Update of the FERMI@Elettra Project

S. Milton for the FERMI Team

ESLS 2008

27 November 2009

DESY

The FERMI@Elettra Project

FERMI@Elettra is a single-pass FEL user-facility covering the wavelength range from 100 nm (12 eV) to 4 nm (310 eV).

The main machine characteristics are:

- High peak power (~GW) optical pulses with synchronization to external laser sources.
- Ultrashort pulses (100 fs to 10 fs).
- APPLE II-type undulators to enable flexible tuning of both photon wavelength and polarization.
- Implementation of seeded harmonic cascade FEL schemes for tunable and controlled short-wavelength photon pulse production.
- Advanced feedback and feed-forward systems to improve output stability.

FERMI@Elettra Core Experimental Programs

Low Density Matter (Coordinator: C. Callegari)

- Cluster and Nanoparticle Spectroscopy
  - Spokespersons: F. Stienkemeier, B. von Issendorff (Univ. of Freiburg)
- Ultrafast Processes and Imaging of Gas Clusters and Nanoparticles
  - Spokespersons: T. Möller, C. Bostedt (TU-Berlin)
- Atomic, Molecular and Optical Science Beamline
  - Spokesperson: K. Prince (Sincrotrone Trieste)
- Spectroscopic Studies of Reaction Intermediates
  - Spokesperson: S. Stranges (University of Rome La Sapienza)

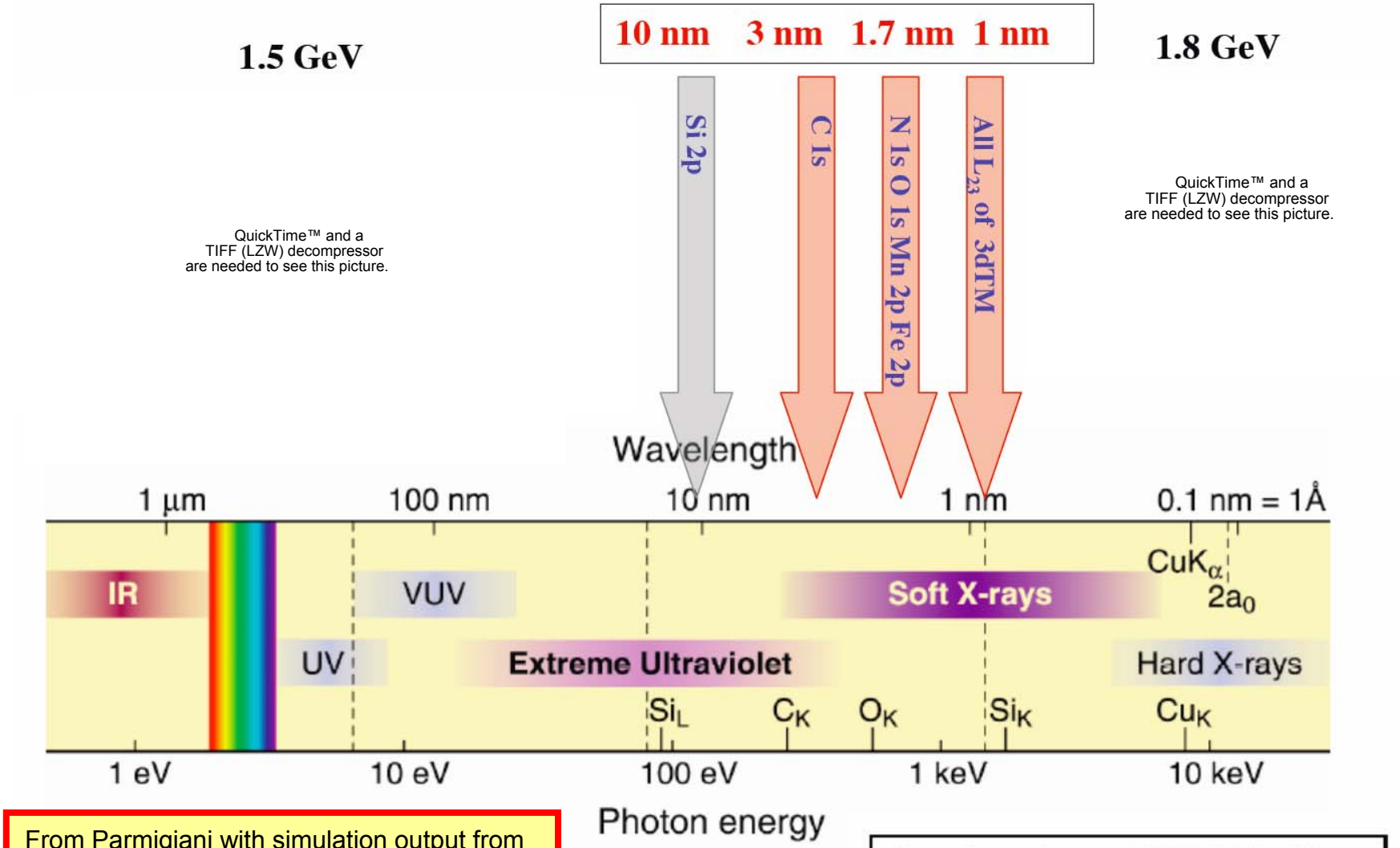
Diffraction and Projection Imaging (Coordinator: M. Kiskinova)

- Ultrafast Coherent Imaging at FERMI
  - Spokesperson: H. Chapman (CFEL-DESY), J. Haidu (Stanford Univ. and Uppsala Univ.)
- Full Field X-ray Microscopy and Lensless Imaging
  - Spokespersons: M. Kiskinova, B. Kaulich (Sincrotrone Trieste), T. Wilhein, IXO, Rhein Ahr Campus Remagen, Germany

Elastic and Inelastic Scattering (Coordinator: C. Masciovecchio)

- TIMER and TIMEX
  - Spokespersons: C. Masciovecchio (Sincrotrone Trieste), A. Di Cicco (UNICAM and Univ. Paris IV), G. Ghiringhelli (POLIMI)

Critical Absorption Edges



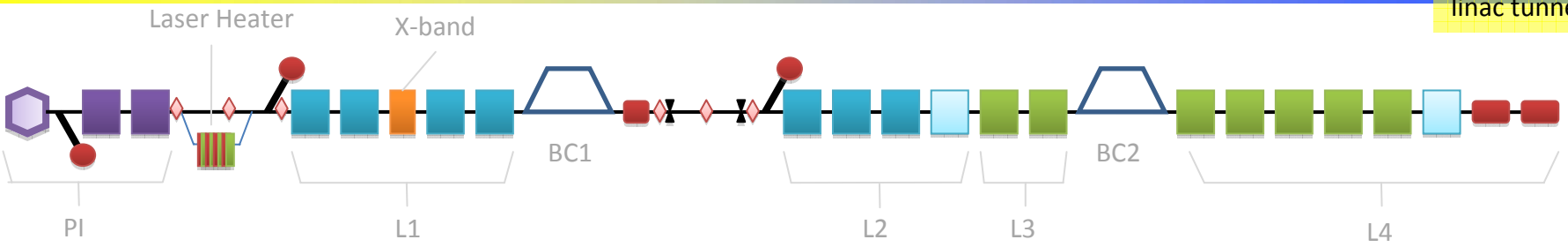
QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

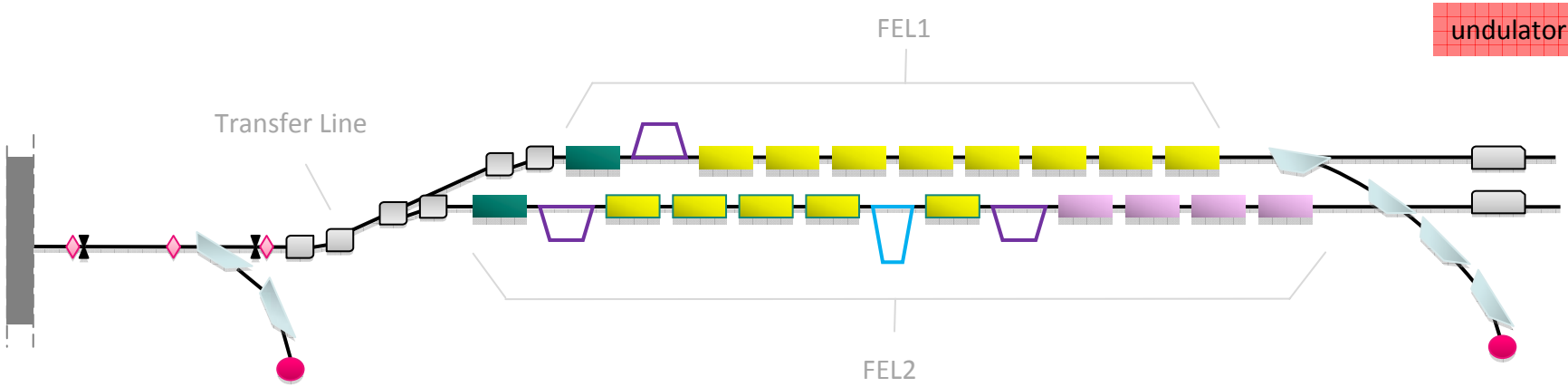
From Parmigiani with simulation output from Allaria, DeNinno and Fawley

$$\hbar\omega \cdot \lambda = hc = 1239.842 \text{ eV nm}$$

linac tunnel

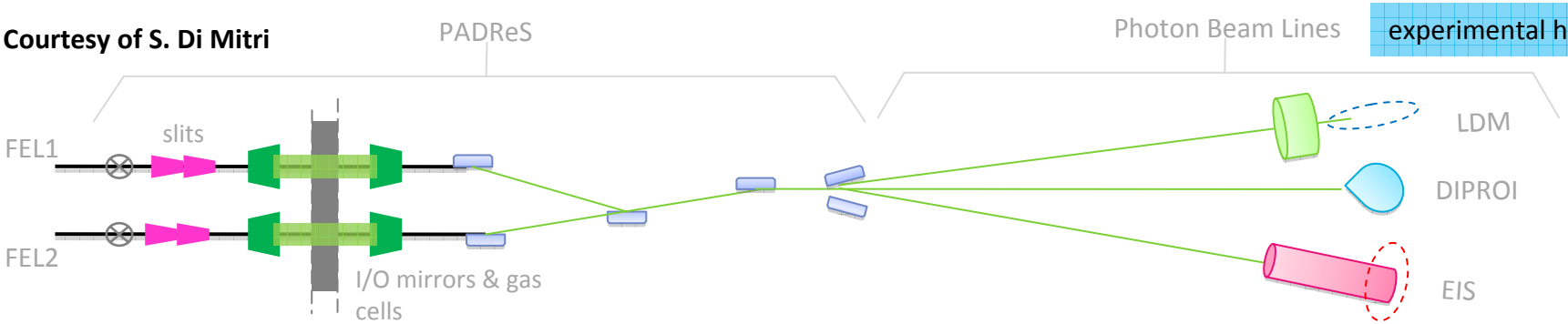


undulator hall



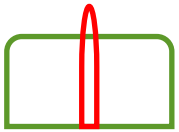
experimental hall

Slide Courtesy of S. Di Mitri

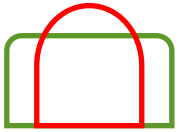


photon dynamics

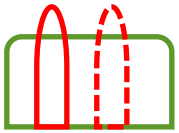
SASE →



Seeded FEL
Short pulse →



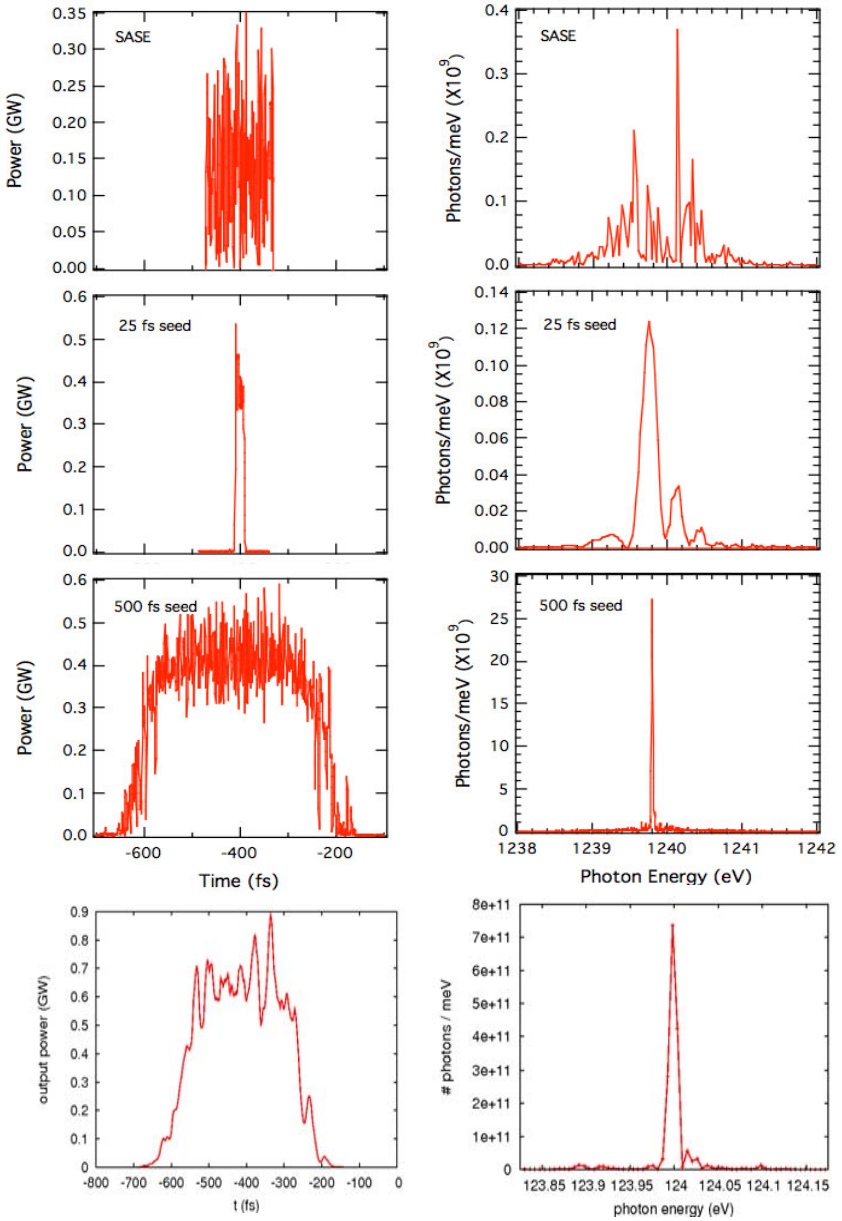
Seeded FEL
Long pulse →



Seeded FEL
Fresh bunch →

10^{13} photons at 10 nm
5 meV bandwidth (1.5xFTL)

