CAS 3 November 2008

On behalf of the INFN and the LNF staff
I WELCOME you all to FRASCATI

1) quick introduction
2) lecture ….presenting the LNF….
3) conclusions

M.Calvetti
INFN-LNF
Università di Firenze

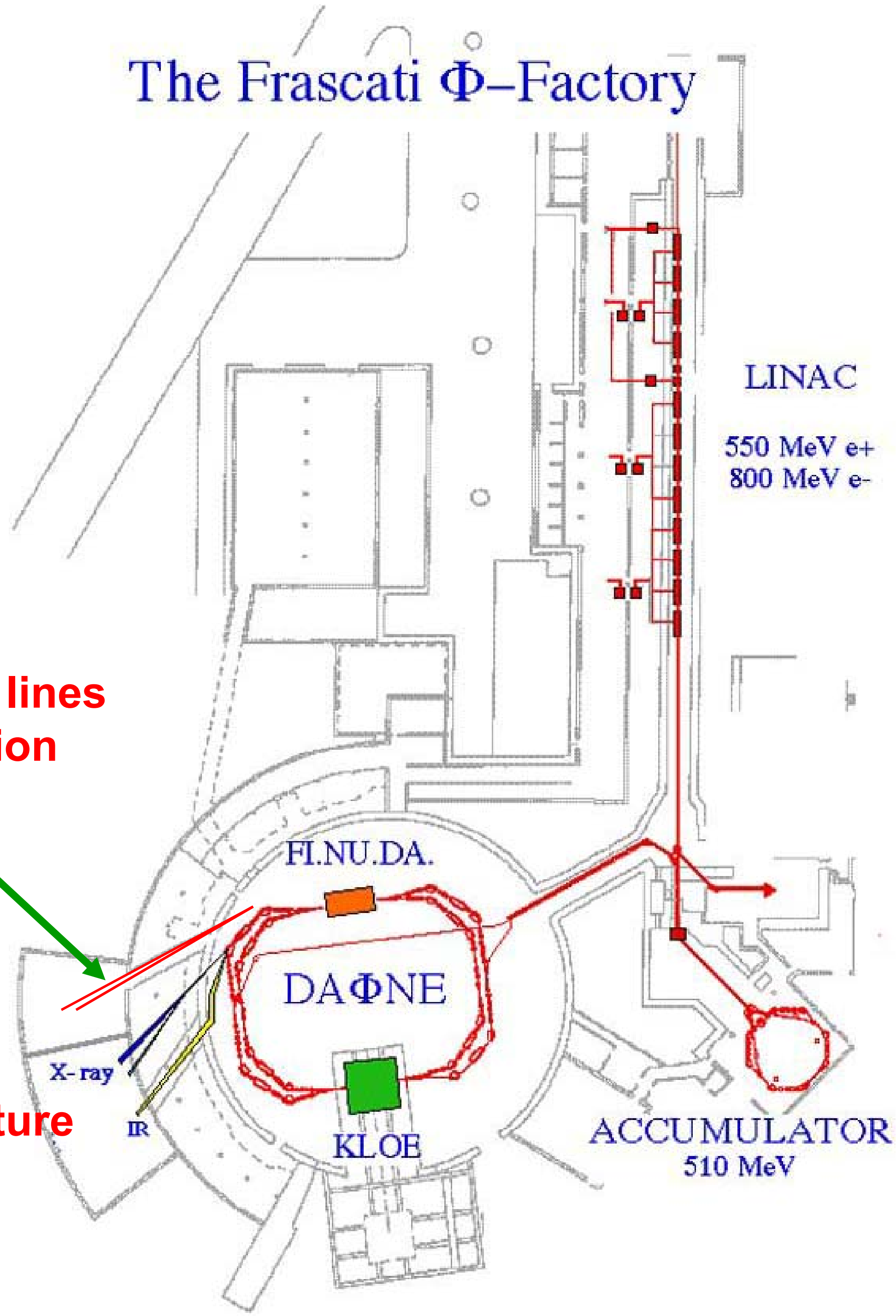
DAFNE

DAFNE- LIGHT Laboratory

Two new soft X-ray lines under construction

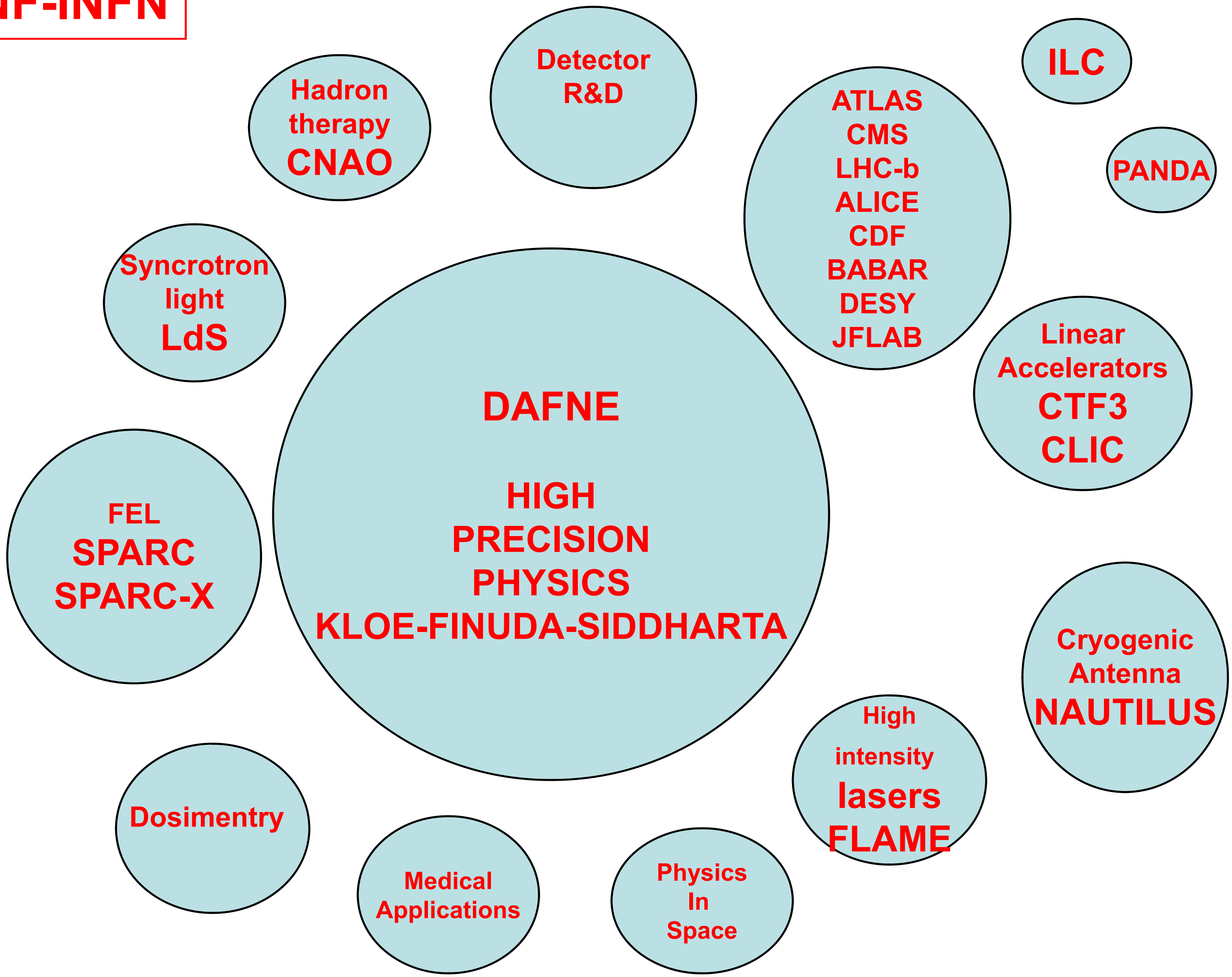
Syncrotron ligth from DAFNE
SPARC
SPARX
Conventional sources

LNF are part of the European Infrastructure for syncrotron light




Staff = 350
Associates = 181
Visitors = 463
TOTAL 994
I Laboratori Nazionali
di

LNF-INFN



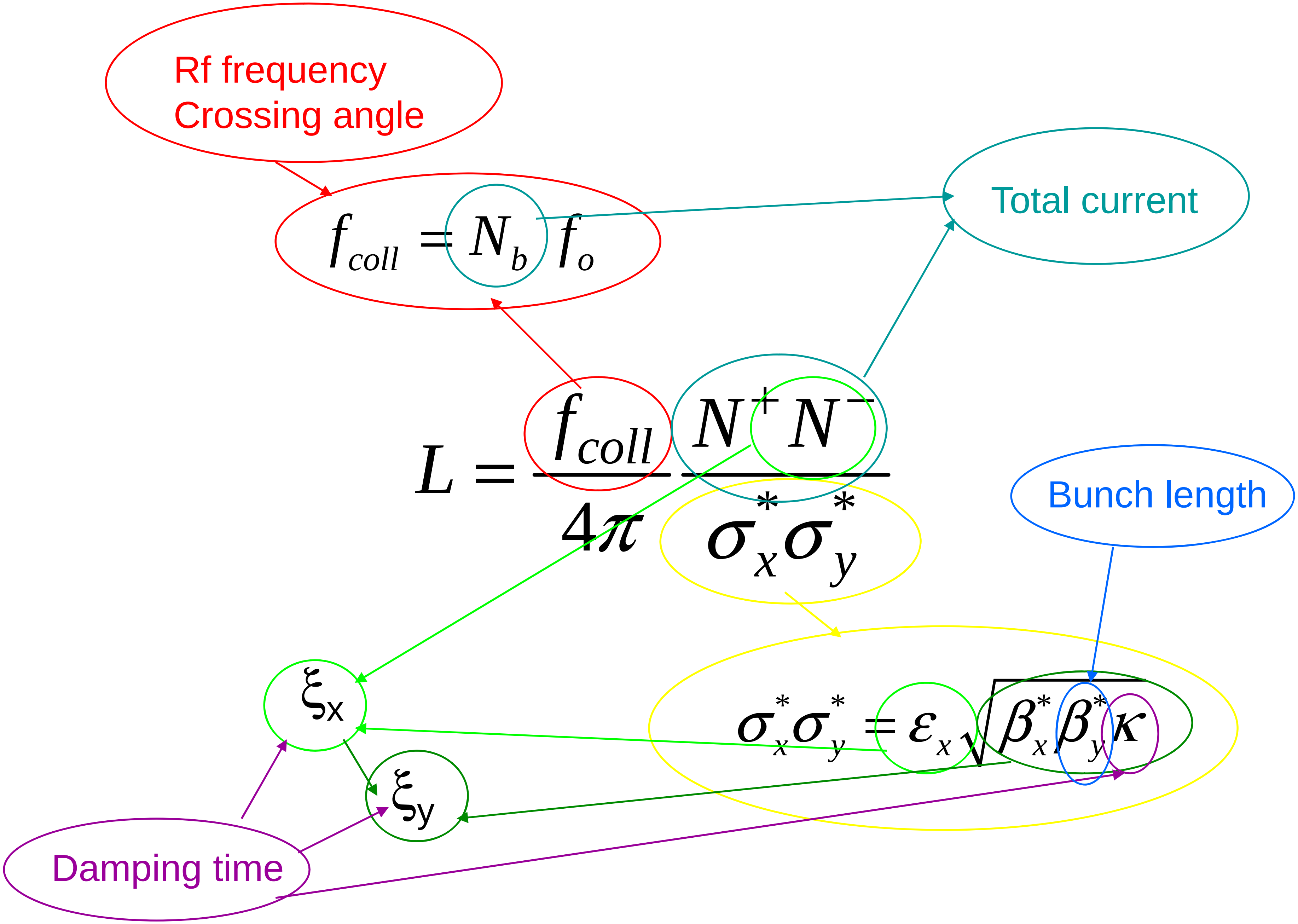
Hadron therapy CNAO
Detector R&D
ATLAS CMS LHC-b ALICE CDF BABAR DESY JFLAB
ILC
PANDA
Syncrotron light LdS
DAFNE
HIGH PRECISION PHYSICS
KLOE-FINUDA-SIDDHARTA
Linear Accelerators CTF3 CLIC
FEL SPARC SPARC-X
Cryogenic Antenna NAUTILUS
High intensity lasers FLAME
Dosimentry
Medical Applications
Physics In Space

COLLIDING BEAMS

FEL

APPLICATIONS

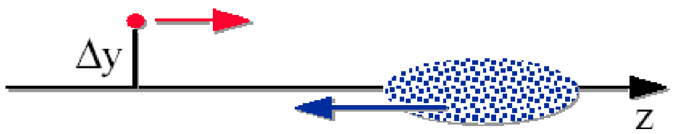
NEW IDEAS …..very important ….

