaboration meeting CERN 2-4 December 2008



Within ANAC

- Different approaches for measuring the beam emittance have been suggested or tested in the past
- To avoid errors induced by shot to shot fluctuations in the emittance measurement INFN will develop a single shot emittance measurement or a specific technique to reduce those errors. This diagnostics will be tested at the SPARC Lab in Frascati, where a low emittance RF gun is available
- The selected technique will be then tested and used at LOA where a laser plasma accelerator will be developed for this purpose

- Task Partners:
  - CNRS, France
  - INFN, Italy

- LOA: budget used to hire one Post doc for two years
- INFN: budget used to hire one Post doc for two years

Conclusions

- ANAC WP collects innovative ideas in very different fields
- Novel methods have been proposed for colliders, muon and laser-plasma acceleration
- 5 existing infrastructures will be used
- Very small budget spread over 5 participant Institutions
- Profit from collaboration with non-EU partners:

"The Panel agrees that both these institutes (BINP,...) are making unique and high-value contributions to this proposal, and thus their participation is well-justified." *(EuCARD evaluation summary report)*

We are small but we will have BIG results !