Slide Courtesy of S. Di Mitri



FERMI@Elettra Performance

Wavelength Range

- 100 nm to 4 nm (Fundamental)

Pulse Duration

- 100 fs to 20 fs

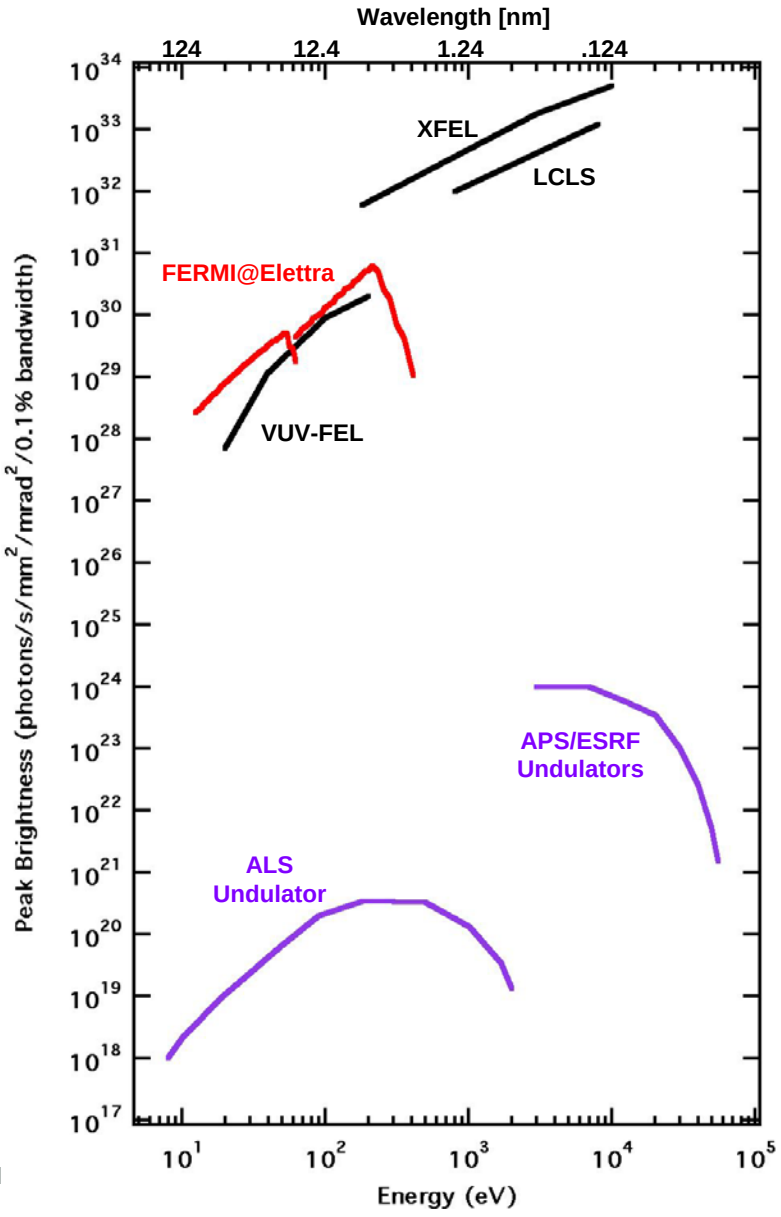
Polarization

- Fully Variable

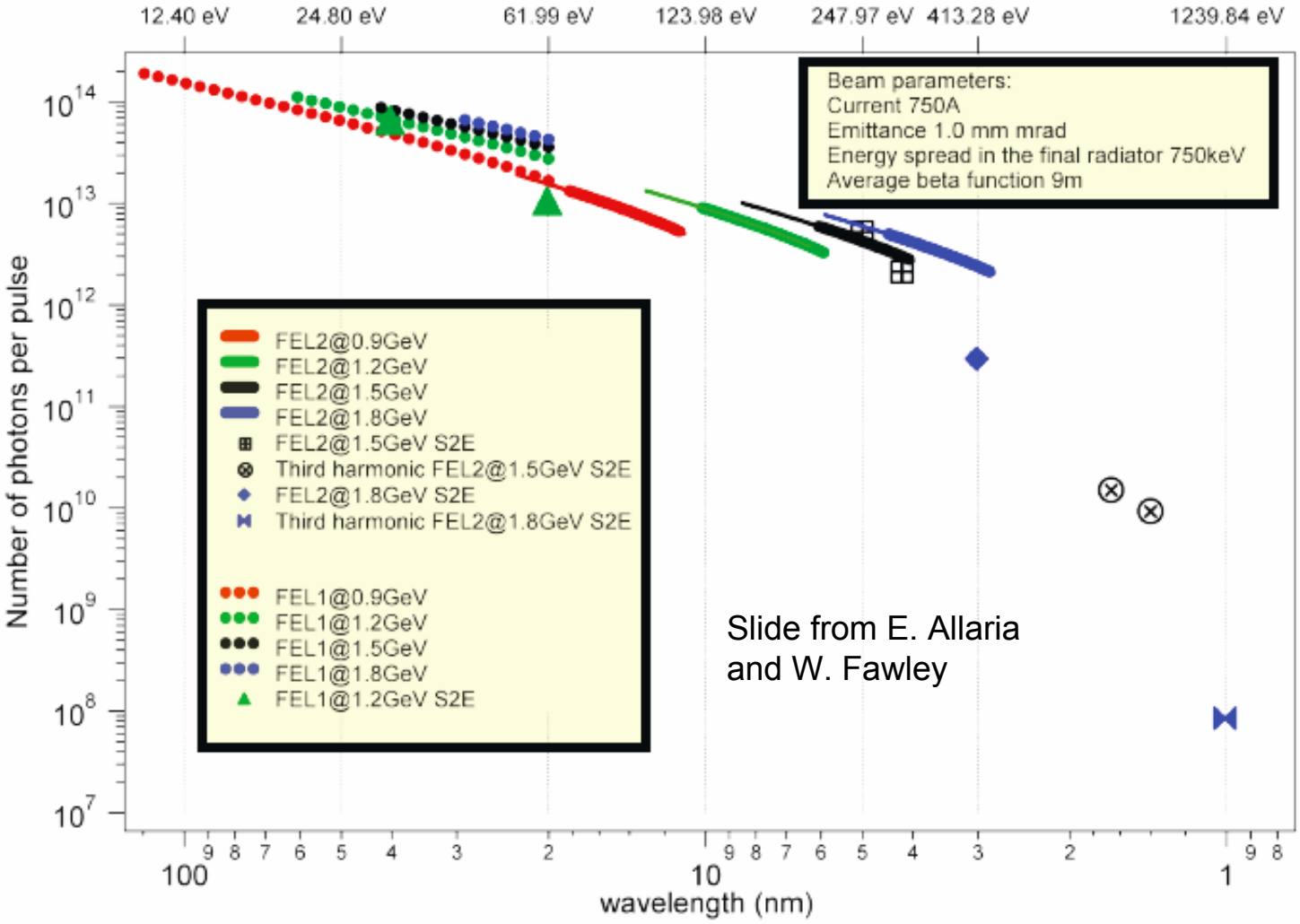
Seeded Operation

- Strong longitudinal and full transverse coherence

Parameter	FEL-1	FEL-2
HGHG Stages	1	2 (fresh bunch in 2nd stage)
Fundamental Wavelength range [nm]	100 to 20	20 to 4 (1.3 at 3rd harm.)
Output pulse length (rms) [fs]	< 100	20 – 100 (< 10 future goal)
Bandwidth (rms) [meV]	17 (at 40 nm)	100 (at 4.2 nm)
Polarization	Fully Variable	Fully Variable
Repetition rate [Hz]	50	50
Peak power [GW]	1 to >5	0.5 to 2
Harmonic peak power (% of fundamental)	~2	~0.2 (at 4.2 nm)
Photons per pulse	10^{14} (at 40 nm)	$2x10^{12}$ (at 4.2 nm)
Pulse-to-pulse stability	² 30 %	~40 %
Pointing stability [μrad]	< 20	< 20
Virtual waist size [μm]	250 (at 40 nm)	120
Divergence (rms, intensity) [μrad]	50 (at 40 nm)	10 (at 4.2 nm)



FEL Operational Range

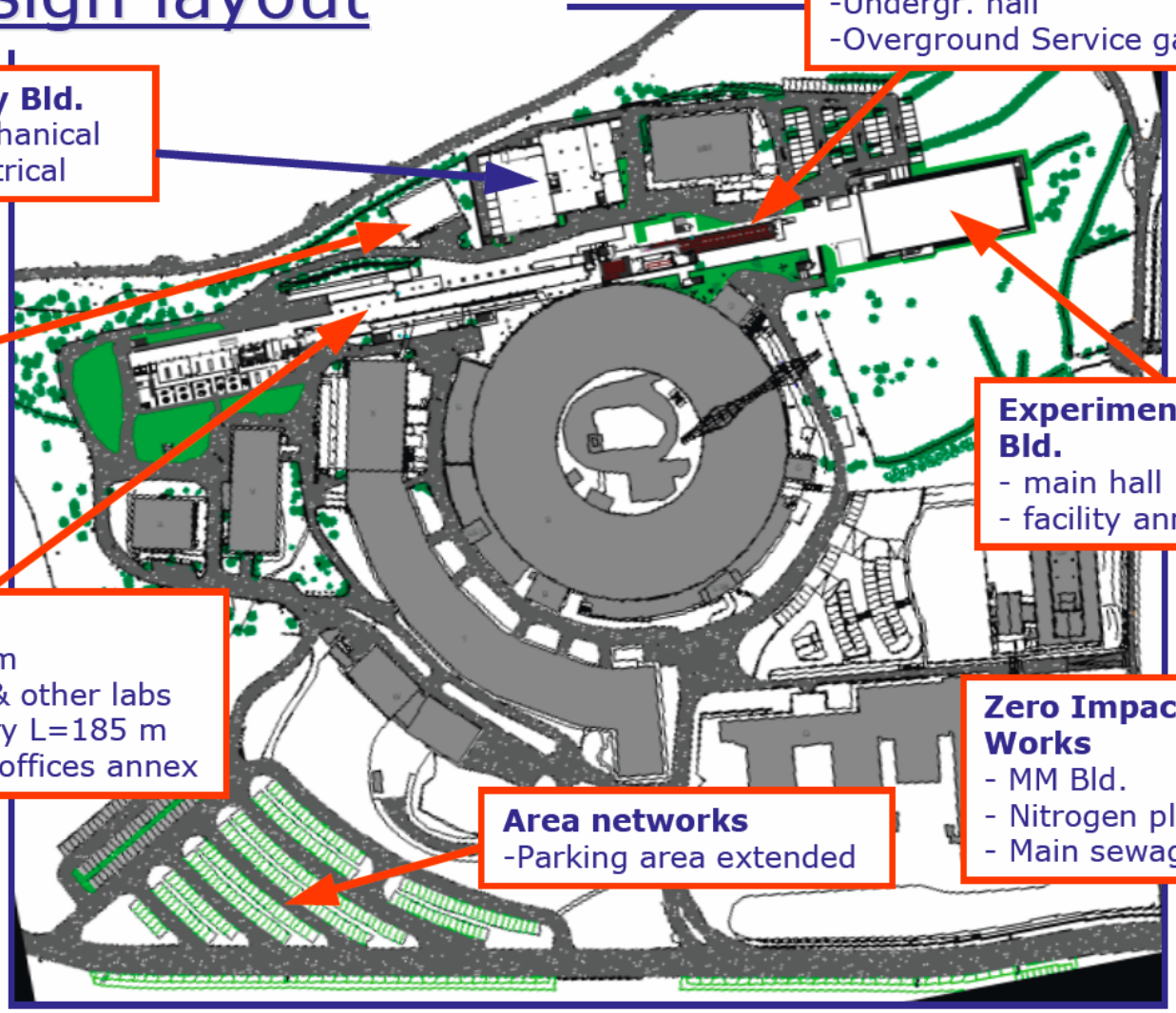


Slide from E. Allaria and W. Fawley

Lines predicted using M.Xie formulae for expected FERMI parameters assuming 40fs pulse length
Points Ginger and Genesis simulations for S2E files

Civil Engineering Scope

General design layout



Undulator Bld.
-Undergr. hall
-Overground Service gallery

Utility Bld.
- mechanical
- electrical

Prefab. Bld.
- labs
- offices

Experimental Bld.
- main hall
- facility annex

Linac Bld.
- extended tunnel L=191m
- undergr. area for laser & other labs
- extended klystron gallery L=185 m
- control room, labs. and offices annex