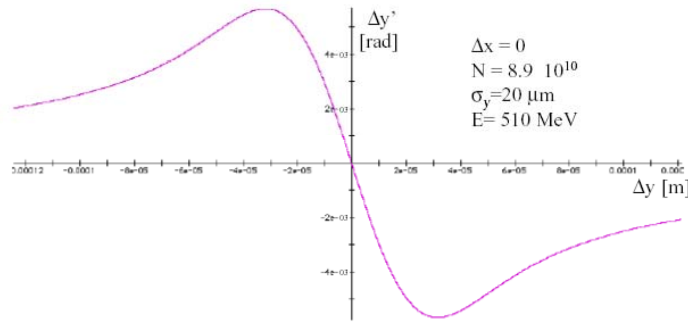


Rf frequency
Crossing angle
$f_{coll} = N_b f_o$
Total current
$L = \frac{f_{coll}}{4\pi} \frac{N^+ N^-}{\sigma_x^* \sigma_y^*}$
Bunch length
ξ_x
ξ_y
$\sigma_x^* \sigma_y^* = \varepsilon_x \sqrt{\beta_x^* \beta_y^* \kappa}$
Damping time

C.Biscari

Beam – beam effect





Beam – beam force

$$Q_{x,y} = Q_{x,y} + \xi_{x,y}$$

$$\xi_x = \frac{r_e}{2\pi\gamma}\frac{N\beta_x}{\sigma_x\left(\sigma_x+\sigma_y\right)} \approx \frac{r_e}{2\pi\gamma}\frac{N}{\varepsilon_x}$$

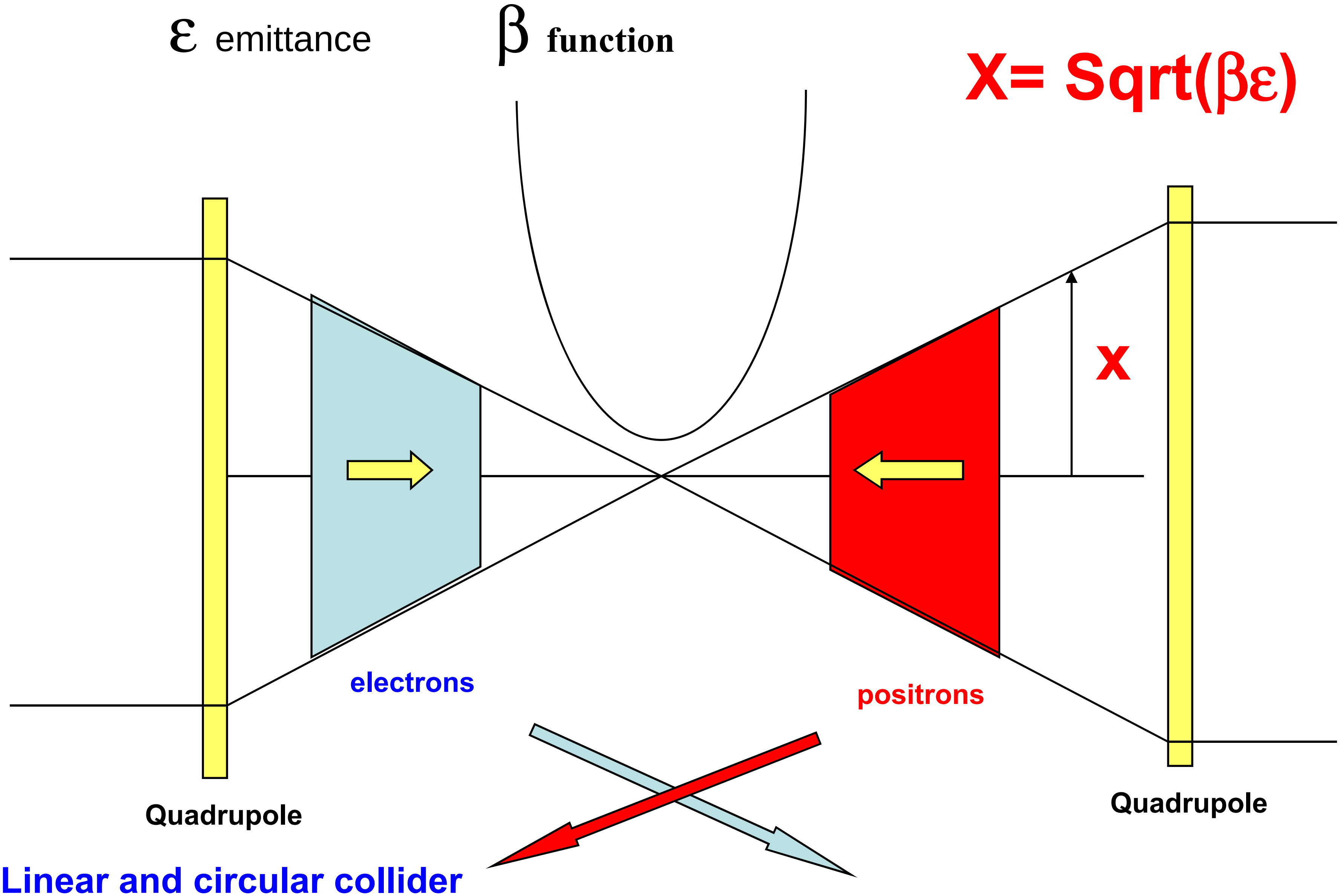
$$\xi_y = \frac{r_e}{2\pi\gamma}\frac{N\beta_y}{\sigma_y\left(\sigma_x+\sigma_y\right)} \approx \xi_x\sqrt{\frac{\beta_y}{\kappa\beta_x}}$$

- Large emittance
- Demand on damping time
- Demand on dynamic aperture

C.Biscari

EXAMPLE OF BEAM DYNAMICS EXPERIMENT at DAFNE

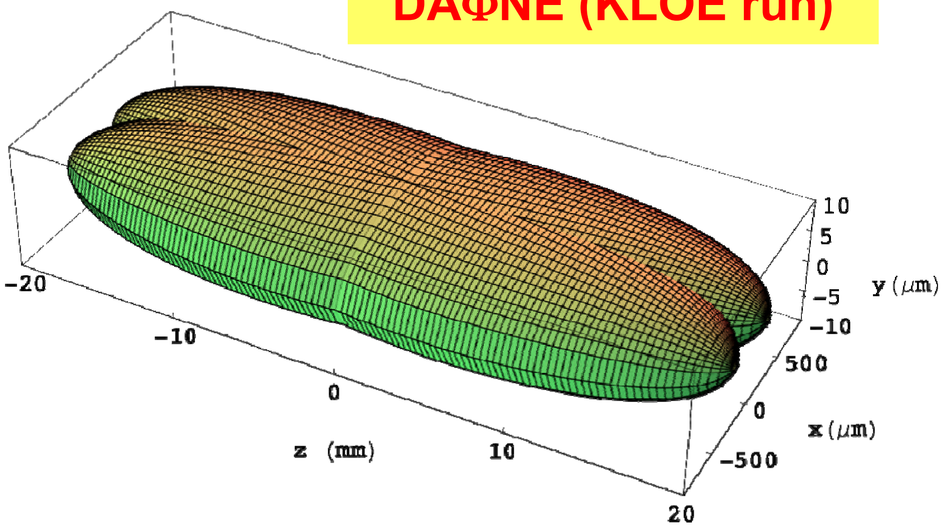
THE DAFNE CRAB-CROSSING - STUDY OF BEAM-BEAM DYNAMICS

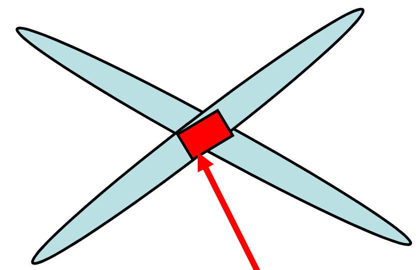


[Linear and circular collider]

BEAM PROFILES @IP AND NEW PARAMETERS

DAΦNE (KLOE run)

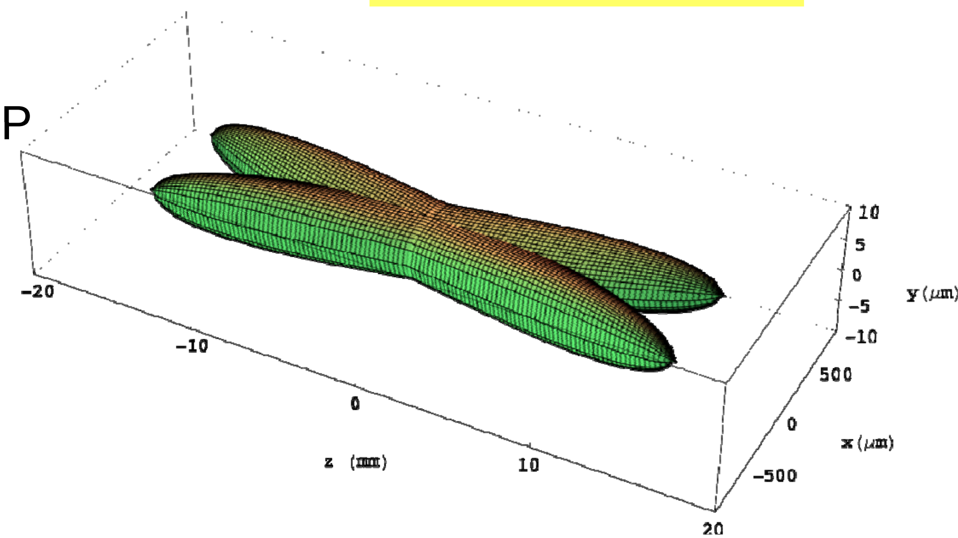




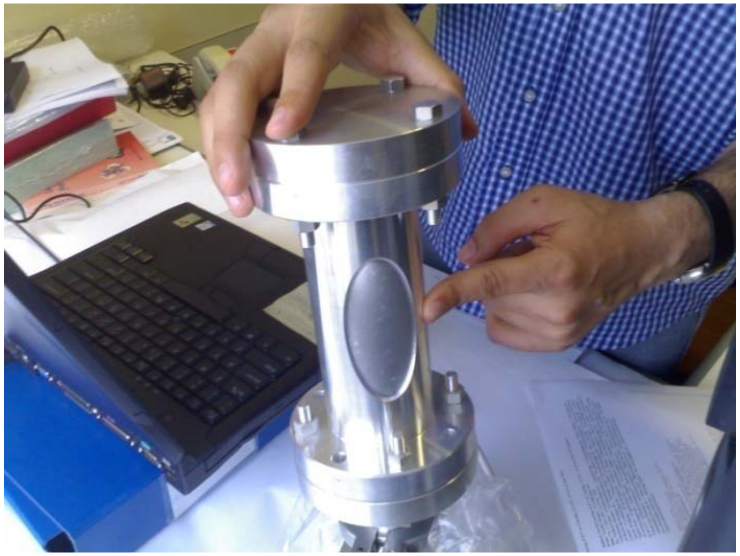
Increase crossing angle 12mrad → 25 mrad

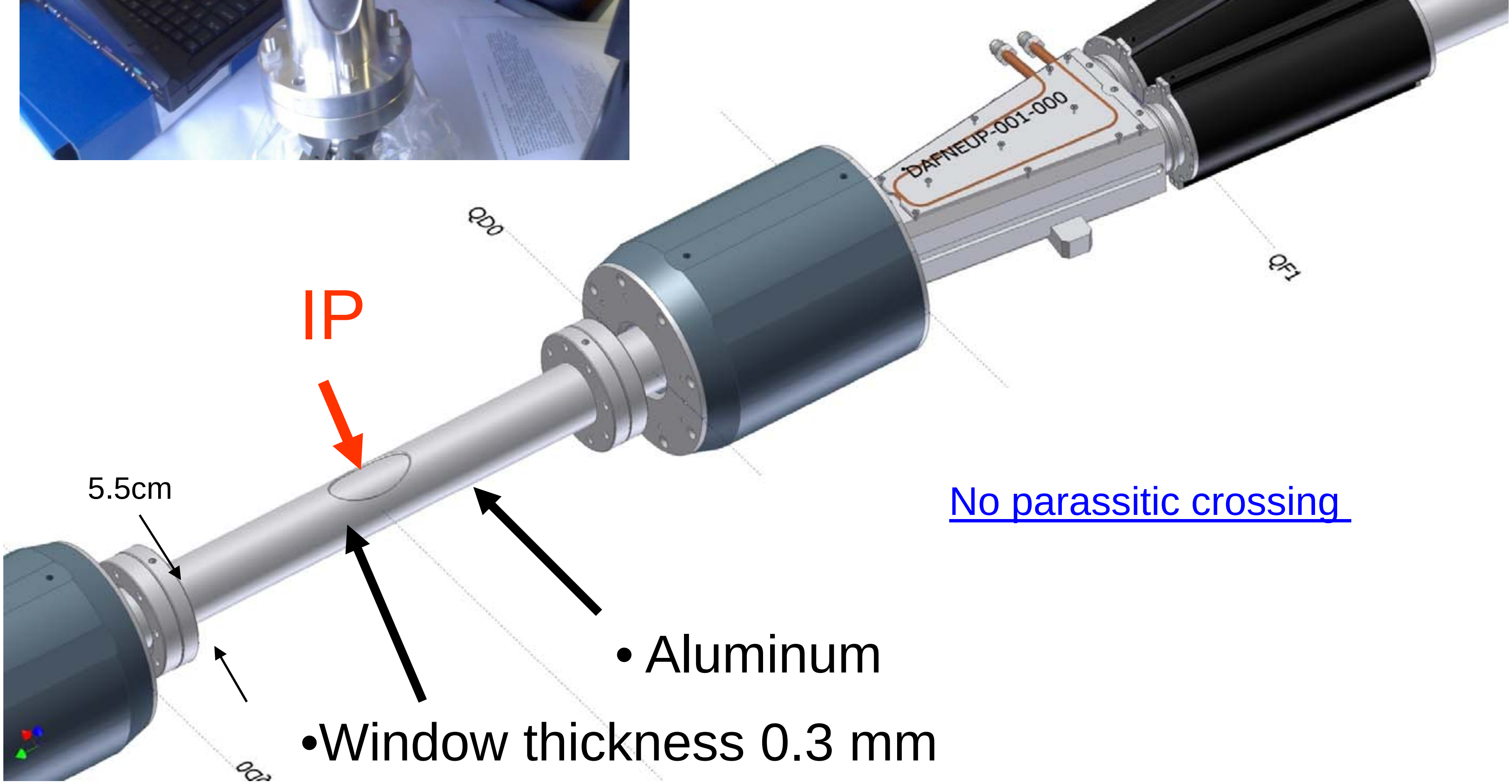
To recover luminosity:
Reduce horizontal and vertical sigmas at IP

DAΦNE Upgrade



No parassitic crossing





No parassitic crossing

Large Piwinski angle $\Phi_{P=}\theta\sigma_z / \sigma_x$

small β_y^* ($\beta_y^* \sim \sigma_x/\theta$)

Geometric luminosity gain

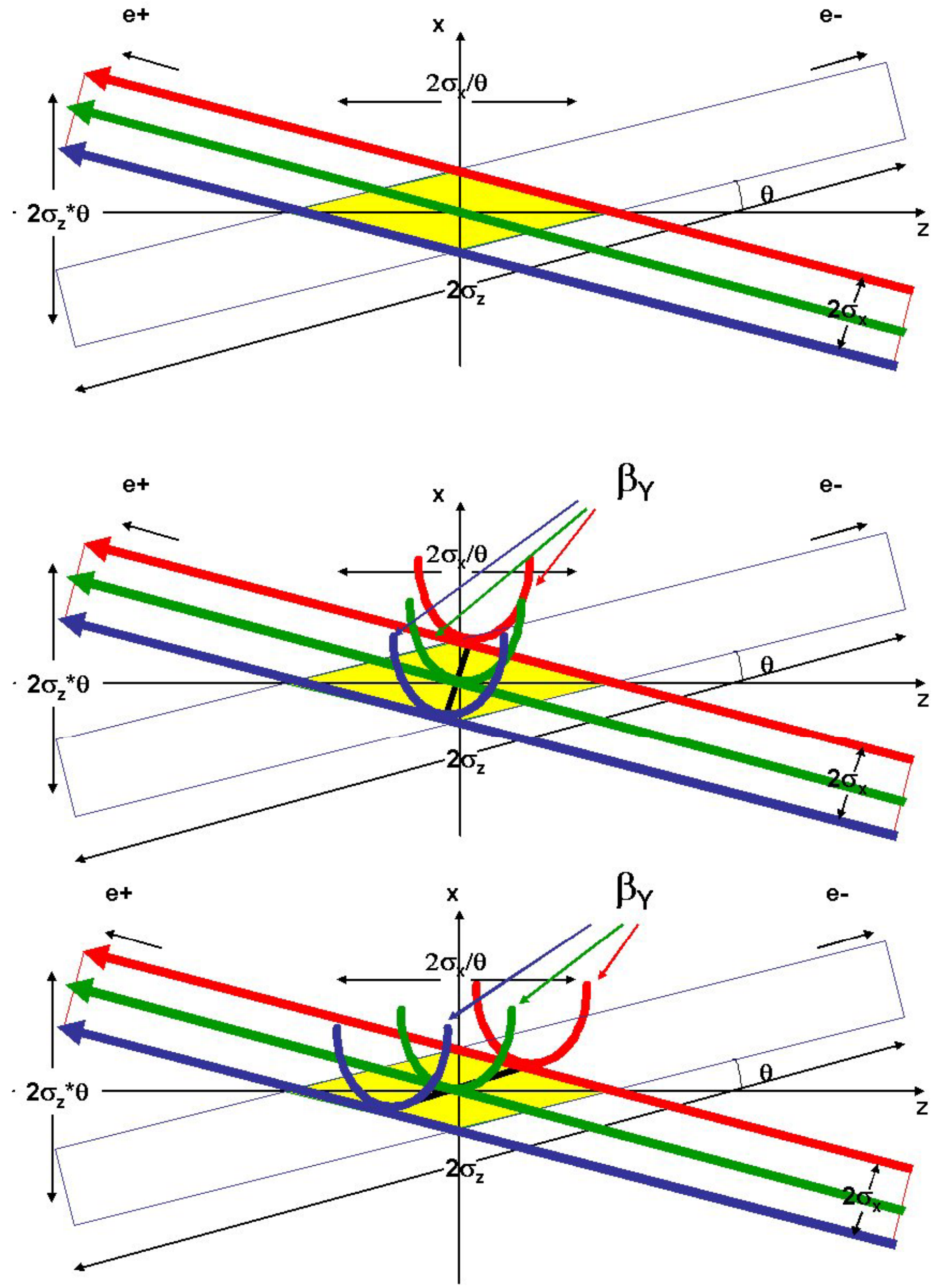
Very low horizontal tune shift

No parasitic collisions

short overlap region

Geometric luminosity gain

low vertical tune shift



Crab waist transformation (realized with two sextupoles @π in x and 1.5π in y from IP)