Zero Impact Works
- MM Bld.
- Nitrogen plant
- Main sewage plant

Area networks
-Parking area extended

FERMI@Elettra Civil Construction

Civil Construction

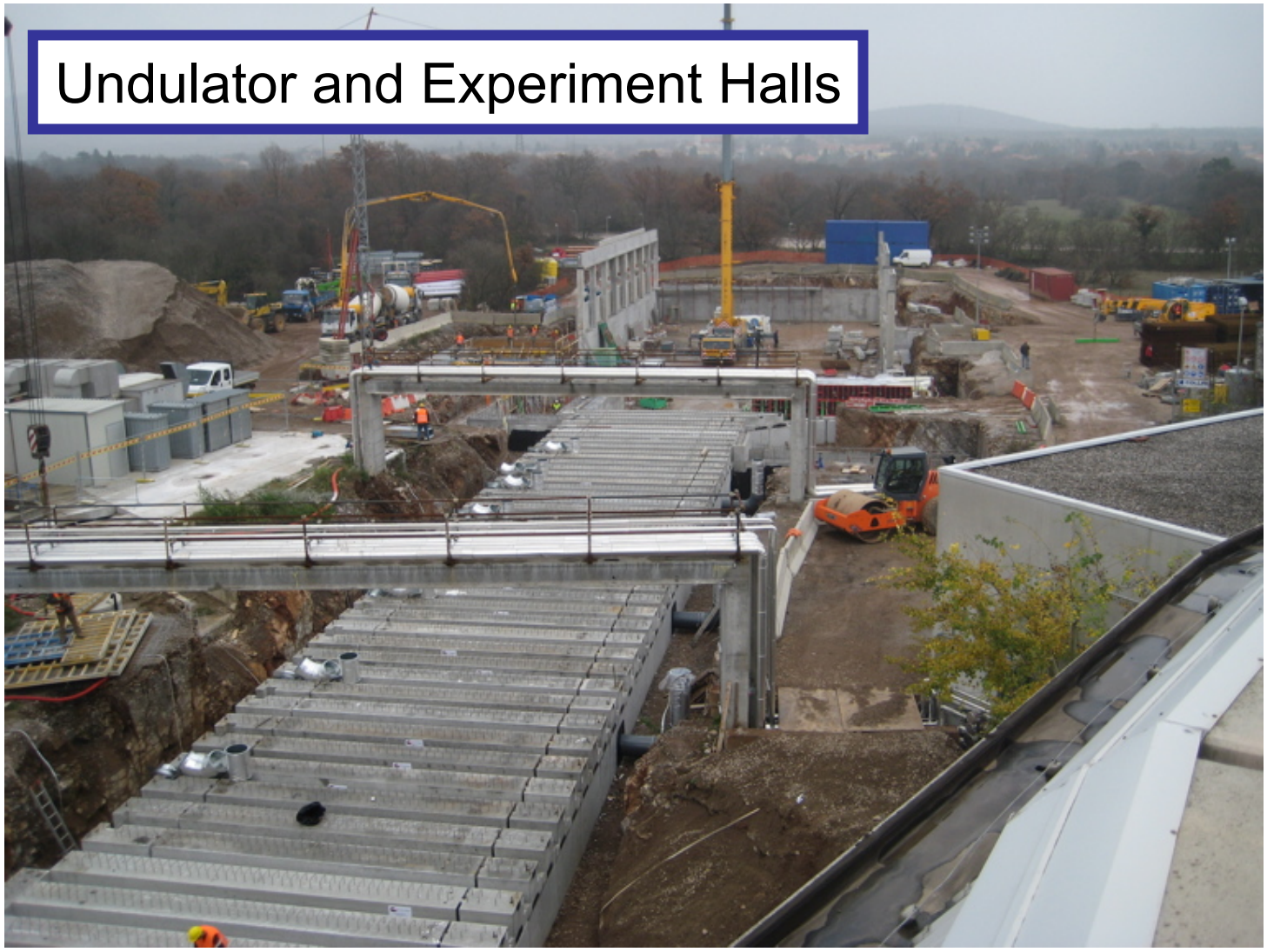
- Linac Building Extension completed
- "Main FERMI" construction began 25 March 2009
  - Completion Scheduled by Summer 2010