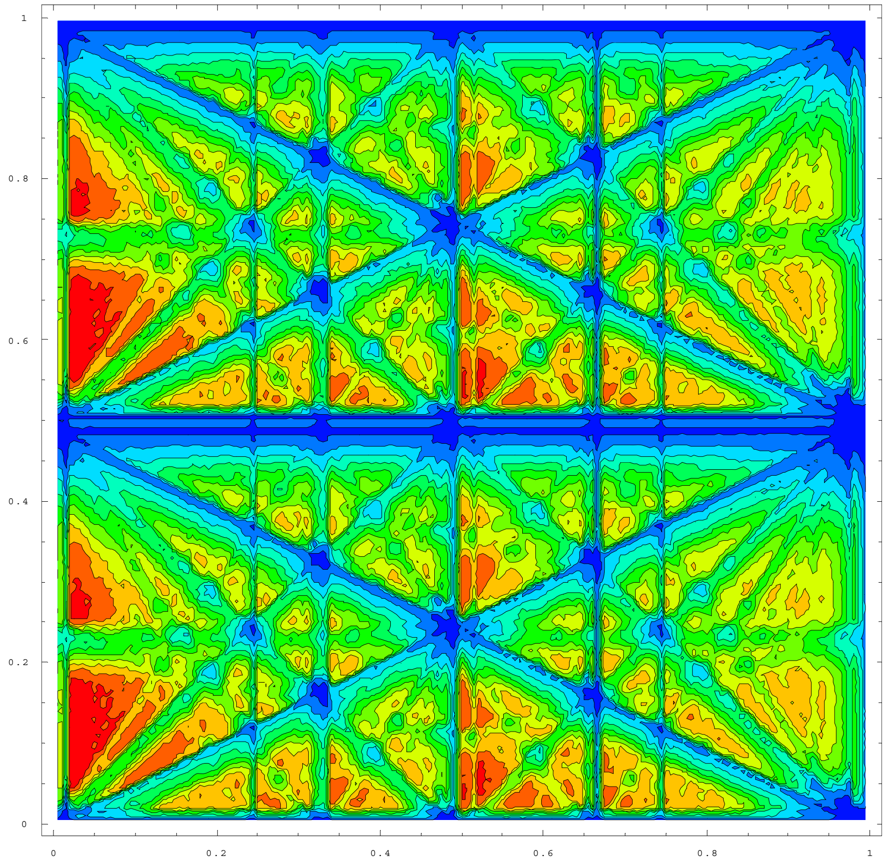
B = Kx quadrupole

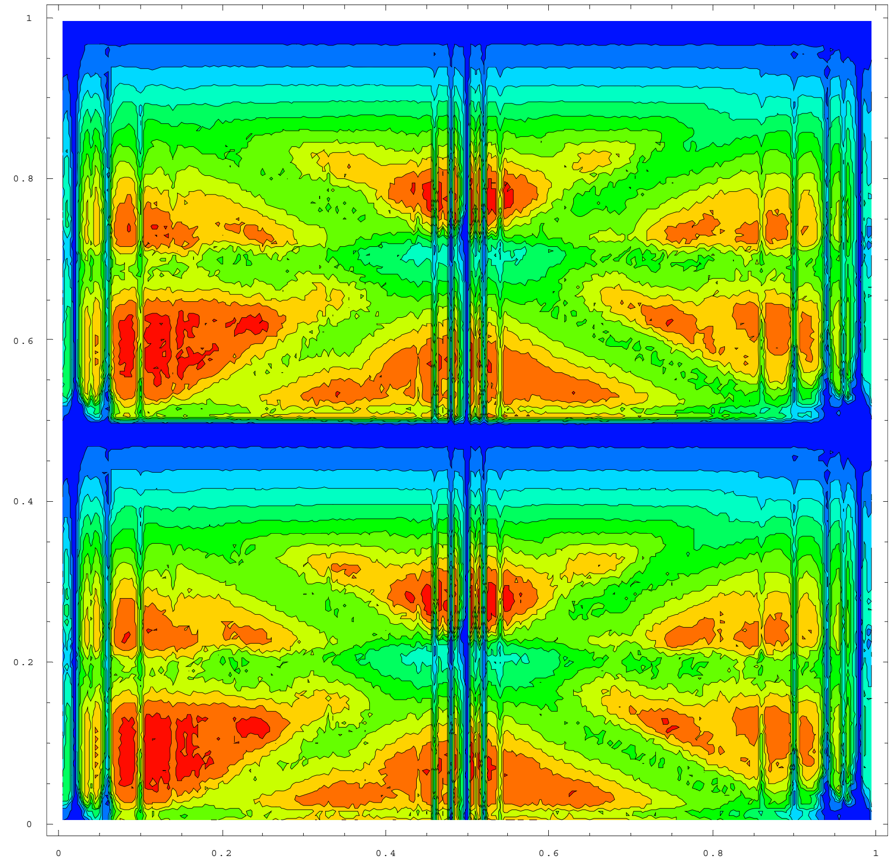
B = Kx^2= (Kx)x sextupole

Beam-beam simulations

X-Y Resonance Suppression

Much higher luminosity?





Typical case (KEKB, DAΦNE etc.):

1. low Piwinski angle $\Phi < 1$
2. β_y comparable with σ_z

Crab Waist On:

1. large Piwinski angle $\Phi >> 1$
2. β_y comparable with σ_x/θ

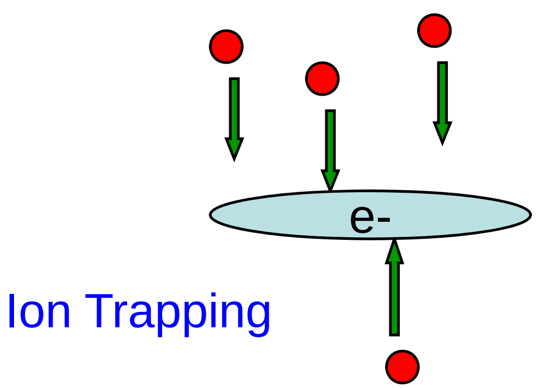
Luminosity limited by collective effetcs?

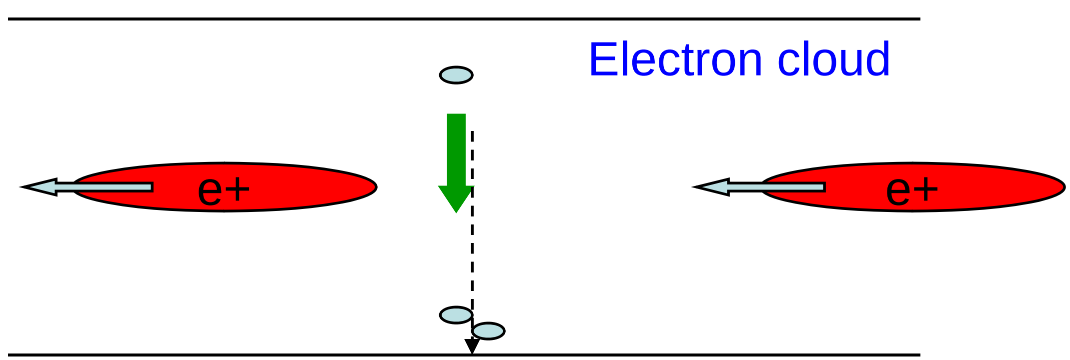
Positive ion trapping
Electron clouds
Ring impedence

20μ x 250μ x 3 cm bunch dimensions with 10^{10} particles

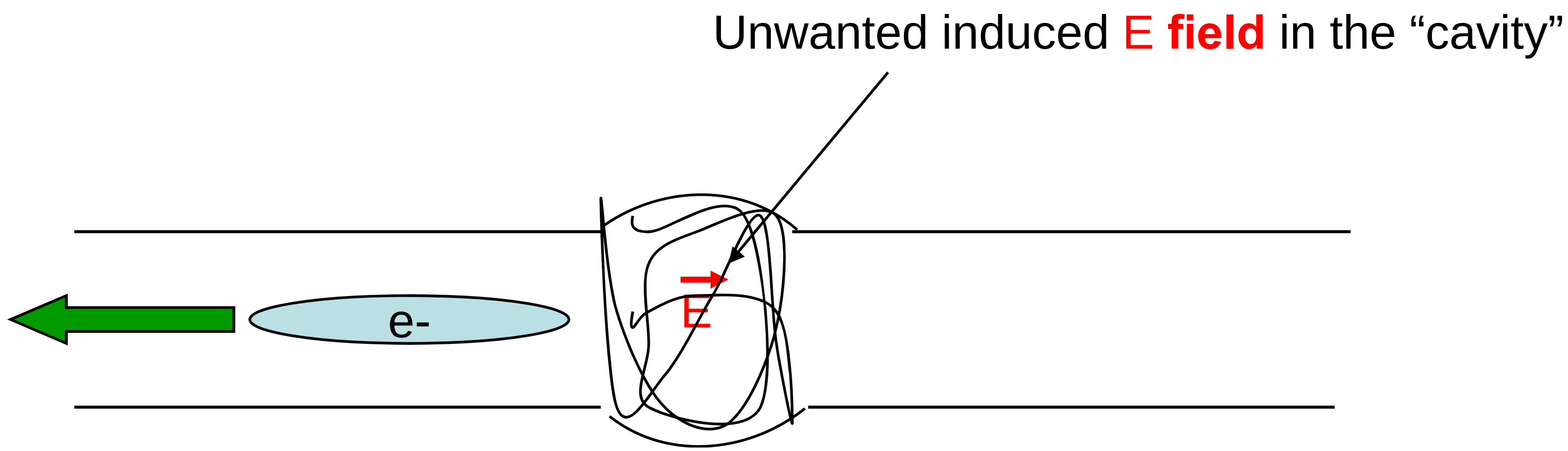
500 H_2 molecules at 10^{-10} tor in the bunch volume

In DAFNE every 60 μs the bunch crosses an amount of molecules equal to the number of electrons in the bunch





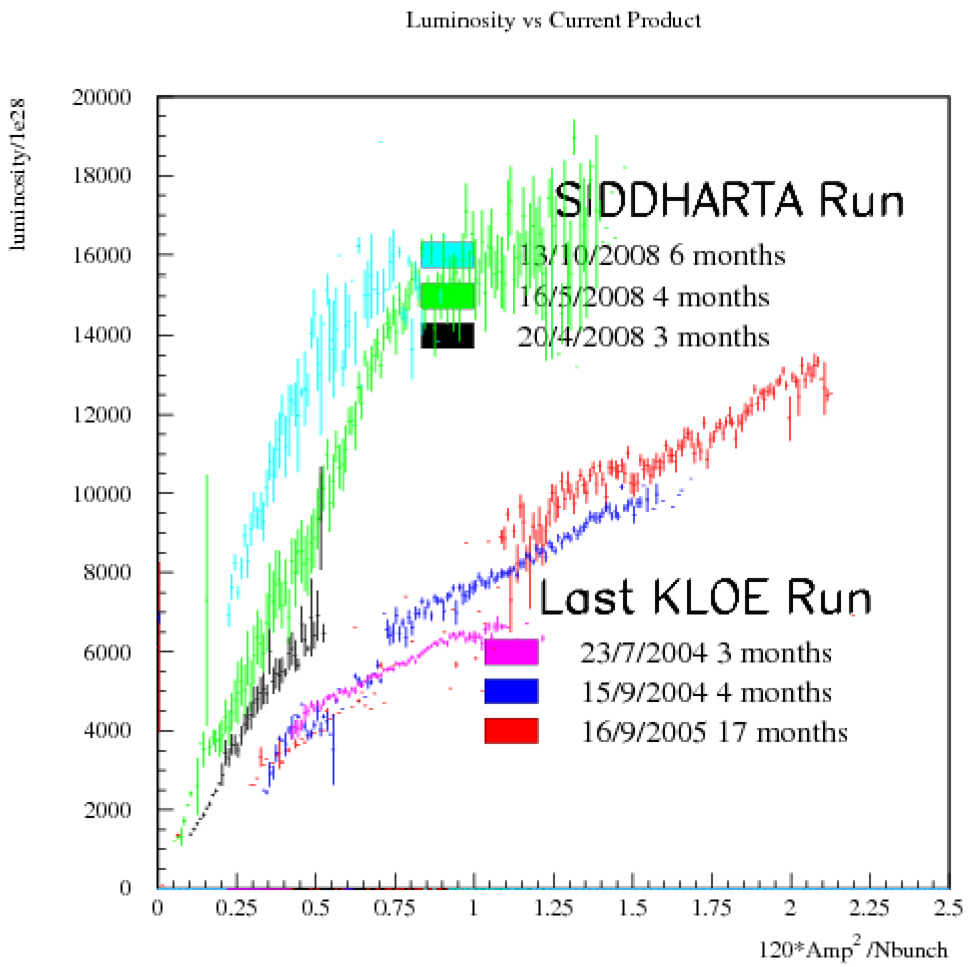
Ring impedence Z



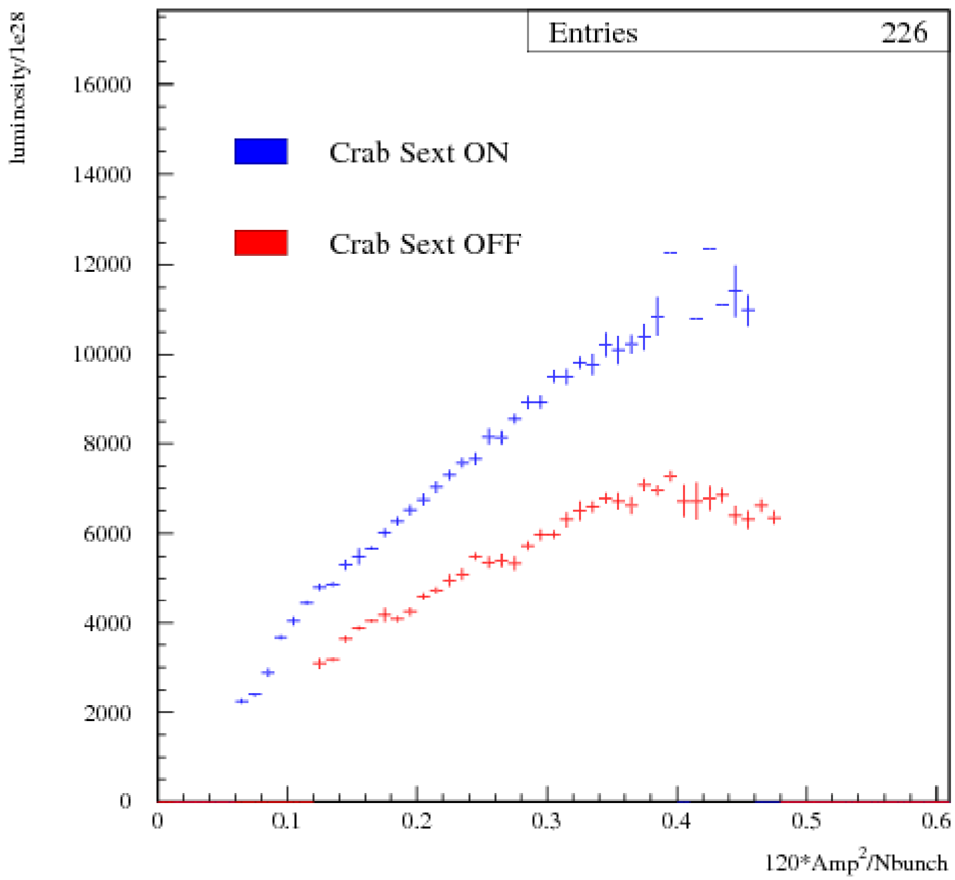
Induced beam Instability …. → active feedbacks

Every accelerator ring has a maximum current !

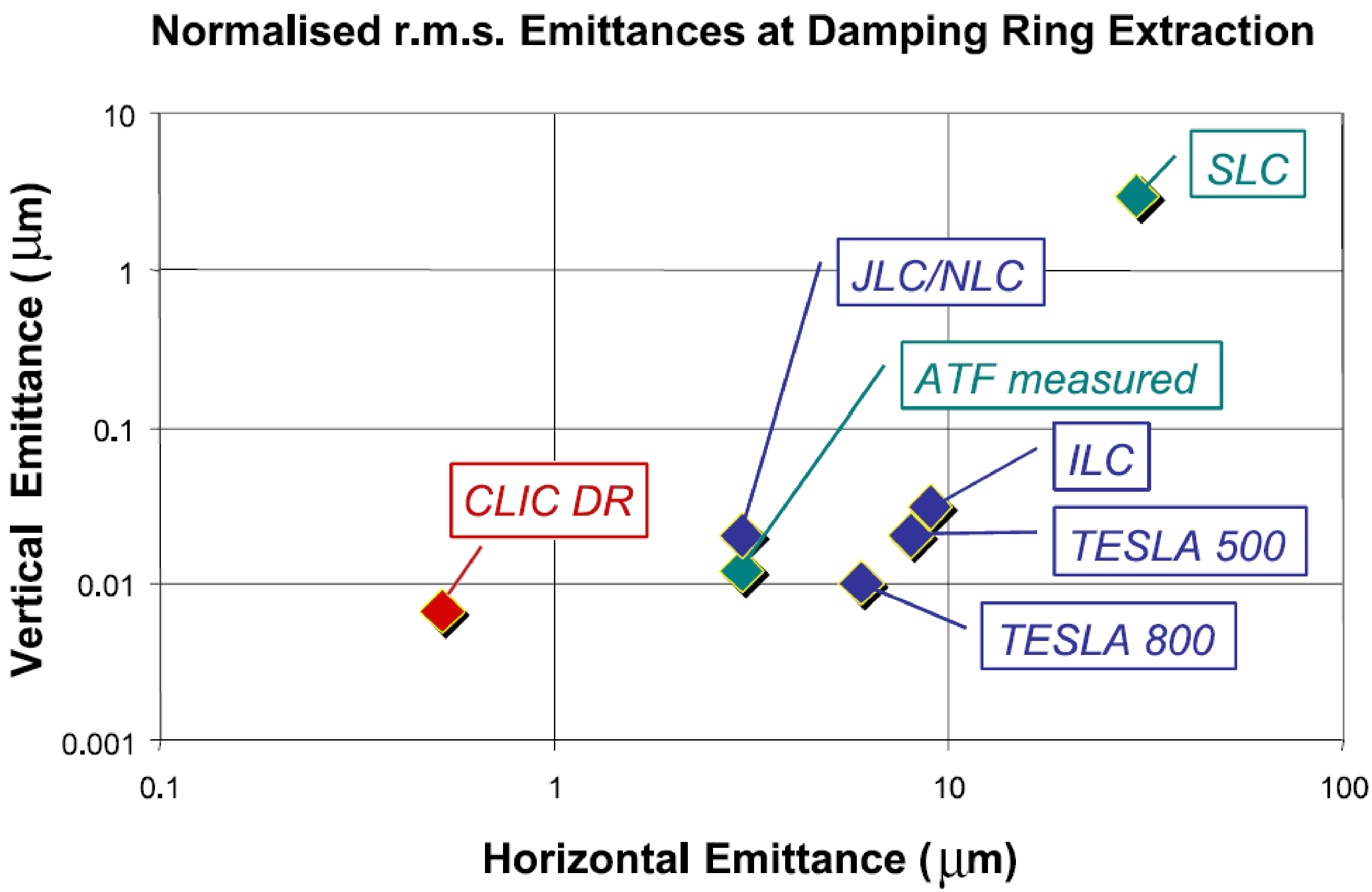
DAFNE specific luminosity increase



It can be used by any storage ring collider, a stronger focusing is usable but measurements are still going on…….



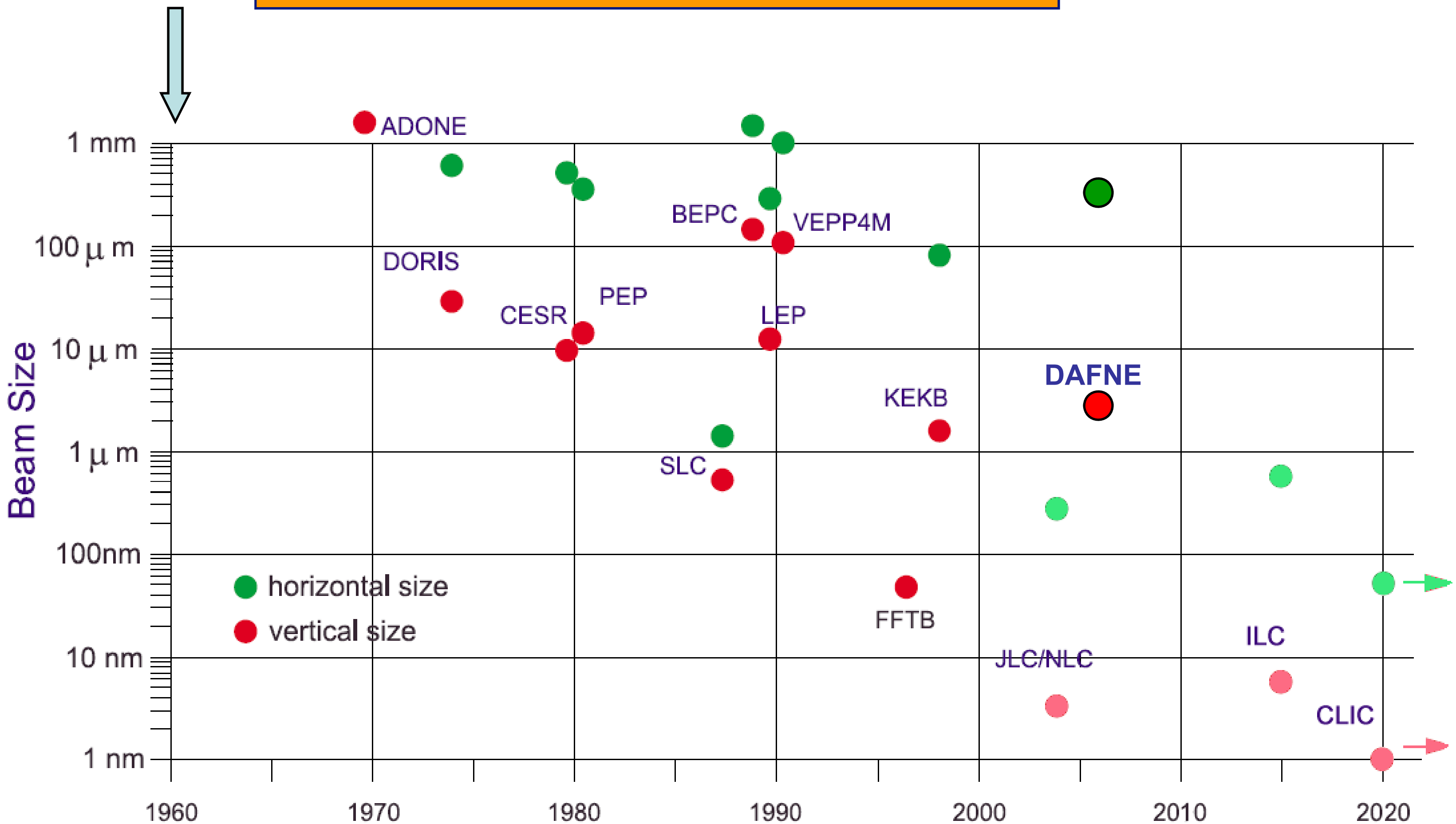
The small emittance challenge



Beta function and emittance

ADA

The small beam size challenge



Adapded from S. Chattopadhyay, K. Yokoya, Proc. Nanobeam `02

What about Linear Colliders?