Construction as Last ESLS 2008

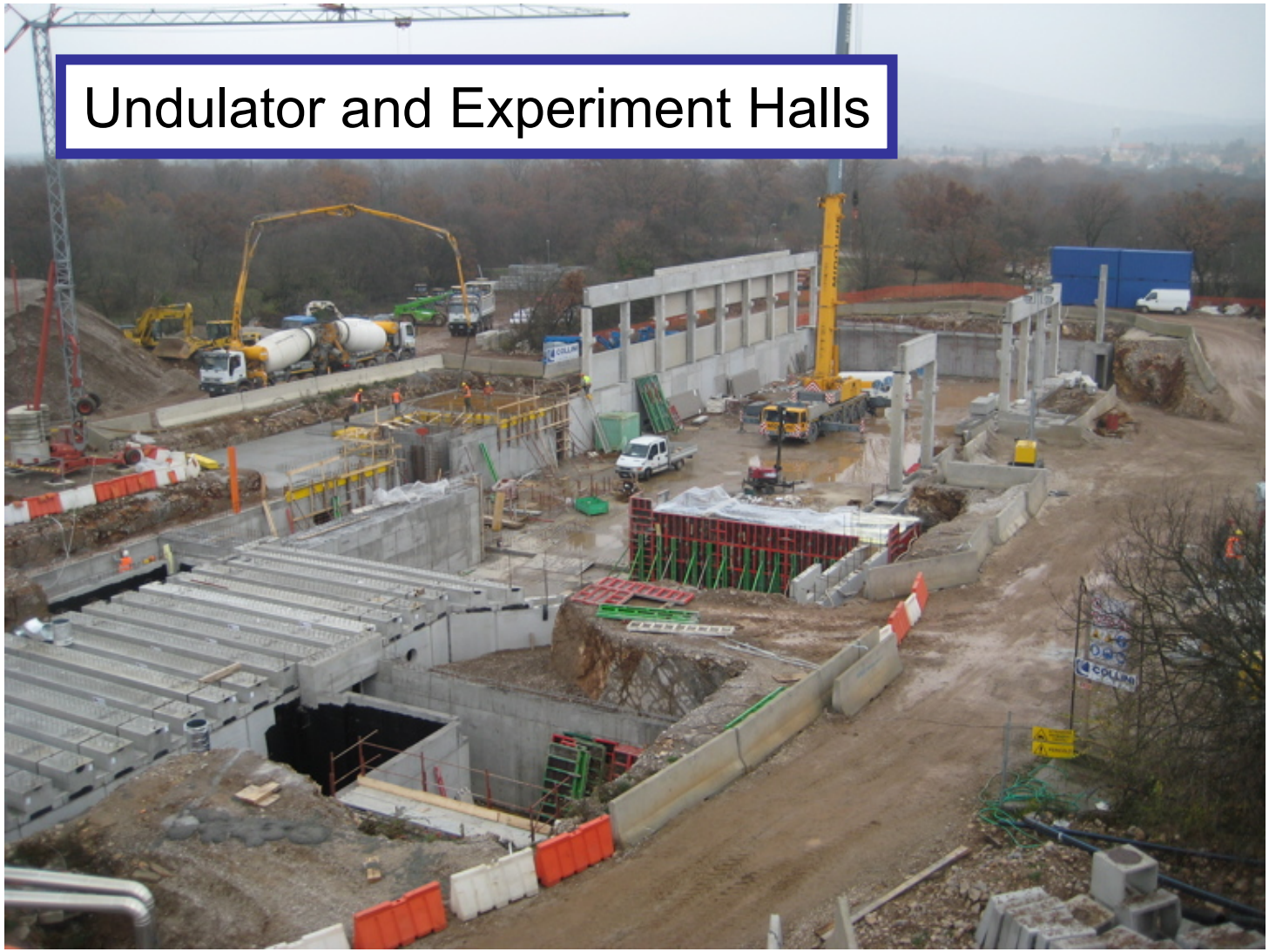
New Lab/Office/Control Room Building

Construction as of 2 days ago

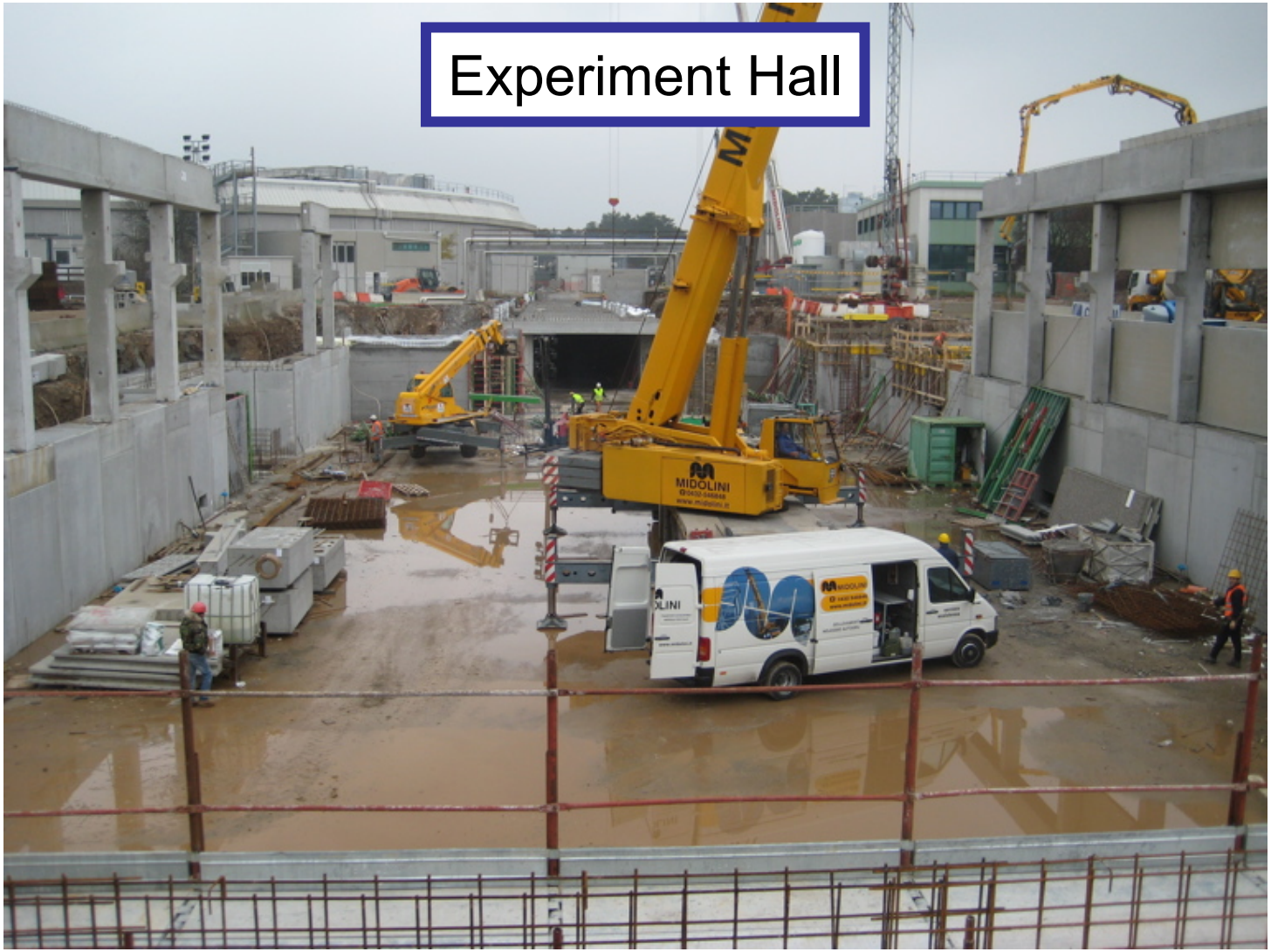
Construction as of 2 days ago



Construction as of 2 days ago



Construction as of 2 days ago

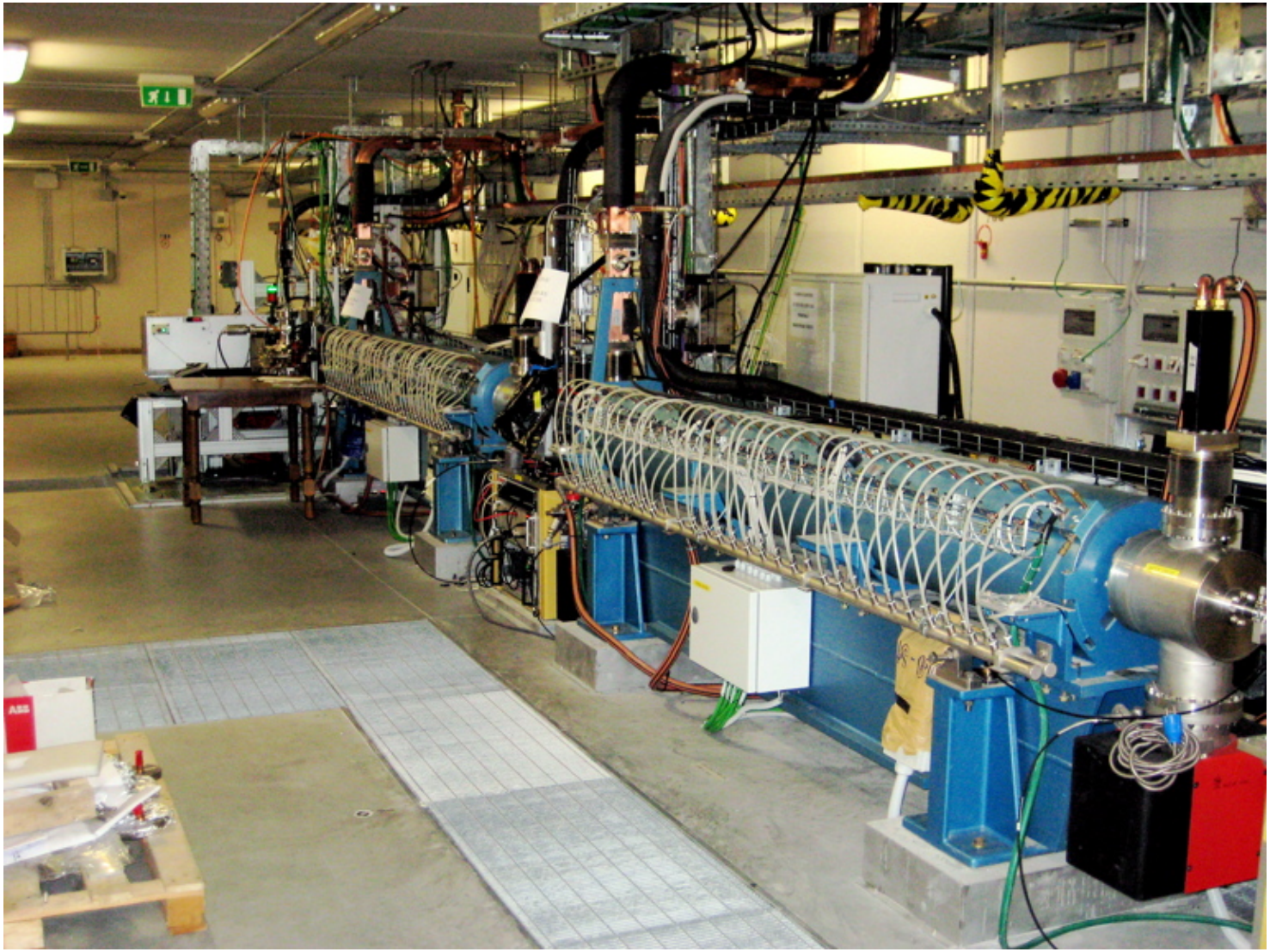


Construction as of 2 days ago

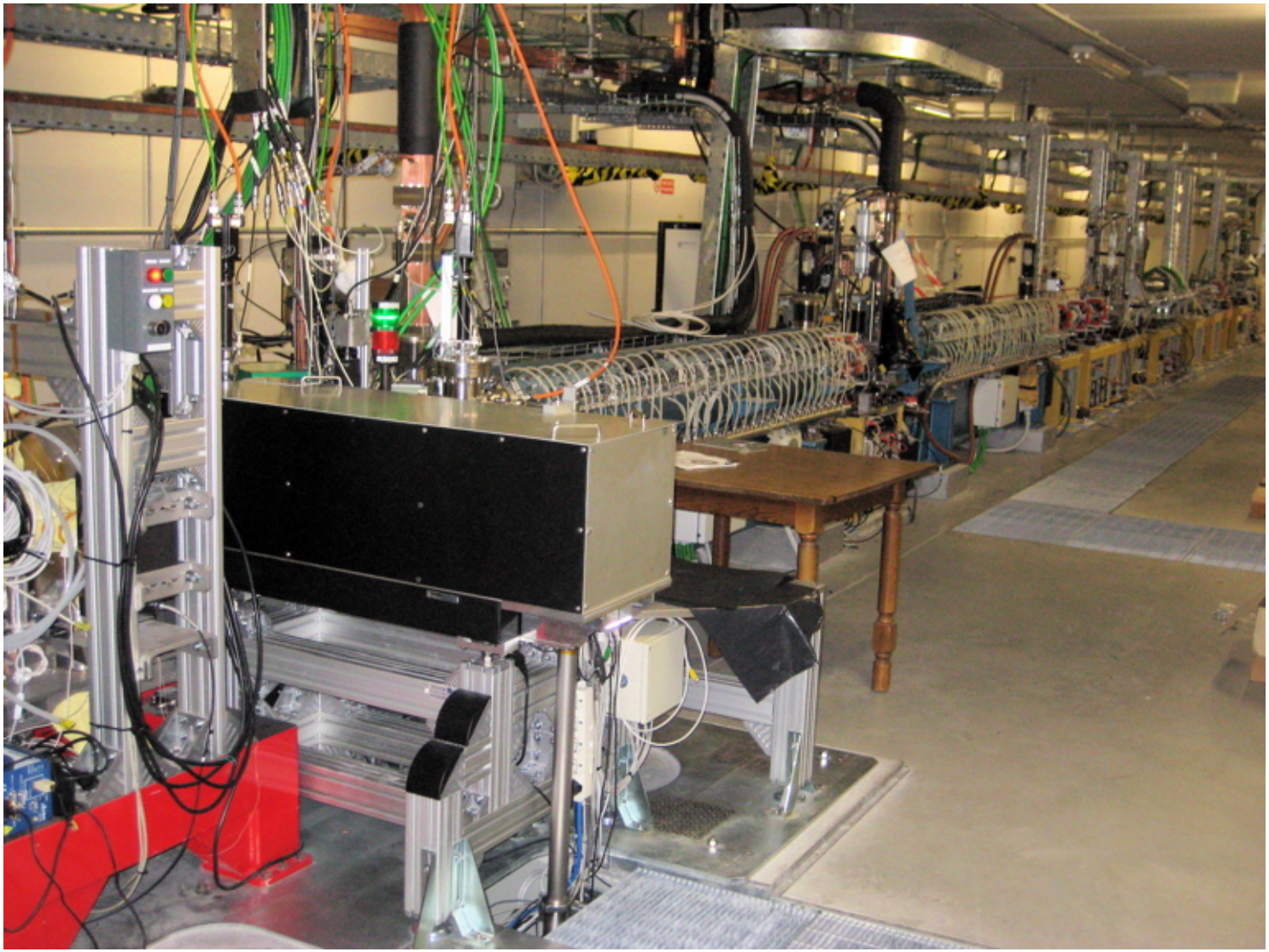
Construction Completion Dates

- Undulator and Experiment Hall Roofs
  - 30 December 2009
- Co-Occupancy Undulator Hall
  - 3 February 2010
- Co-Occupancy Service Gallery
  - 13 March 2010
- Co-Occupancy Experimental Hall
  - 18 April 2010
- Electrical/Mechanical Plants Fully Commissioned
  - 30 May 2010
- Beneficial Occupancy All Buildings and Services
  - 30 June 2010

Injector (Looking upstream)



Injector (Looking downstream through laser heater region)

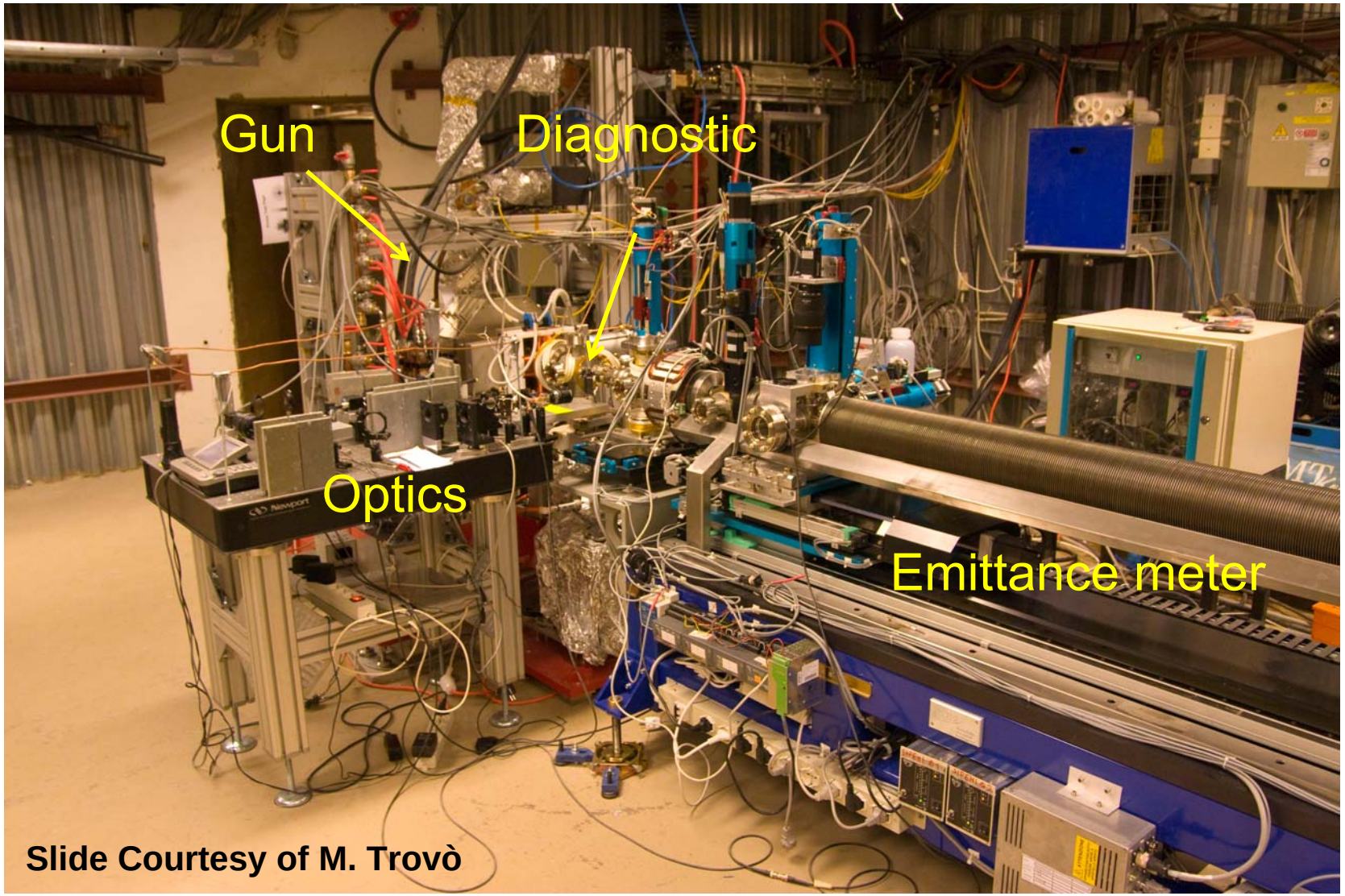


CERN Structures in Place

BTW and SLED Structures in Place

Control Room During Commissioning

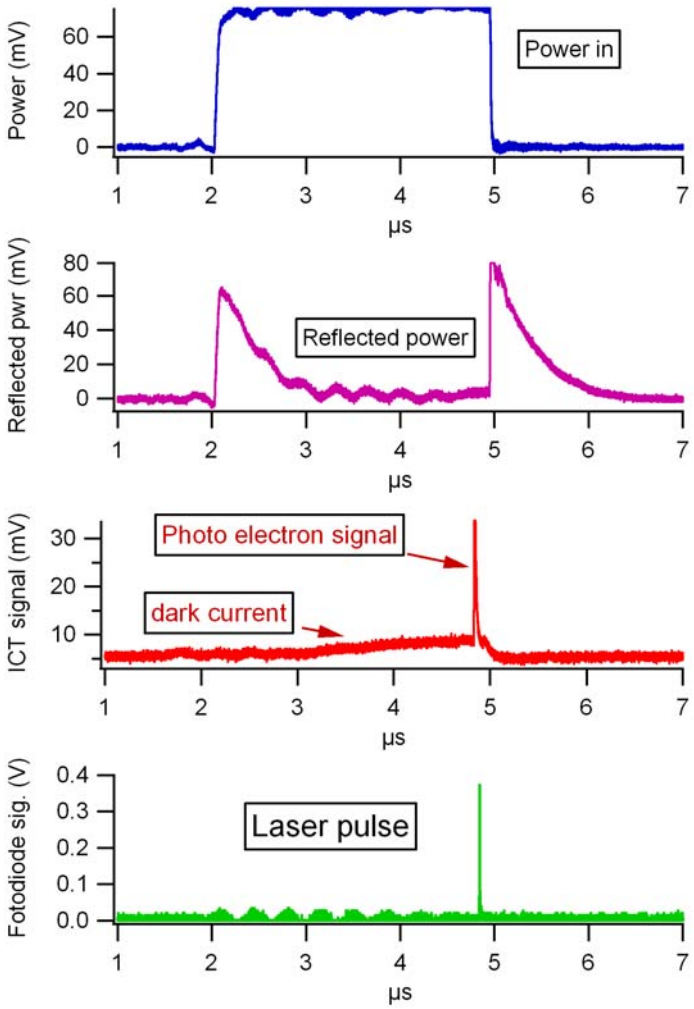
MAX-lab cave 2008/2009



PC Gun beam

Photo electron extraction:

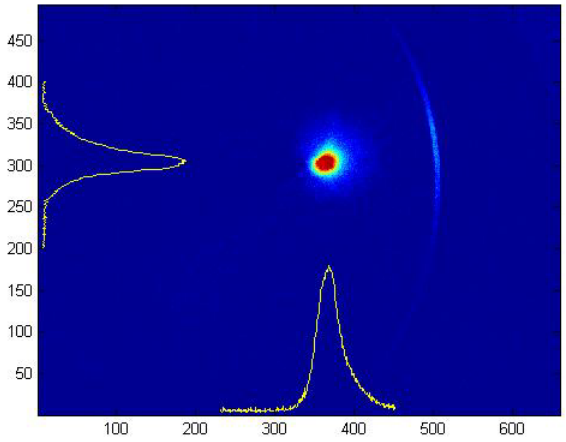
Slide Courtesy of M. Trovò



28 May 08:

First photoelectron beam extraction!

180 pC by 50 μJ



Electron beam on the YAG screen with 80 MV/m RF gradient and $I_{solenoid}$ = 110 A (the horizontal and vertical scales represent the number of the CCD pixel).

Experience at MAX-lab

	ST	INFN (*)
Number of work trips	10	4
Presence at MAX-lab	76 dd	17 dd
Personnel at MAX-lab	20 p.	10 p.
number of man days	297 dd	77 dd
Number of Gun runs - shifts	5 -36	2 - 10

(*) *figures estimated from the logbook.*

Slide Courtesy of M. Trovò

Trip date	days	Activity
12 Oct. '07	2	Collaboration agreement definition
24 Nov. '07	2	Technical meeting and tunnel inspection
14 March '08	9	Supports placement and control station installation
27 March '08	7	Gun system installation
21 May '08	12	Cavity conditioning and first beam
30 June '08	15	Beam measurements and E-meter installation
26 Sept. '08	10	E-meter measurements
15 Dec. '08	5	Beam characterization and test of new Toroid acq. system
11 Feb. '09	8	Cerenkov radiator installation and test
5 Apr. '09	6	Disassembling and packaging.

Early Performance of Drive Laser and PC Gun Beam

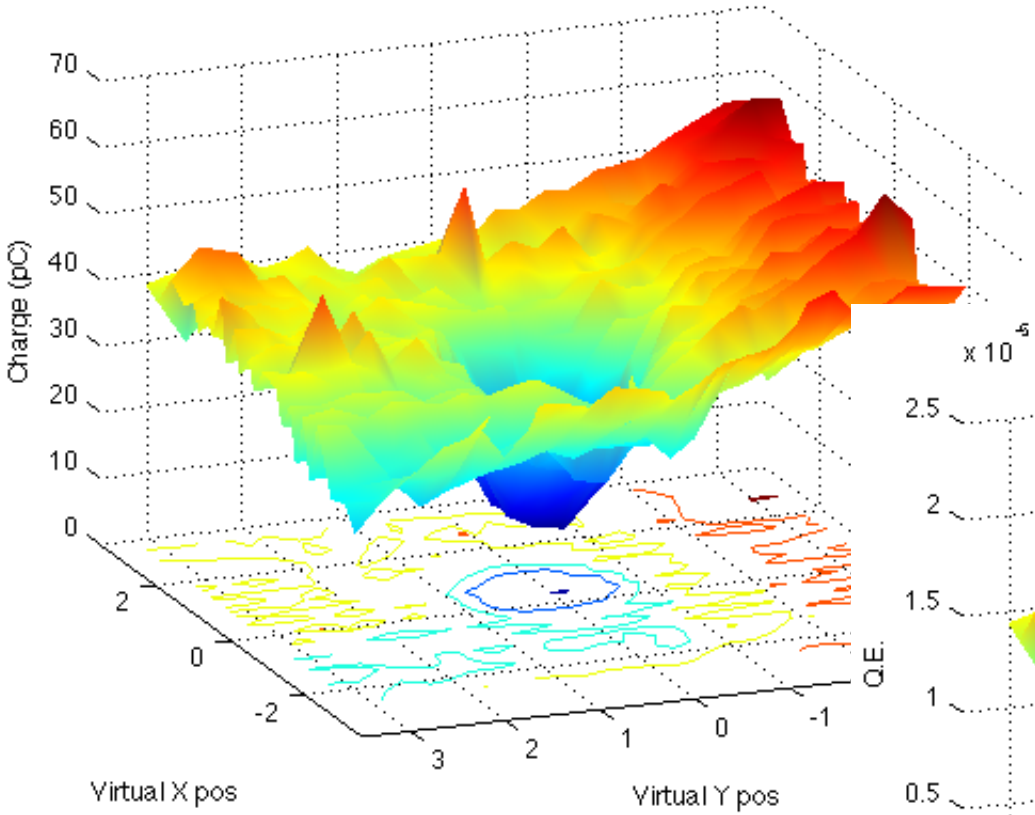
QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

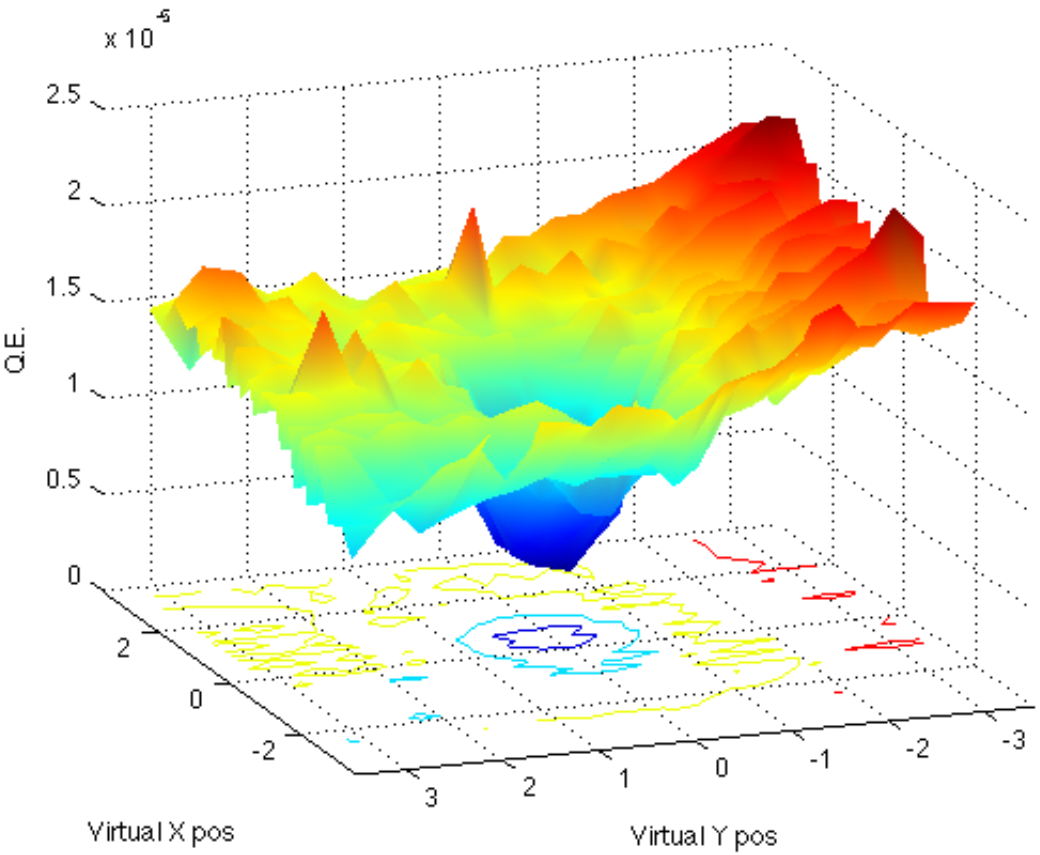
Early Laser Virtual Cathode Measurement

Associated Electron beam Spot on Screen

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Cathode QE map



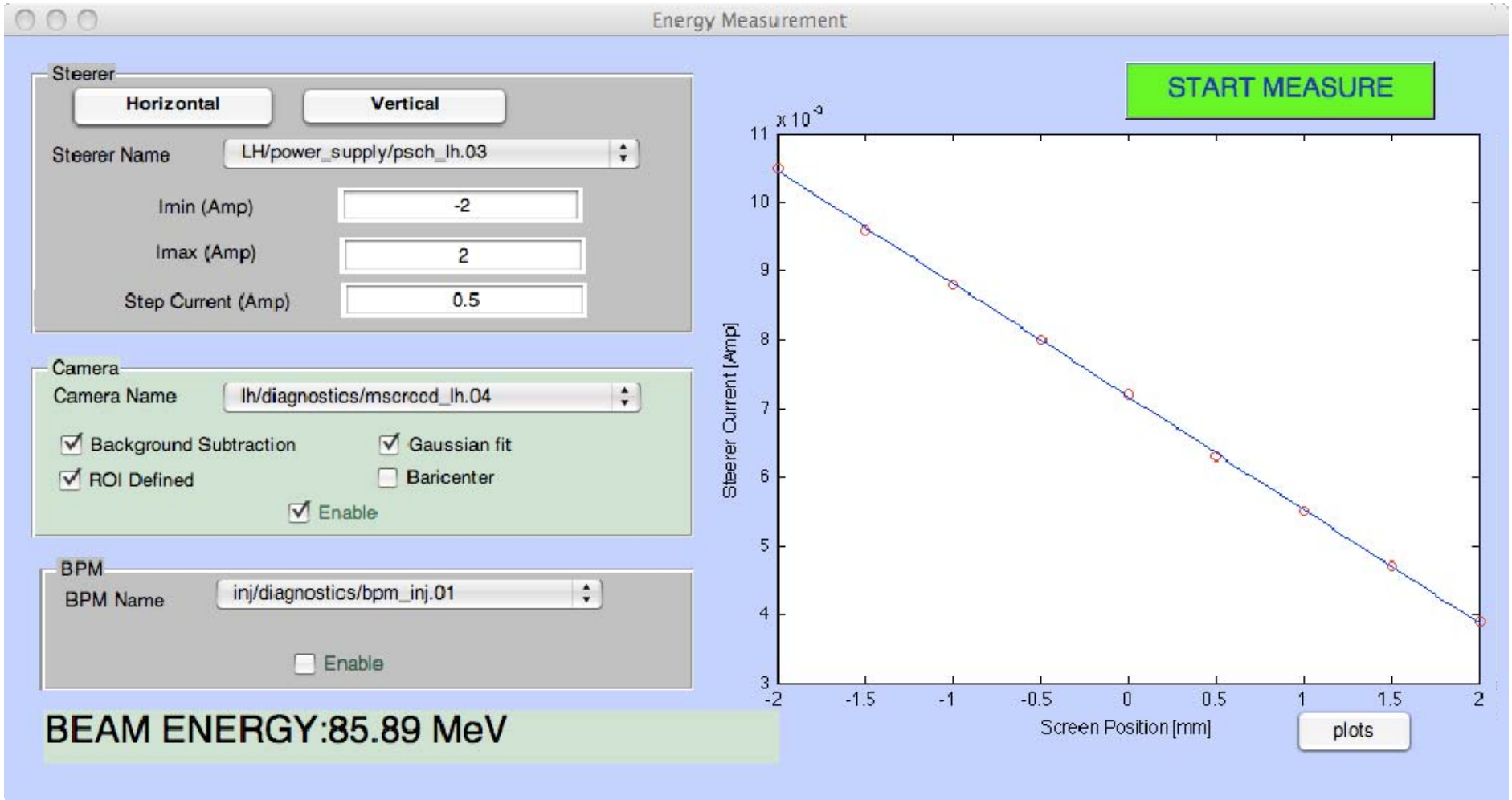


- *26 October 09, after 2 operation months*

Cathode surface sampled by a 200 μm laser spot. and about 10 μJ.