Low emittance
Strong focusing
High currents

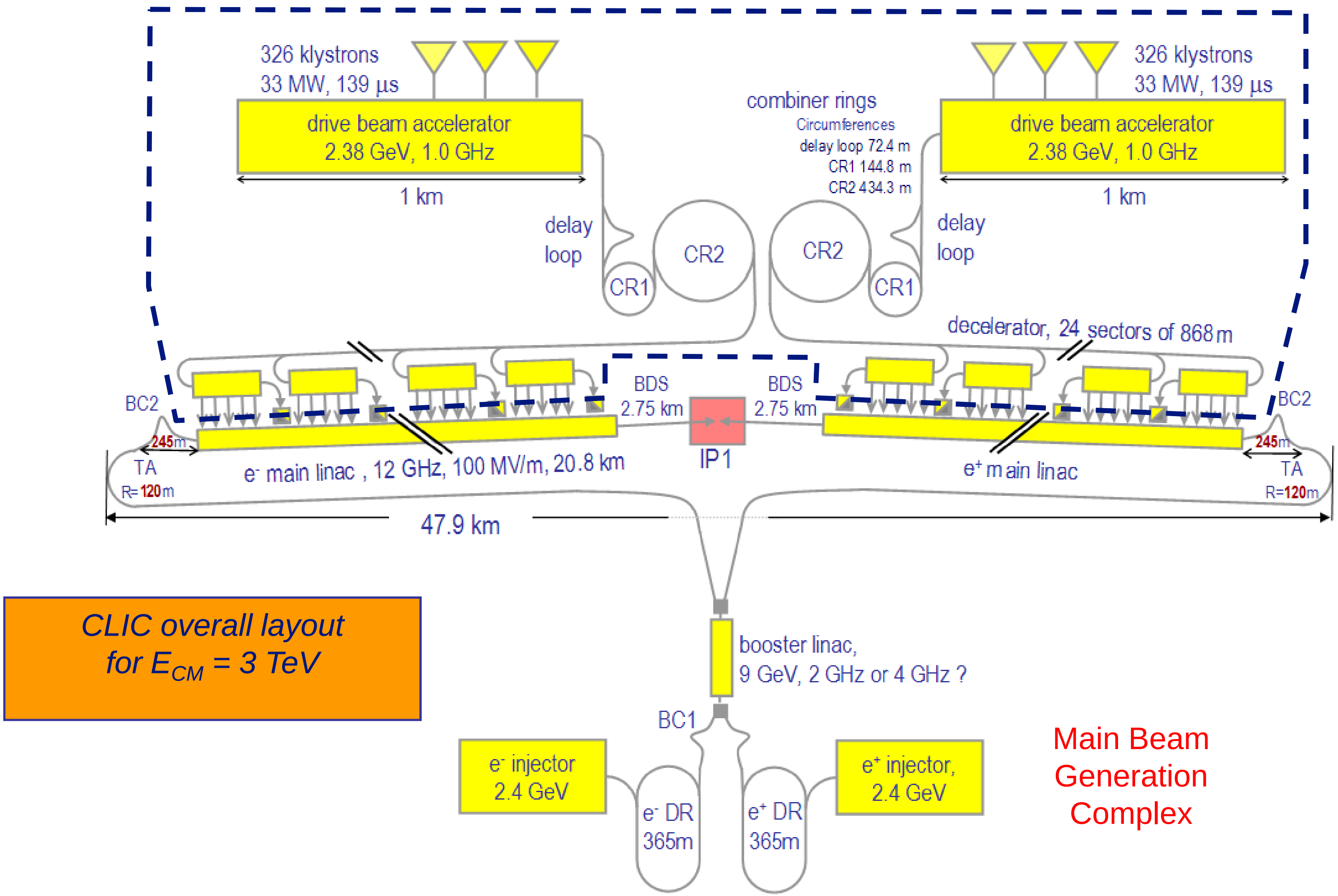
……….the same requirements………

……every Linear Collider has a dumping ring….to have low emmittance…
…but single pass imply very small beam cross section
at the interaction point (30nm)

………it implies to have a strong beam-beam interaction… beamstrahlung…..

…and on time background……

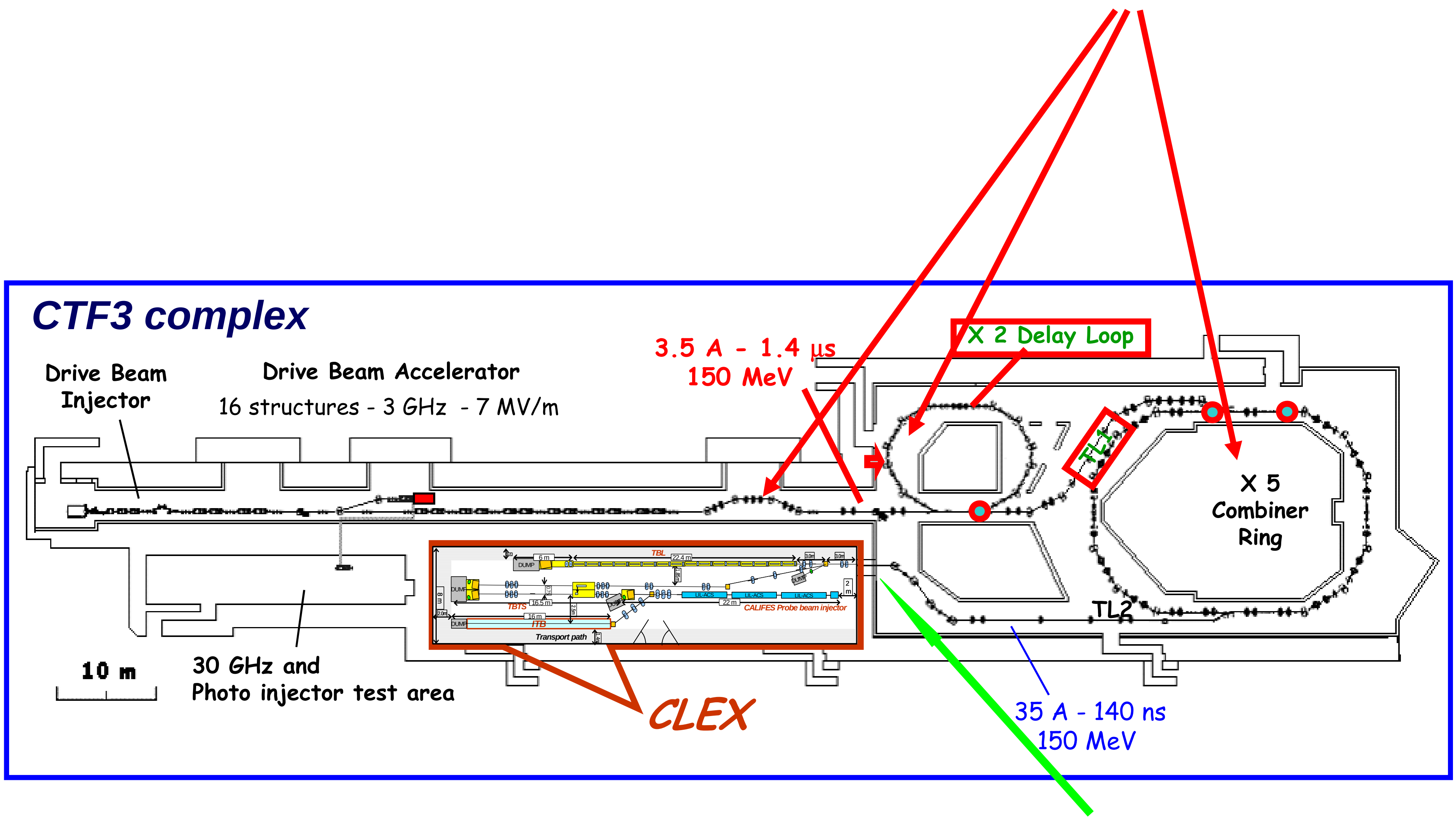
CLIC RF power source



LNF and the Future of Fundamental Research

The CLIC-CTF3 at CERN

LNF contribution to CLIC



12 A…here!

Conclusions by J.Ellis

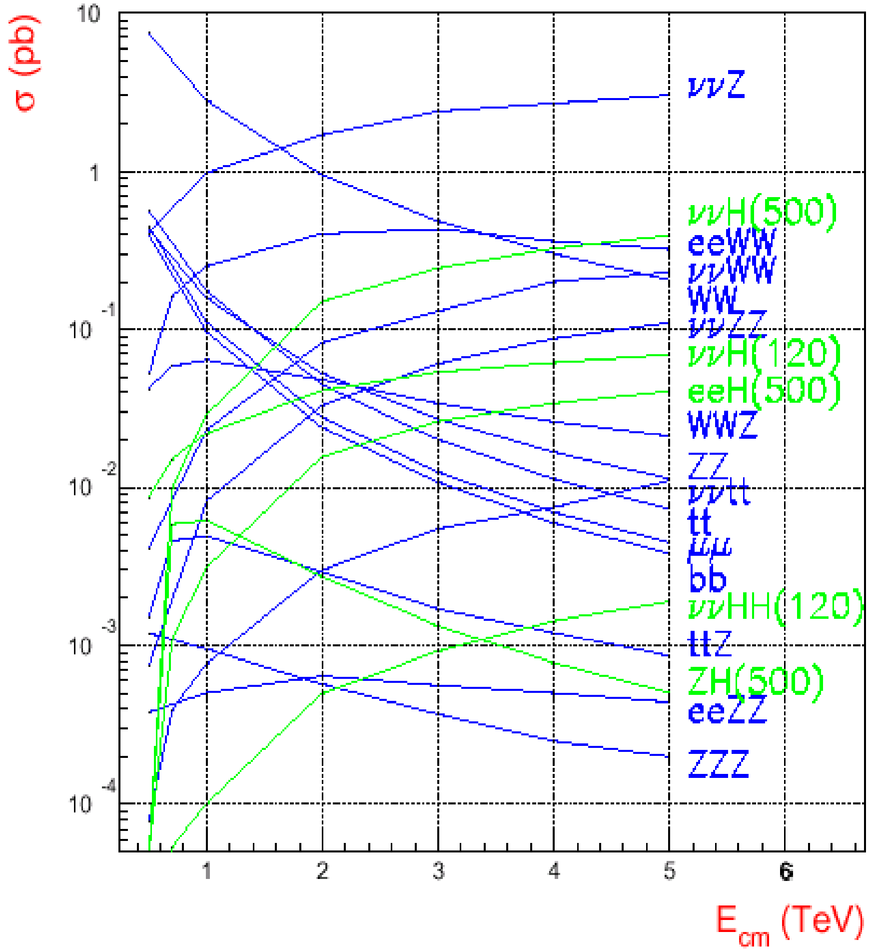
- CLIC will provide unique physics @ energy frontier
- Beamstrahlung and backgrounds not insurmountable problems
- Can exploit fully high c.o.m. energy
- Added value for light Higgs, heavy Higgs, supersymmetry, extra dimensions, …
- Whether light or heavy!

….so, what are we going to do……..