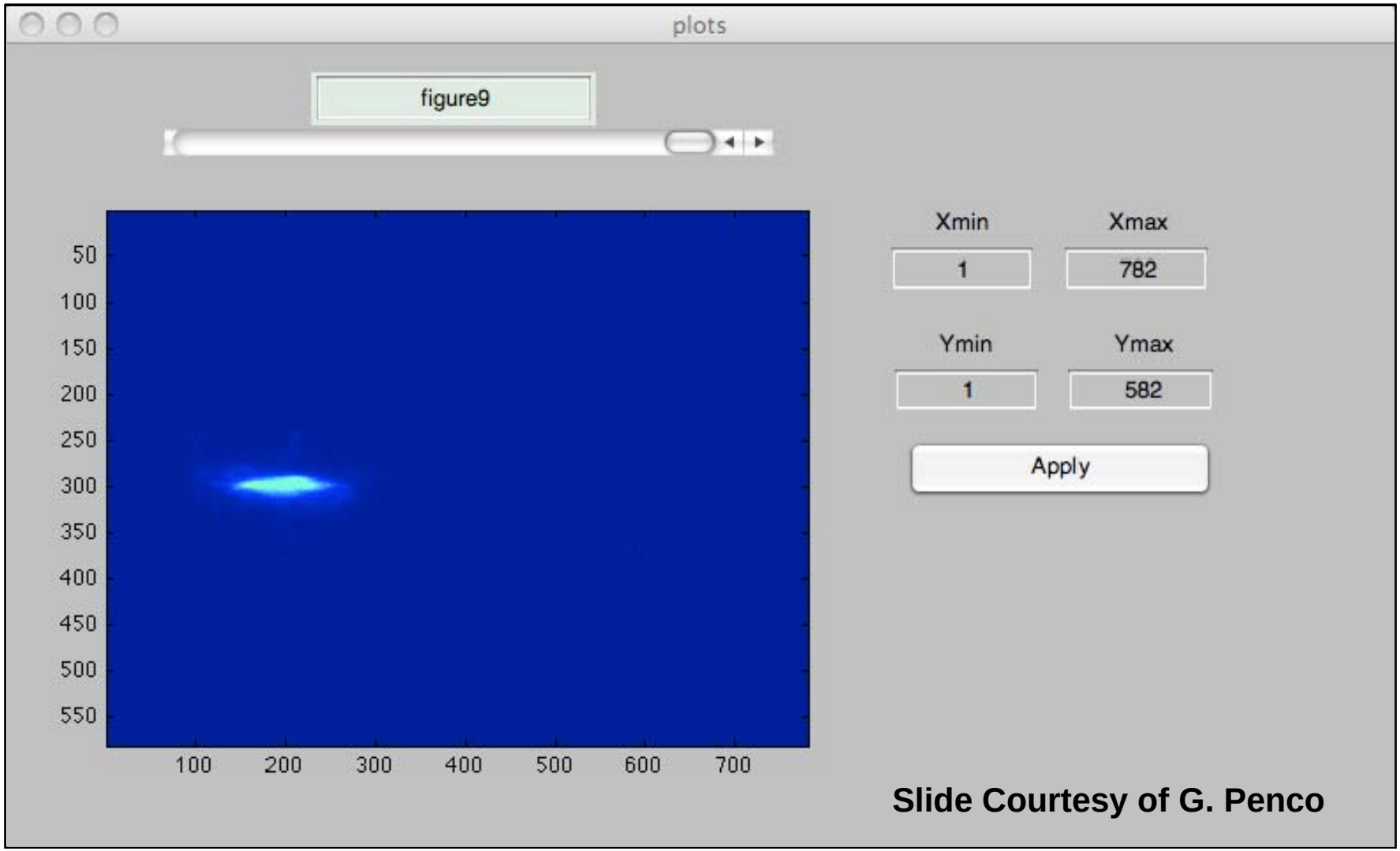
Slide Courtesy of M. Trovò

Energy measurement steerer method



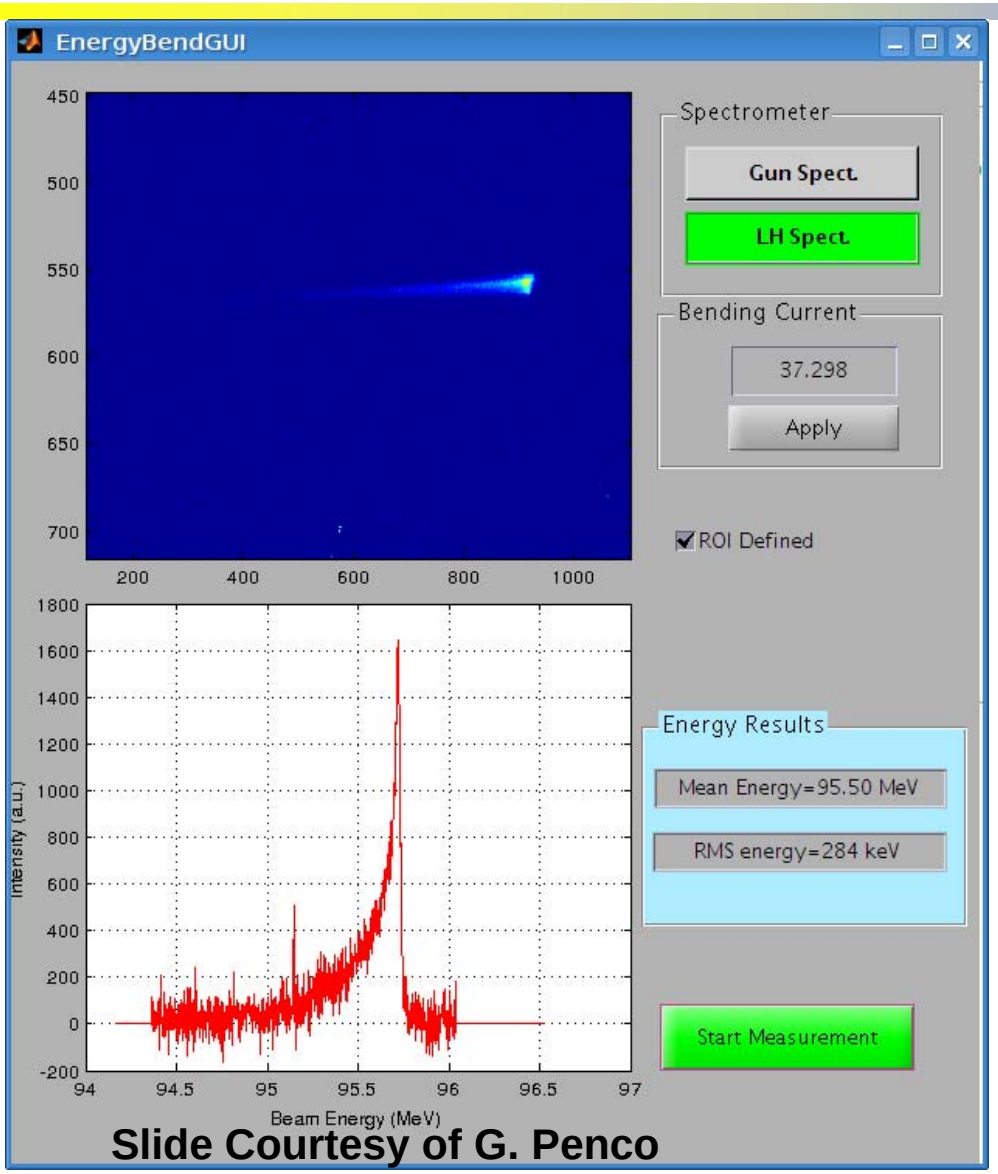
Slide Courtesy of G. Penco

Energy measurement steerer method



Slide Courtesy of G. Penco

Energy measurement Bending magnet



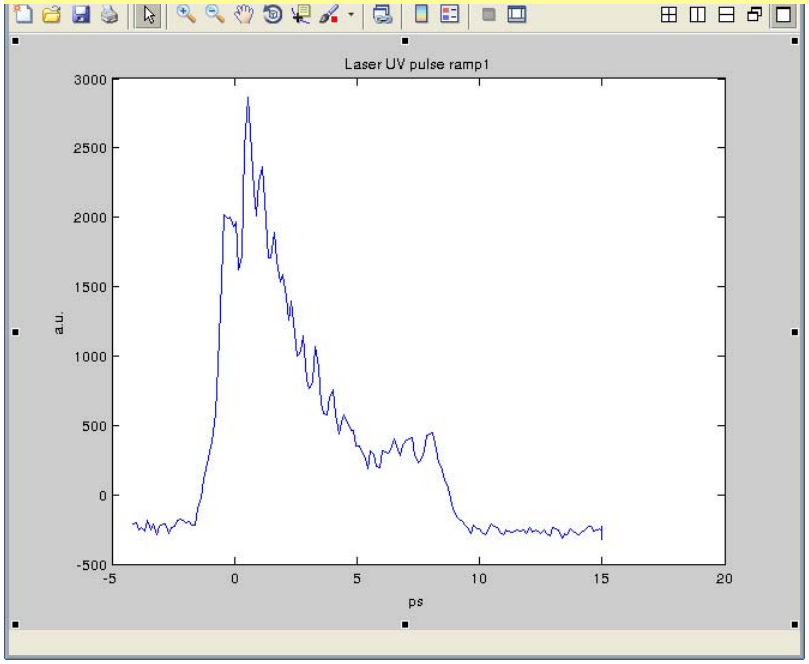
Slide Courtesy of G. Penco

QuickTime™ and a decompressor are needed to see this picture.

Energy jitter (short term) about 3keV (rms) @5MeV

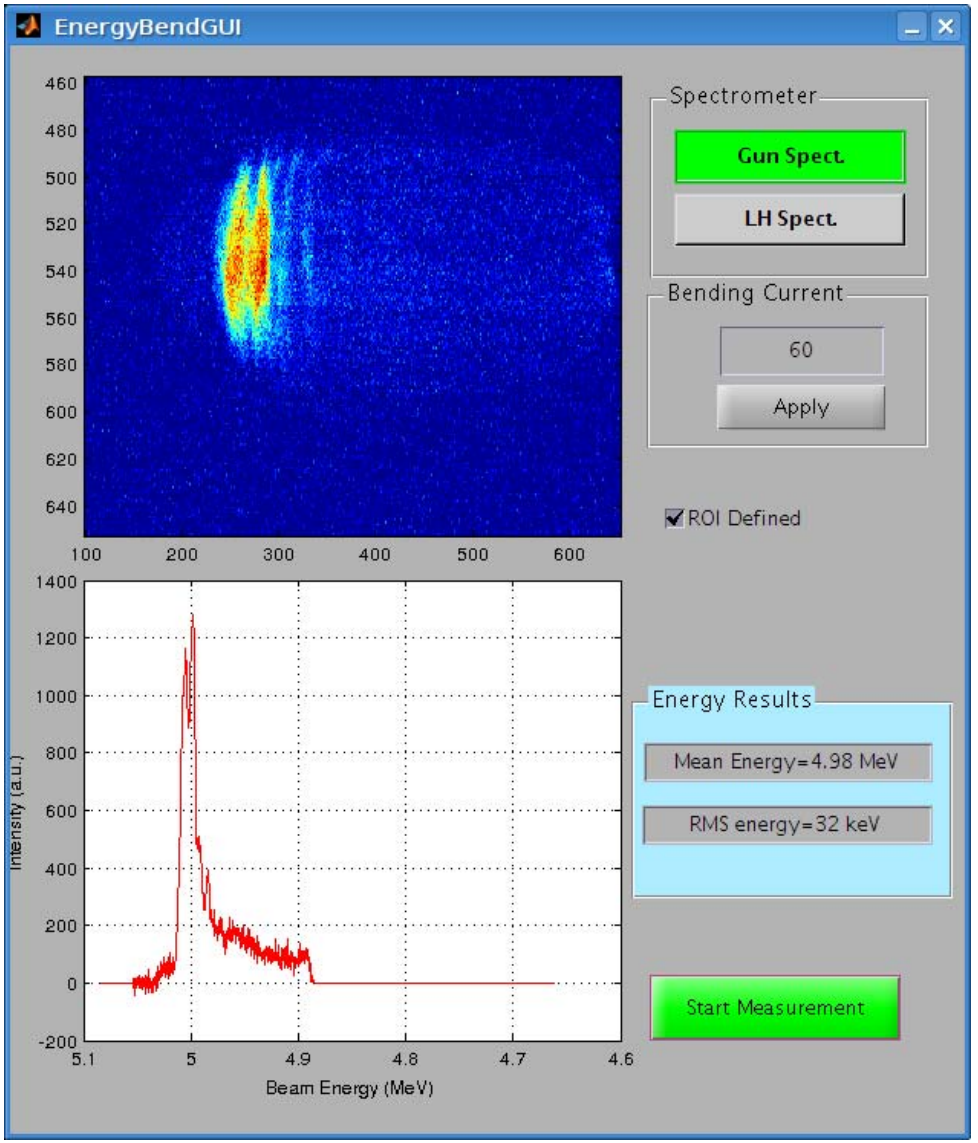
Longitudinal profile investigation (1/2)

First laser longitudinal ramp profile as measured with cross-correlator (head on the right):



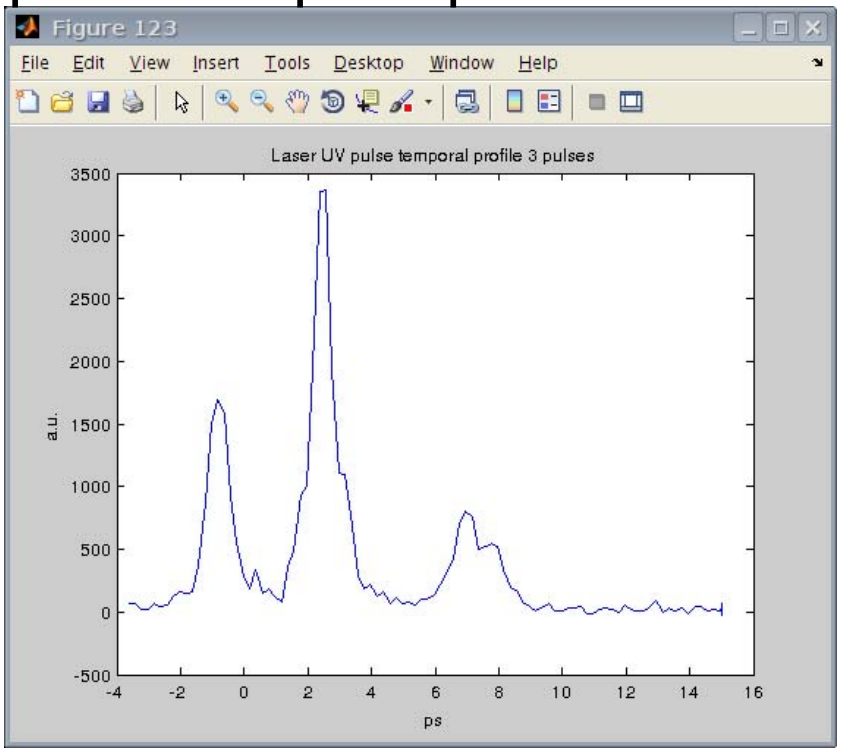
Setting the RF phase of the gun in order to have a linear correlation between time and energy, it is possible to investigate the longitudinal structures with the gun spectrometer

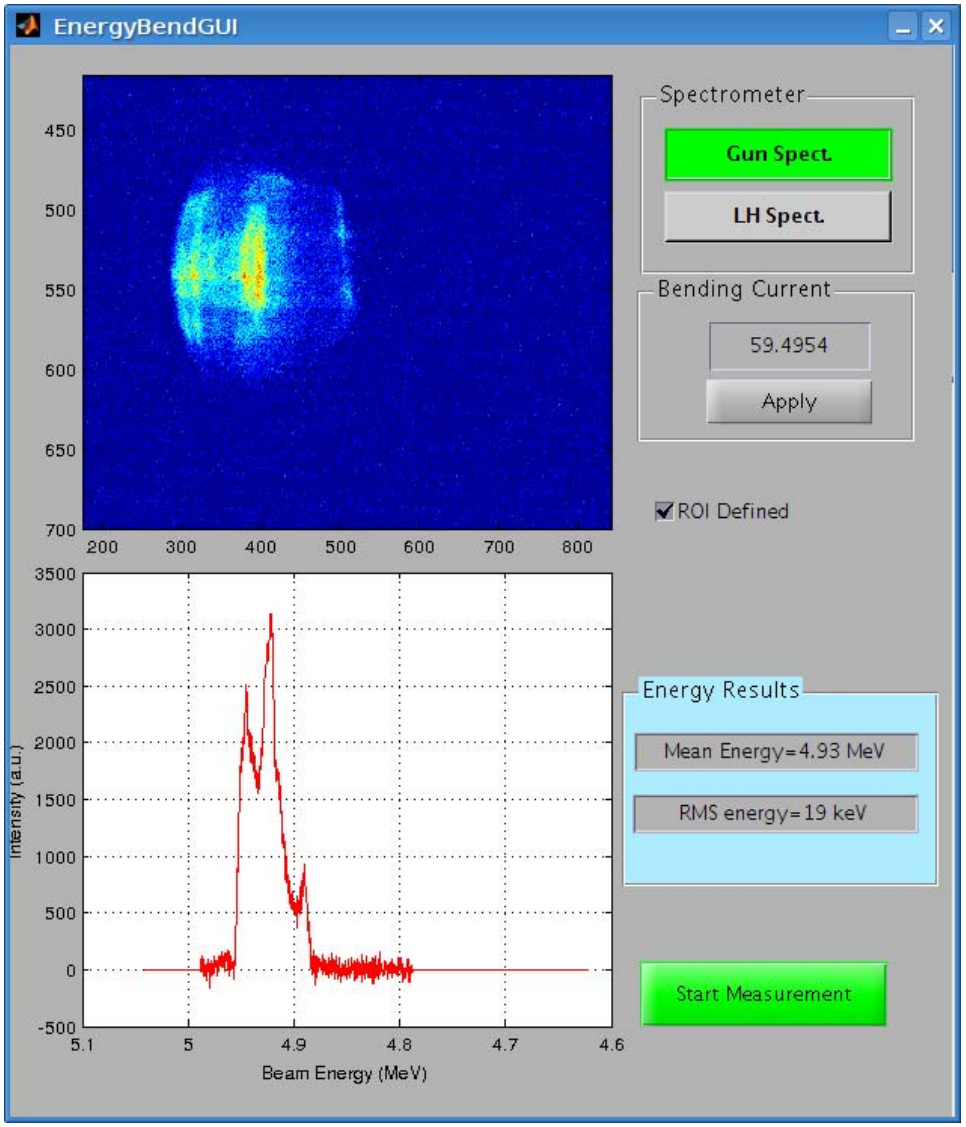
Slide Courtesy of G. Penco



Longitudinal profile investigation (2/2)

Exotic pulse shaping to prove the principle





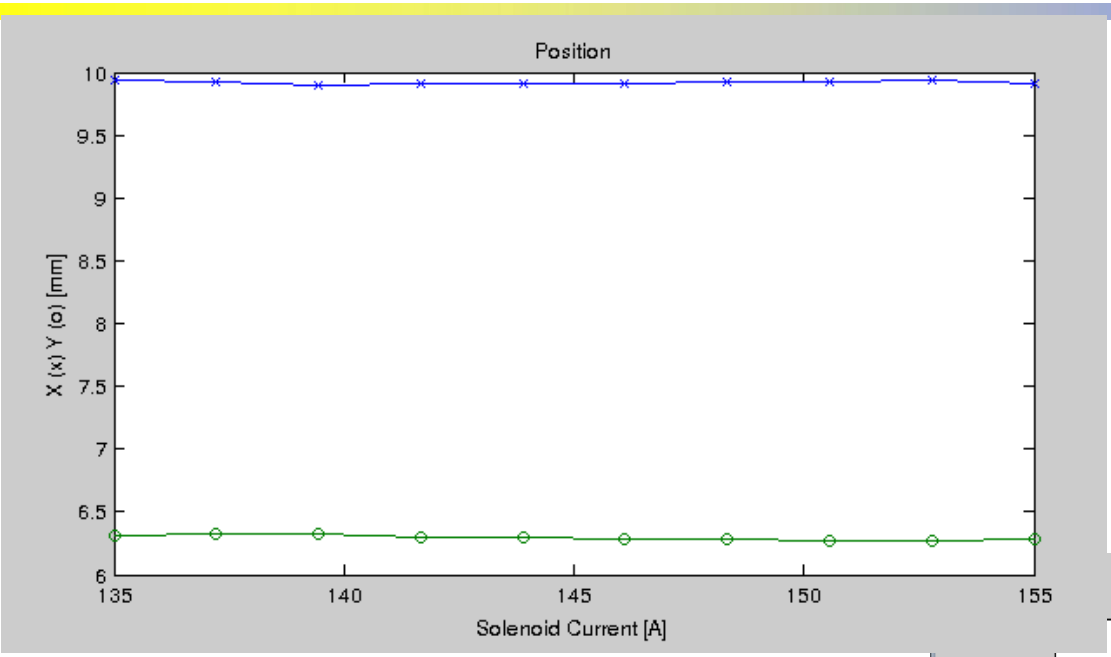
Slide Courtesy of G. Penco

Phase Scan

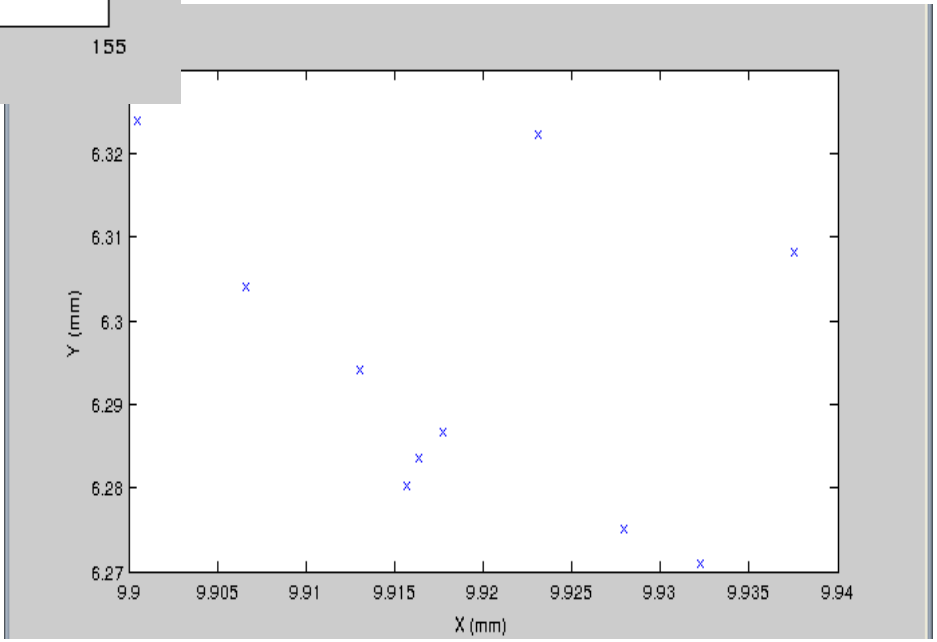
QuickTime™ and a
decompressor
are needed to see this picture.

Slide Courtesy of G. Penco

Gun solenoid allignment



Optimizing the laser pointing (monitoring on the virtual cathode) to minimize the bunch transversal drift when scanning the gun solenoid.



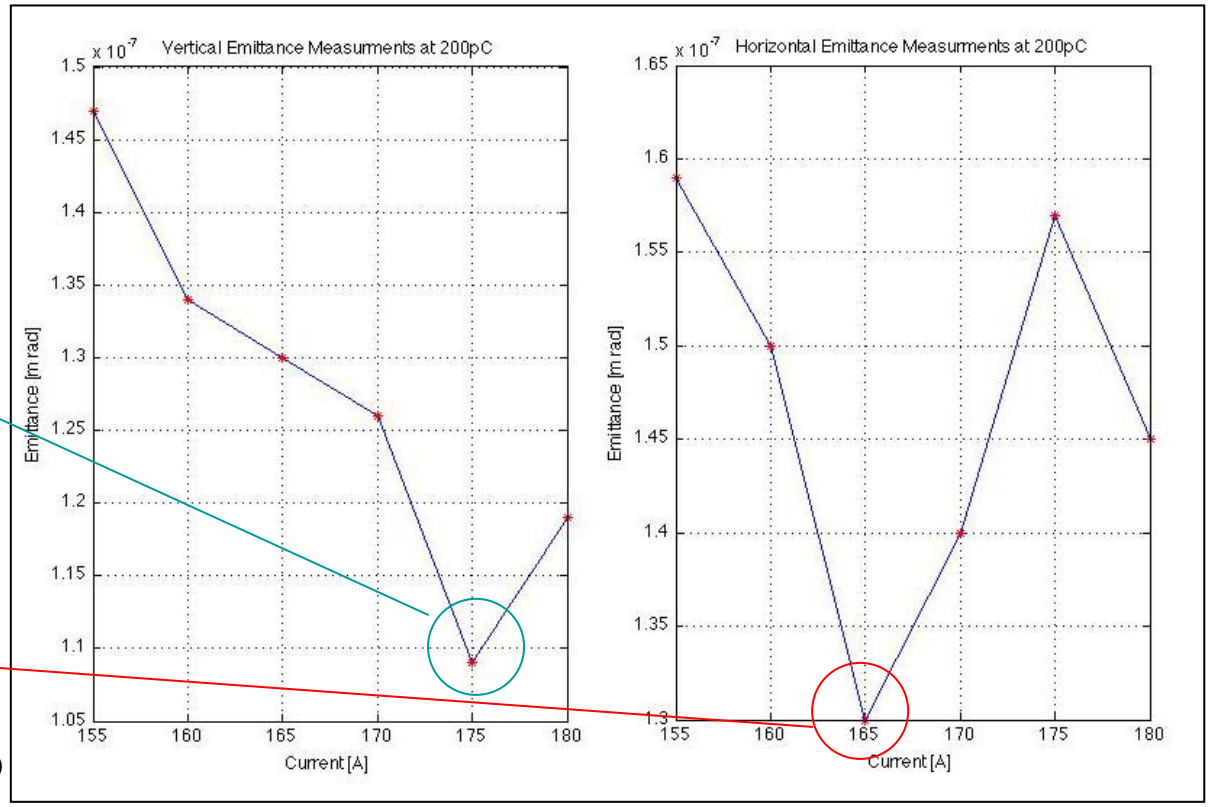
Less than 50μm drift in both planes

Slide Courtesy of G. Penco

e-meas. by slit method @ 5MeV

QuickTime™ and a
decompressor
are needed to see this picture.

Measurements of the emittance in X and Y varying the gun solenoid strength



Y-plane:

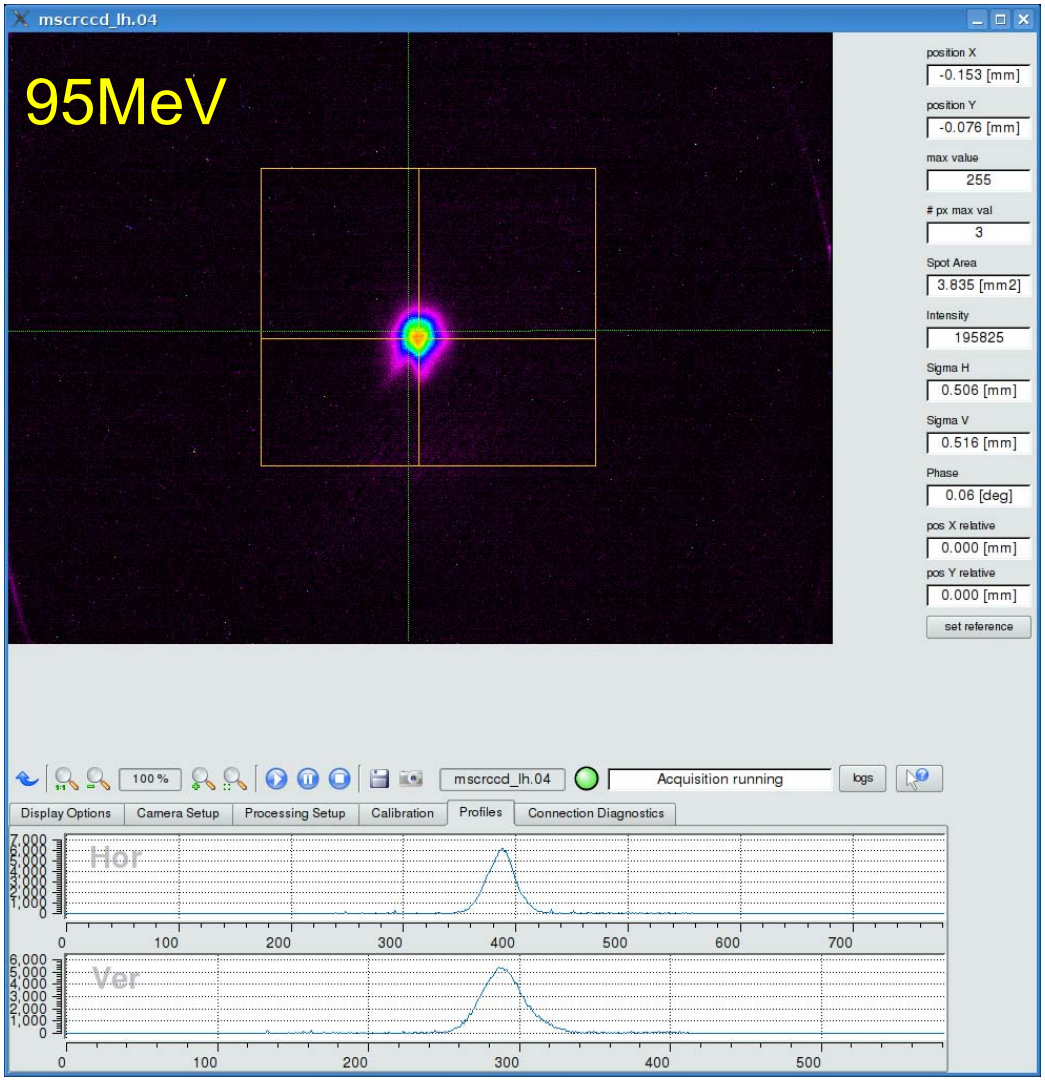
Min. value of 1.08μrad for 175Amps

X-plane:

Min. value of 1.3μrad for 165Amps

Slide Courtesy of G. Penco

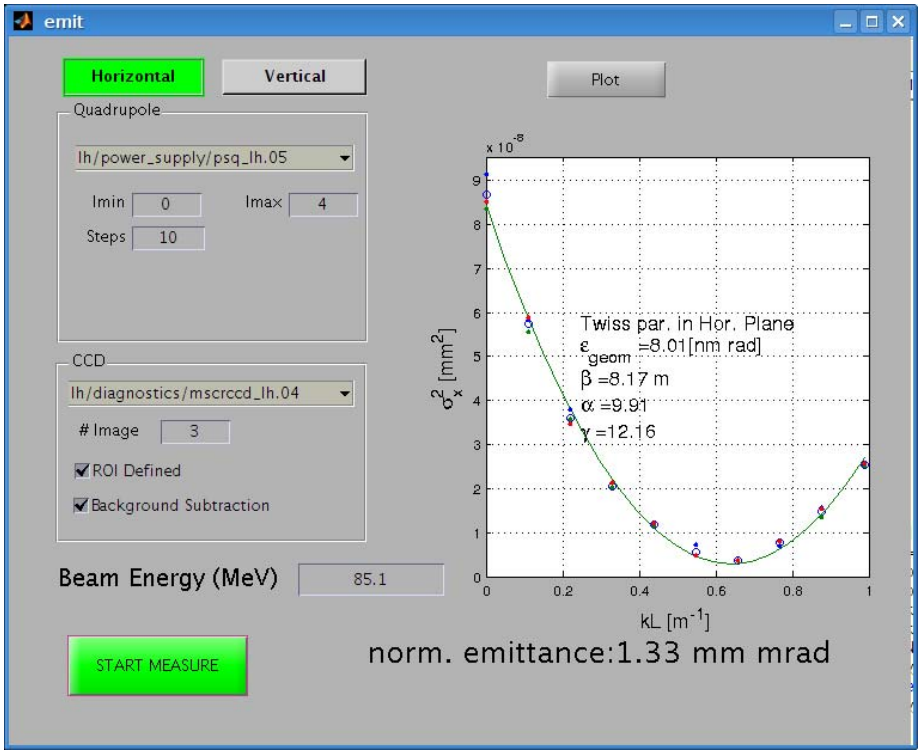
Beam transported up to the injector end

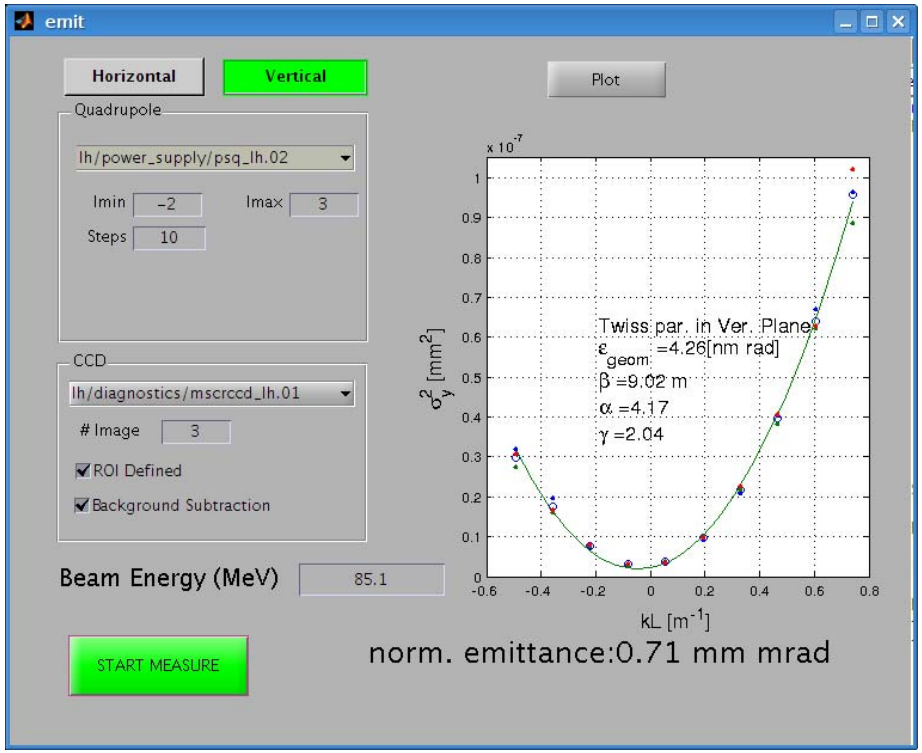


Slide Courtesy of G. Penco

Preliminary emit meas.