New CLIC main parameters

Center-of-mass energy	3 TeV
Peak Luminosity	$7 \cdot 10^{34}$ cm^{-2} s^{-1}
Peak luminosity (in 1% of energy)	$2 \cdot 10^{34}$ cm^{-2} s^{-1}
Repetition rate	50 Hz
Loaded accelerating gradient	100 MV/m
Main linac RF frequency	12 GHz
Overall two-linac length	42 km
Bunch charge	$3.72 \cdot 10^9$
Bunch separation	0.5 ns
Beam pulse duration	156 ns
Beam power/beam	14 MWatts
Hor./vert. normalized emittance	660 / 20 nm rad
Hor./vert. IP beam size bef. pinch	40 / ~1 nm
Total site length	48 km
Total power consumption	322 MW

Cross Sections at CLIC



one year at 10^{35} cm-2 s-1

Event Rates/Year (1000 fb^{-1})	3 TeV 10^3 events	5 TeV 10^3 events
$e^+e^- \to t\bar{t}$	20	7.3
$e^+e^- \to b\bar{b}$	11	3.8
$e^+e^- \to ZZ$	27	11
$e^+e^- \to WW$	490	205
$e^+e^- \to hZ/h\nu\nu$ (120 GeV)	1.4/530	0.5/690
$e^+e^- \to H^+H^-$(1 TeV)	1.5	0.95
$e^+e^- \to \tilde{\mu}^+\tilde{\mu}^-$ (1 TeV)	1.3	1.0

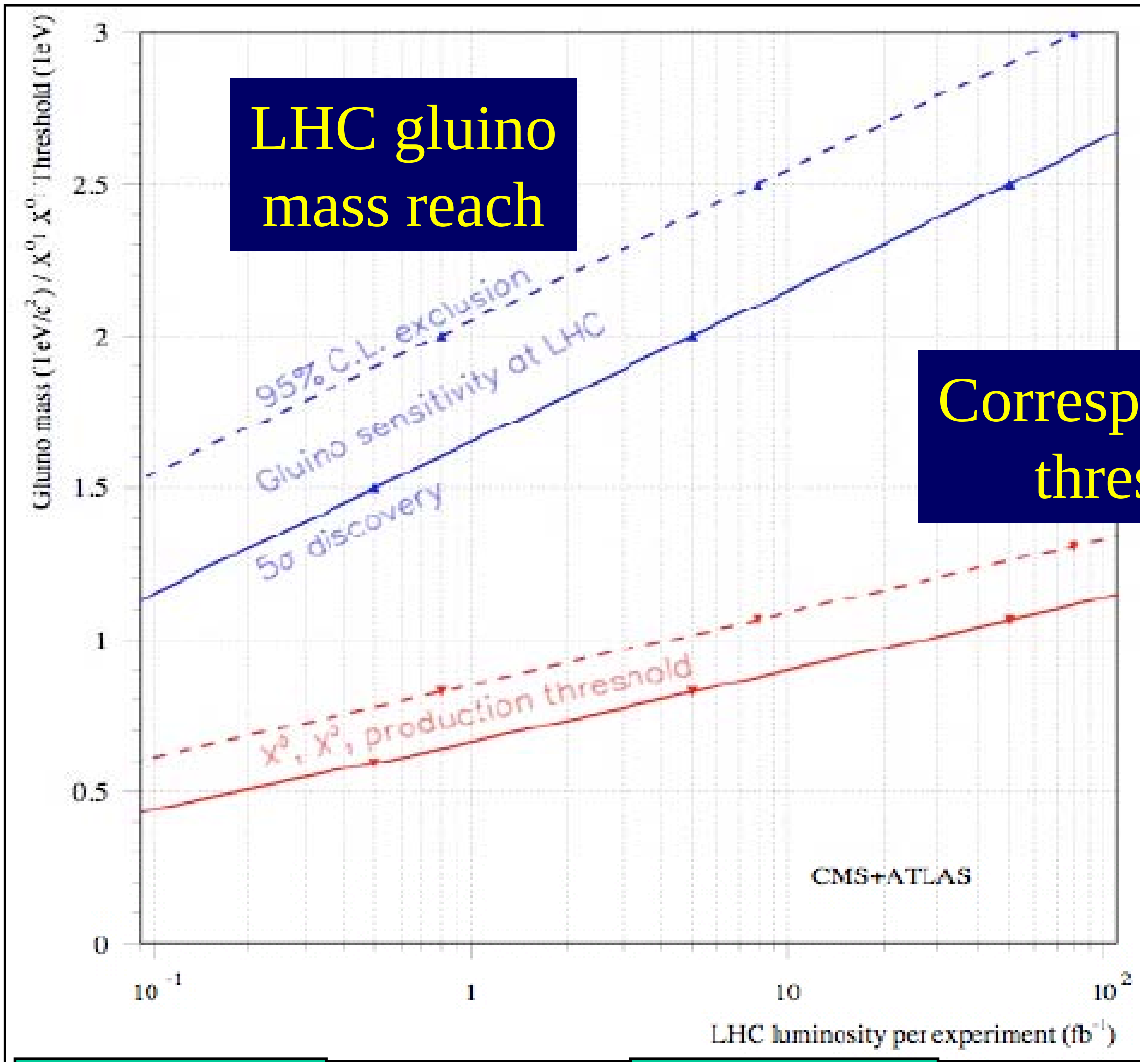
Very low SM cross sections………

$1fb^{-1}$ one year at 10^{32} cm^{-2} s^{-1}

TO BUILD CLIC……WE NEED EVIDENCE for NEW PHYSICS !

In CMSSM

LHC: GOOD NEW



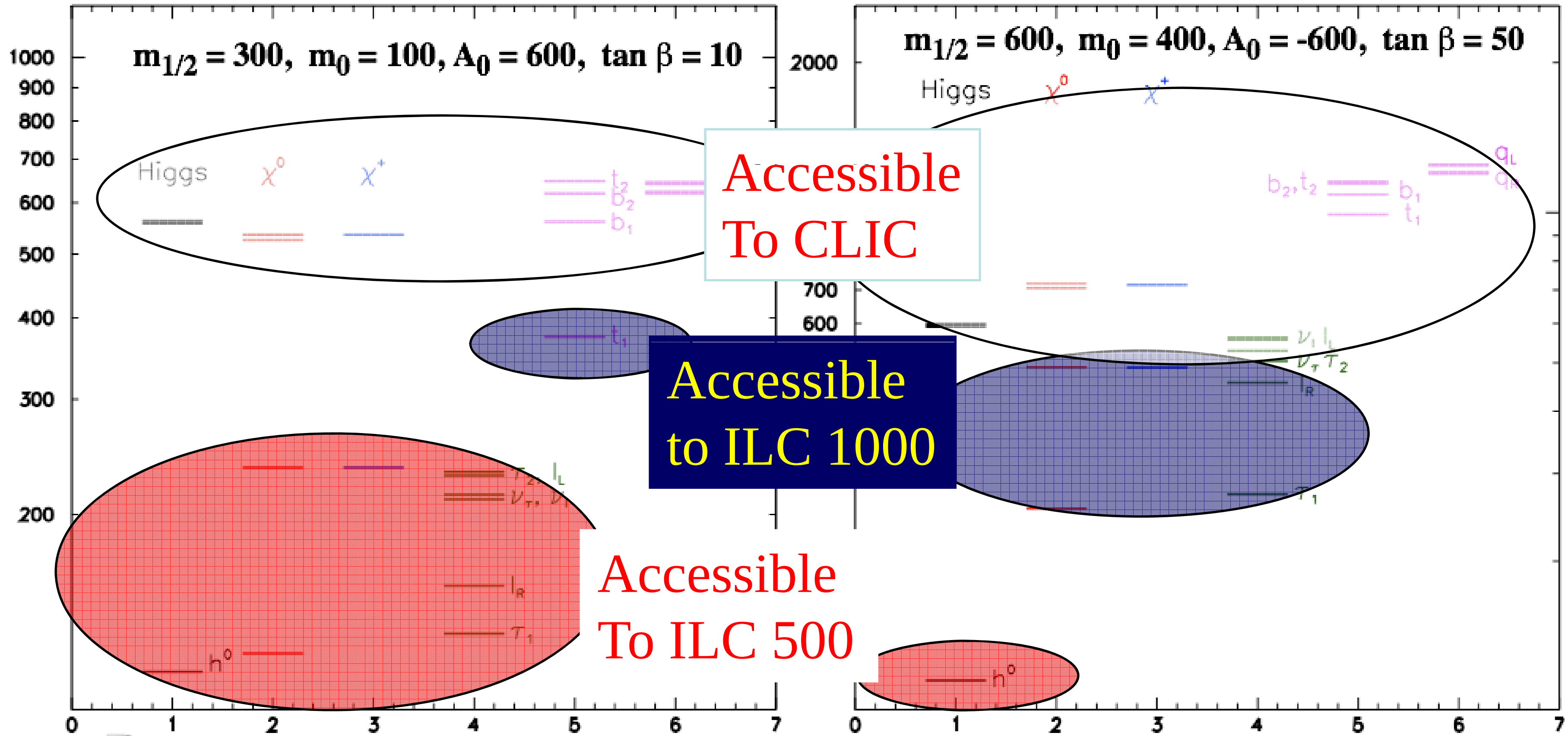
Corresponding sparticle thresholds @ LC

LHC will tell LC where to look

‘month’ @ 10^{32}	‘month’ @ 10^{33}	1 ‘year’ @ 10^{33}	1 ‘year’ @ 10^{34}

Blaising, JE et al: 2006

Spectra at Best-Fit Points



A lot for CLIC to study!

Energy Scan for CLIC?