In this example: beam energy = 85 MeV, Q=100pC. (not optimized)



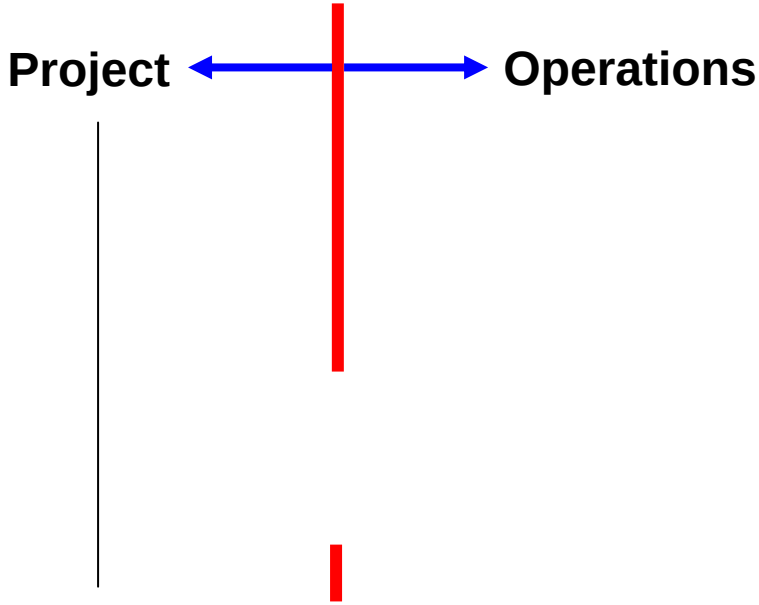


The goal is to match the optics to the nominal one:

- measured optics parameters,
- backtrack up to the L0 exit,
- readjust the 4 quads
- re-measure

Slide Courtesy of G. Penco

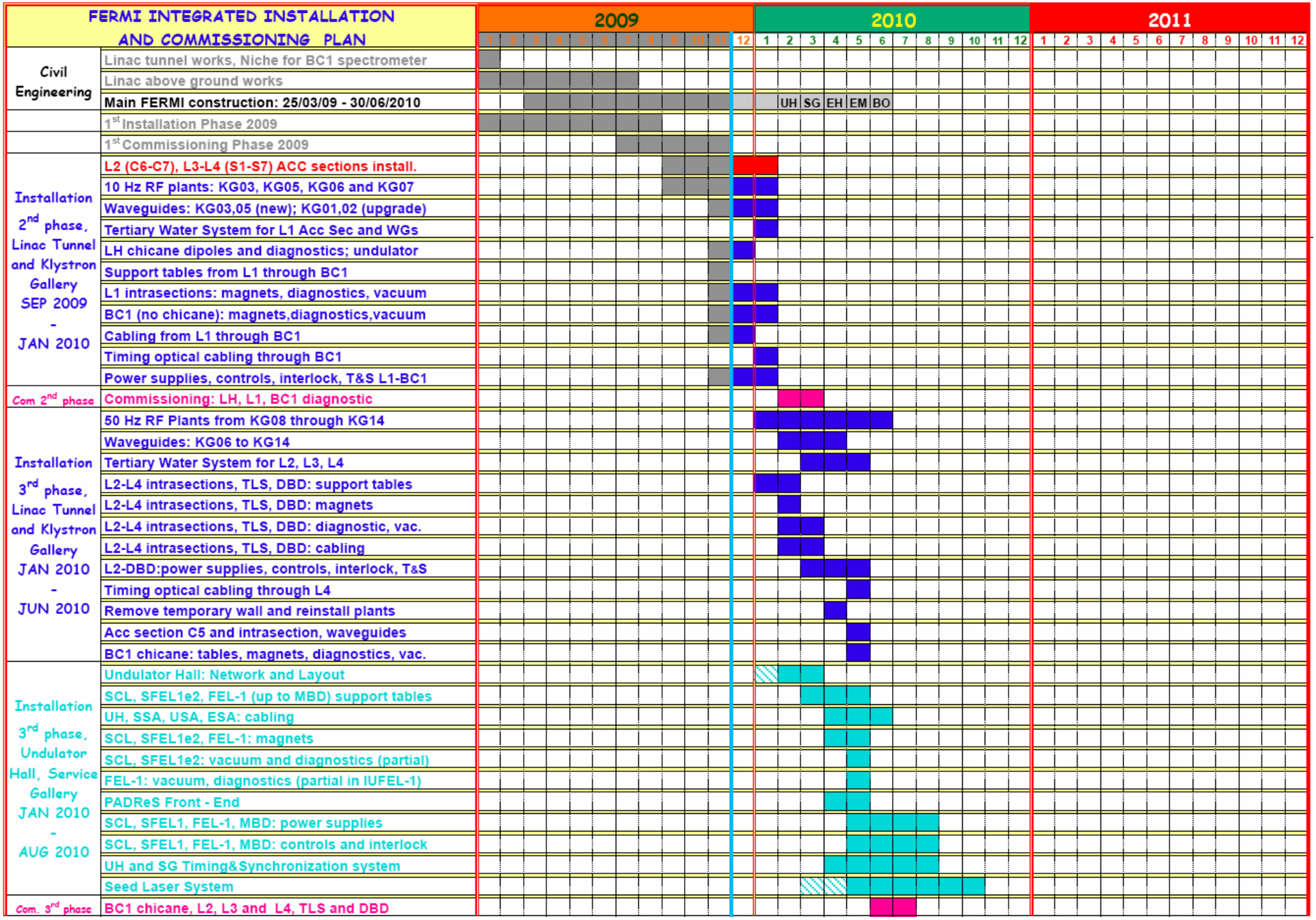
FERMI Global Schedule



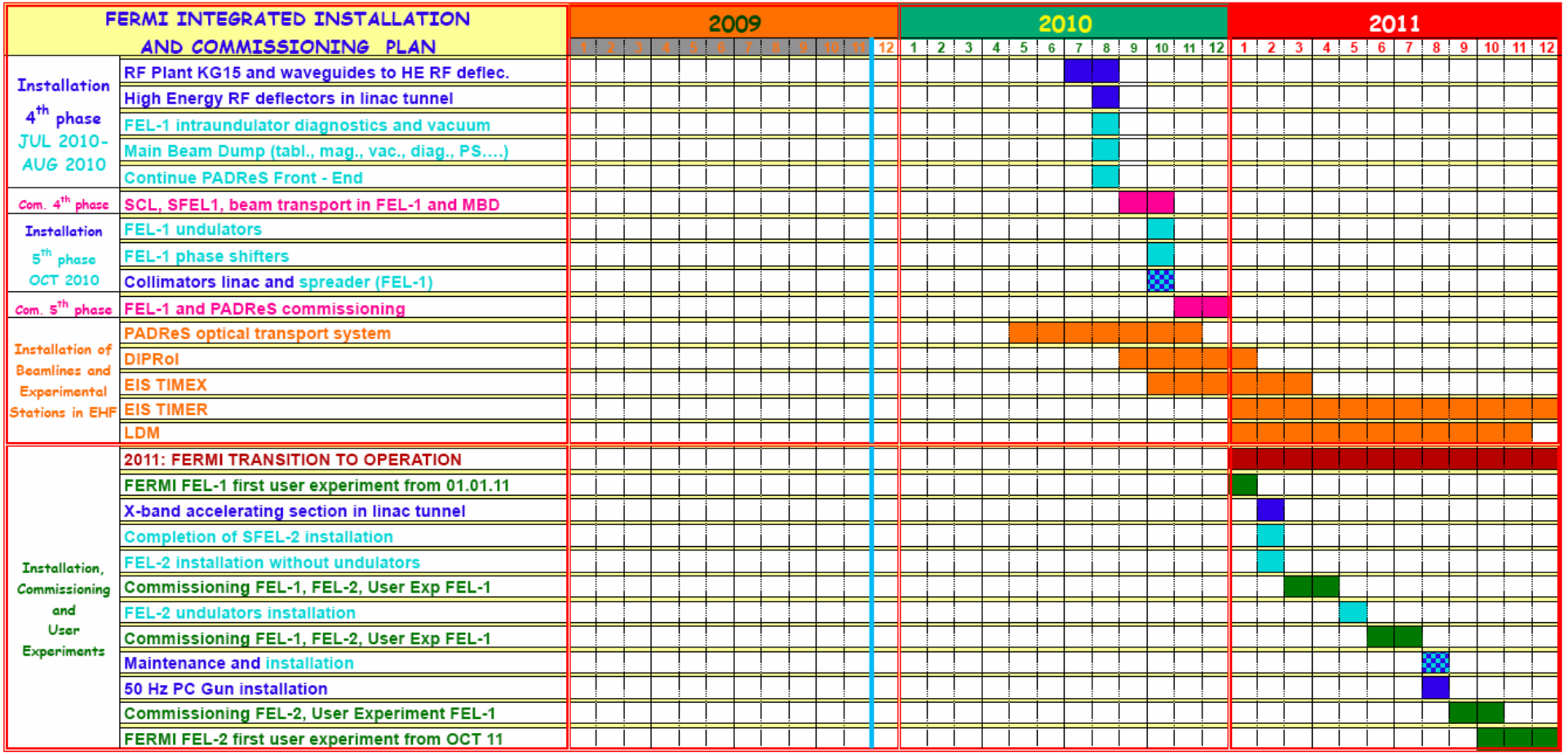
QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

"Shaded" areas merely underline the fact that there are many areas involved, some of which are phased to start earlier or later than other areas

FERMI @ Elettra MASTER PLAN



FERMI @ Elettra MASTER PLAN



LEGENDA - Colour coding
Civil Engineering
Installation activities in Linac Tunnel and Klystron Gallery
Installation activities in Undulator Hall, SG (SSA, USA), ESA
Installation activities in Experimental Hall
Commissioning phases in 2009 and 2010
Commissioning and users' experiments in 2011 transition phase
Modifications compared to previous release of the Master plan: new tasks, delays or advances on existing tasks
Past activities
Present date line

LEGENDA - Acronyms			
CO	Co-Occupancy	SG	Service Gallery
BO	Beneficial Occupancy	SSA	Spreader Service Area
EM	Electric and Mechanic plants commissioned	SLR	Seed Laser Room
		UTDR	Undulator Timing and Diagnostic Room
		USA	Undulator Service Area
LT	Linac Tunnel		
Lm	Linac Sector number m	UH	Undulator Hall
LH	Laser Heater	SCL	Spreader Common Line
BC	Bunch Compressor	SFEL-1	Spreader FEL-1
DBD	Diagnostic Beam Dump	SFEL-2	Spreader FEL-2
TLS	Transport Line Straight	IUFEL-1	IntraUndulator sections FEL-1
		MBD	Main Beam Dump
KG	Klystron Gallery	PADReS	Photon Analysis Delivery and Reduction System
KGnn	RF Plant number nn	EH	Experimental Hall
		ESA	Experimental Service Area
		DIPRoI	DIffraction and PRojection Imaging
		EIS	Elastic and Inelastic Scattering
		LDM	Low Density Matter

Installation/Commissioning Schedule

2010 FERMI@Elettra Beam and Shutdown schedule

Installation with beam possible from Linac2 through Main Beam Dump and EH

Installation with beam possible in PADReS Safety Hutch and EH

Installation with beam possible in EH: PADReS and Beamlines

Gennaio January

date	M	L	N	W
1				53
2				
3				
4	Instal. L1 through BC1 Spectro -meter			
5				
6				
7				1
8				
9				
10				
11				2
12				
13				
14				
15				
16				
17				3
18				
19				
20				
21				
22				
23				4
24				
25				
26				
27				
28				
29				
30				5
31				

Febbraio February

date	M	L	N	W
1				4
2				
3	CoOcc UH			
4	Comm. L1 through BC1 Spectro -meter			
5				
6				5
7				
8				
9				
10				6
11				
12				
13				
14				
15				7
16				
17				
18				
19				
20				8
21				
22				
23				
24				
25				9
26				
27				
28				

Marzo March

date	M	L	N	W
1				8
2				
3				
4				
5				
6				9
7				
8				
9				
10				10
11				
12				
13	CoOcc SG			
14				
15				11
16				
17				
18				
19				
20				12
21				
22				
23				
24				
25				13
26				
27				
28				
29				
30				14
31				

Aprile April

date	M	L	N	W
1				13
2				
3				
4				
5	Install BC1 chicane and C5; temp wall removal			
6				14
7				
8				
9				
10				15
11				
12				
13				
14				
15				16
16				
17				
18	CoOcc EH			
19				
20				17
21				
22				
23				
24				
25				18
26				
27				
28				
29				
30				19

Maggio May

date	M	L	N	W
1				18
2				
3				
4				
5				
6				19
7				
8				
9				
10				20
11				
12				
13				
14				
15				21
16				
17				
18				
19				
20				22
21	Electric ON			
22				
23				
24				
25				23
26				
27				
28				
29				
30	Mech. ON			
31				24

Giugno June

date	M	L	N	W
1				22
2				
3				
4				
5				
6	Comm. BC1 and from L2 through DBD			
7				23
8				
9				
10				
11				24
12				
13				
14				
15				25
16				
17				
18				
19				
20				25
21				
22				
23				
24				
25				26
26	BEN. OCC.			
27				
28				
29				
30				26

Luglio July

date	M	L	N	W
1				26
2				
3				
4				
5				
6				27
7				
8				
9				
10				28
11				
12				
13				
14				
15				28
16				
17				
18				
19				
20				29
21				
22				
23				
24				
25				30
26				
27				
28				
29				
30				30
31				

Agosto August

date	M	L	N	W
1				30
2	Install HE RF Defl-ectors Comple-te FEL-1 and FEL-1 Diagn-ostics			
3				31
4				
5				
6				31
7				
8				
9				32
10				
11				
12				
13				32
14				
15				
16				33
17				
18				
19				33
20				
21				
22				34
23				
24				
25				34
26				
27				
28				
29				
30				35
31				

Settembre September

date	M	L	N	W
1				35
2				
3	Comm. Spread -er and FEL-1 through MBD			
4				36
5				
6				
7				36
8				
9				
10				37
11				
12				
13				37
14				
15				
16				38
17				
18				
19				38
20				
21				
22				39
23				
24				
25				39
26				
27				
28				
29				
30				39

Ottobre October

date	M	L	N	W
1				39
2				
3				
4				
5				
6				40
7				
8				
9				40
10				
11				
12				41
13				
14				
15				41
16				
17				
18	Install FEL-1 Undul-ators, colli-mators			42
19				
20				
21				42
22				
23				
24				43
25				
26				
27				43
28				
29				
30				43
31				

Novembre November

date	M	L	N	W
1				43
2				
3				
4				
5				
6				44
7				
8				
9				44
10				
11				
12	Comm. FEL-1 and PADReS			45
13				
14				
15				45
16				
17				
18				46
19				
20				
21				46
22				
23				
24				47
25				
26				
27				47
28				
29				
30				47

Dicembre December

date	M	L	N	W
1				48
2				
3				
4				
5				
6				49
7				
8				
9				49
10				
11				
12				50
13				
14				
15				50
16				
17				
18				51
19				
20				
21				51
22				
23				
24				52
25				
26				
27				52
28				
29				
30				52
31				

LEGENDA:

- Shutdown periods: NO BEAM
- Commissioning from Gun to BC1: parallel installation downstream temporary wall
- Commissioning through MBD: parallel installation only in Experimental Hall

Milestones MAIN FERMI Yard (Collini)

For details of installation and commissioning phases see FERMI MASTER PLAN

The FERMI Team

117 people in the picture, but not everyone was able to make it out that day