IF NEW PHYSICS IS DISCOVERED at LHC

than

A LINEAR COLLIDER WILL BE BUILT

WE HAVE TO PREPARE THE TECHNOLOGY

TO PROPOSE THE APPROPRIATE ACCELERATOR

AT THE RIGHT TIME

YOU ARE WELCOME ON BOARD

Try to be a good student, better than the teacher

For example………

1) Do not forget the applications

CNAO: Centro Nazionale Adroterapia Oncologica

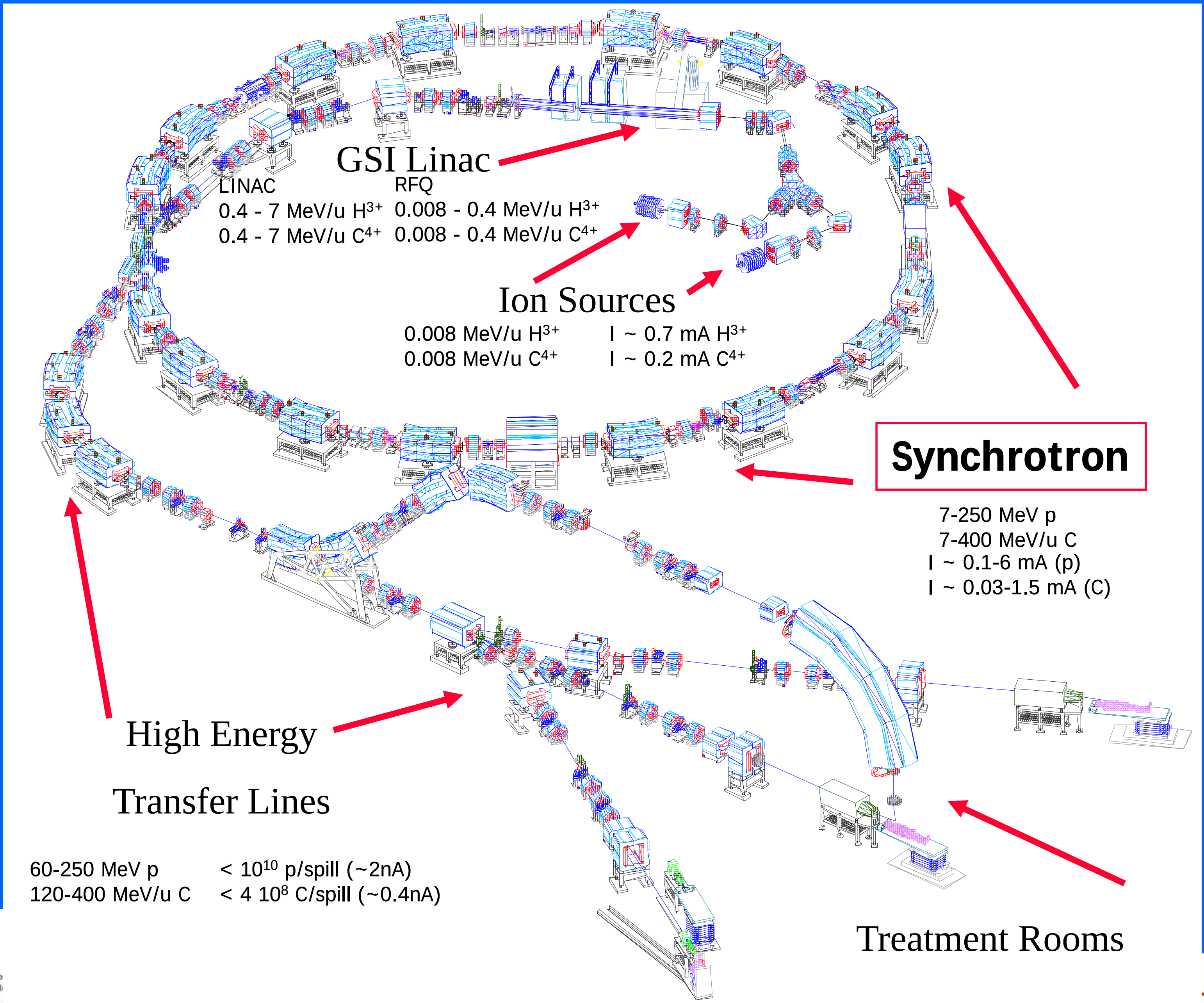
SPARC : Free Electron Laser

2) Very important: use YOUR fantasy and creativity

Plasma Wave Field Acceleration

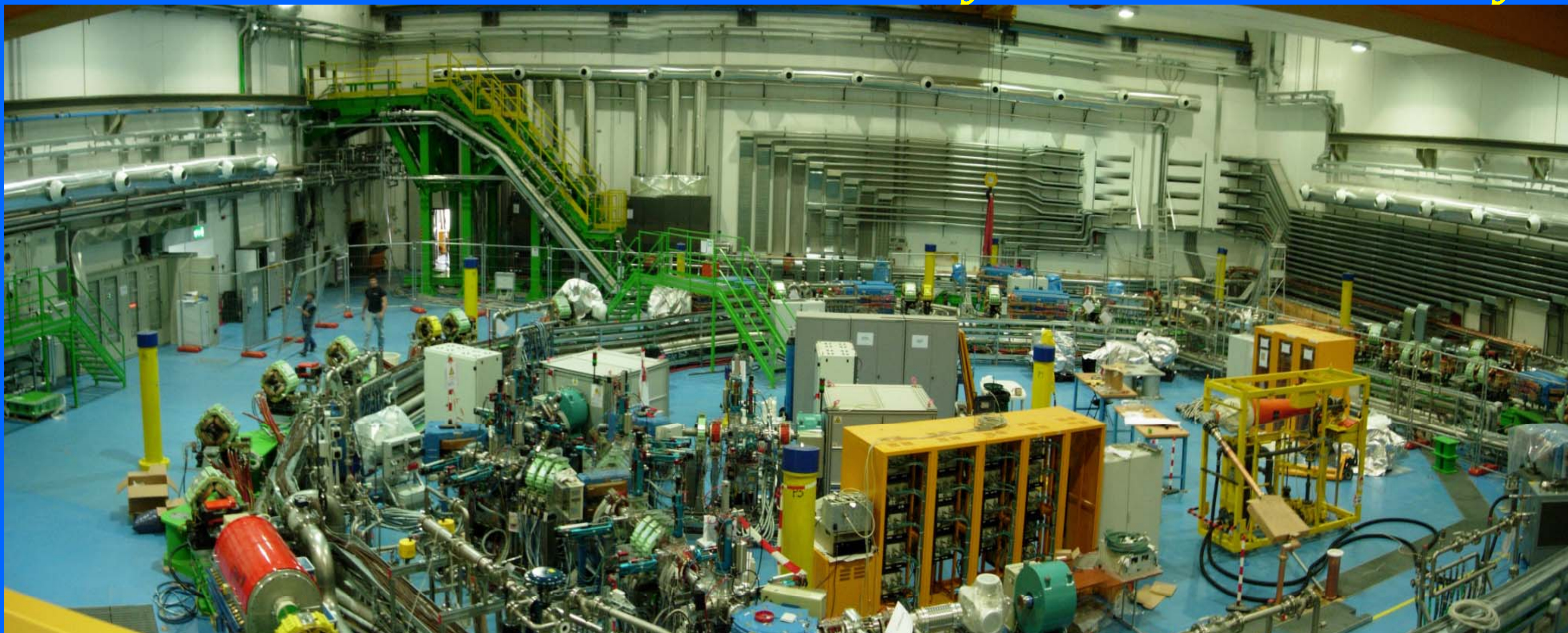
The "FLAME" project at LNF: 300 TW, 0.8 m, 20 ft laser pulse

The CNAO High technology



INFN Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

Synchrotron hall today



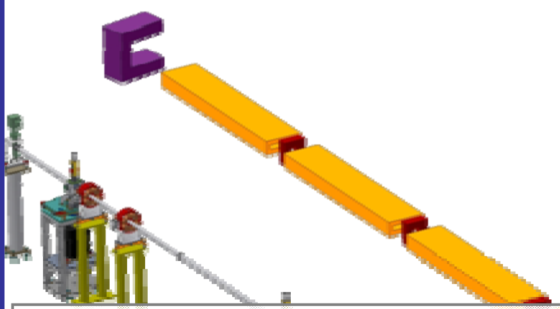
The INFN-LNF in Pavia

Cancer therapy

ECR Ion Sources for CNAO

Ions	Current (requested) [μA]	Current (available) [μA]	After improvements by INFN-LNS [μA]	Emittance (requested) π mm.mrad	Emittance (new extractor) π mm.mrad	Stability [99,8%]
C^{4+}	200	200	250	0.75	0.56	36 h
H_2^+	1000	1000		0.75	0.42	2 h
H_3^+	700	600	1000	0.75	0.67	8 h
He^+	500	500		0.75	0.60	2 h

NEW INSTRUMENTS



GUN PARAMETERS

Frequency: 2856 MHz

Peak Field: 120 MV/m

Beam Energy: 5.6 MeV

Charge: 1 nC

Emittance < 2 mm-mrad

Laser: 10 ps (Flat Top with <2 ps rise time)

LINAC PARAMETERS

Frequency: 2856 MHz

Accelerating Field: 25 MV/m

Beam Energy: 155 MeV

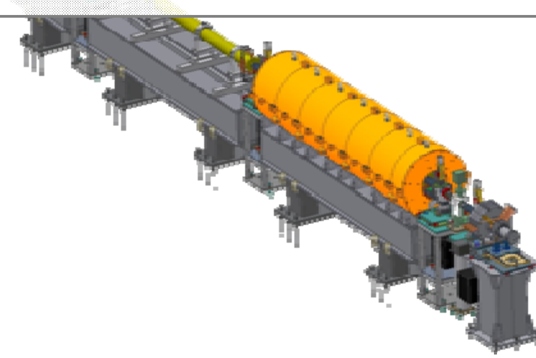
Energy Spread 10^{-3}

Peak Current 100 A

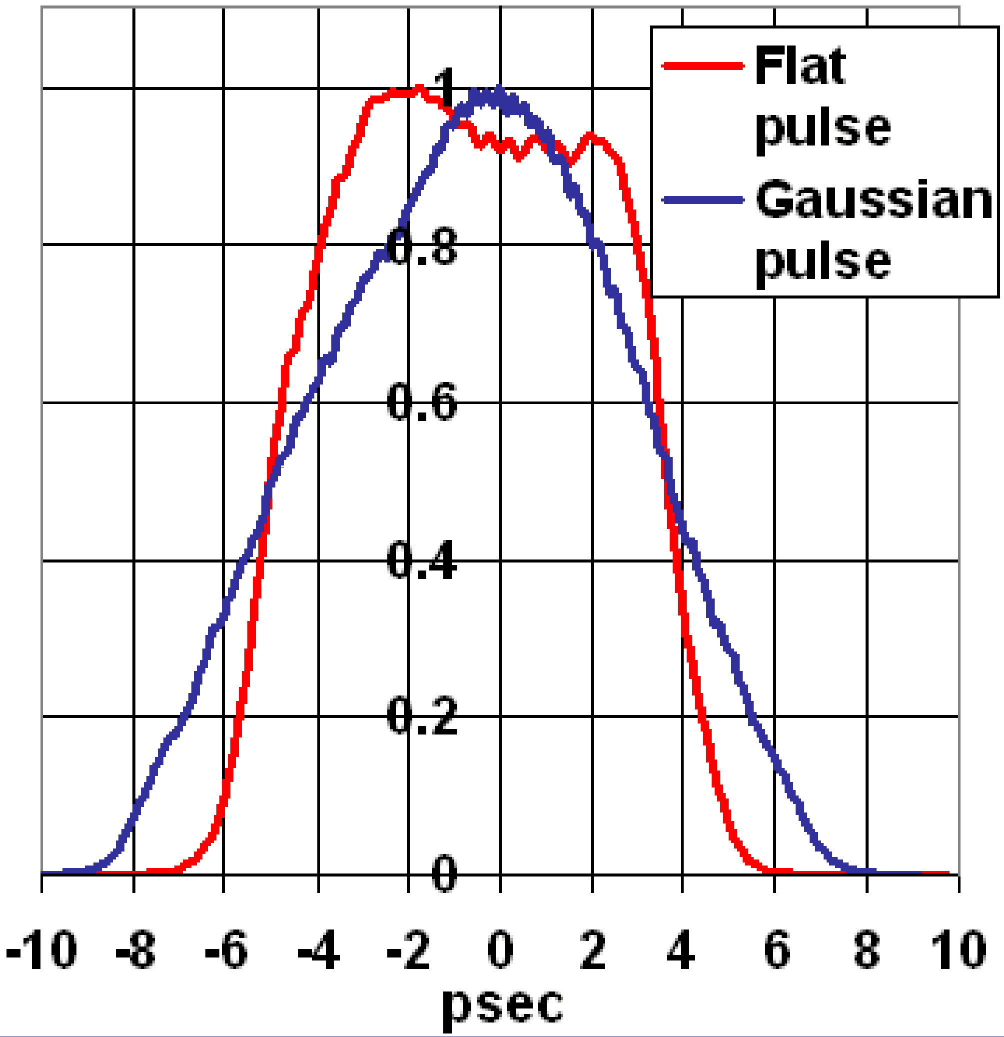
FEL PARAMETERS

Wavelength: 530 nm

Undulator period 2.8 cm



Emittance for flat top and gaussian pulse shape

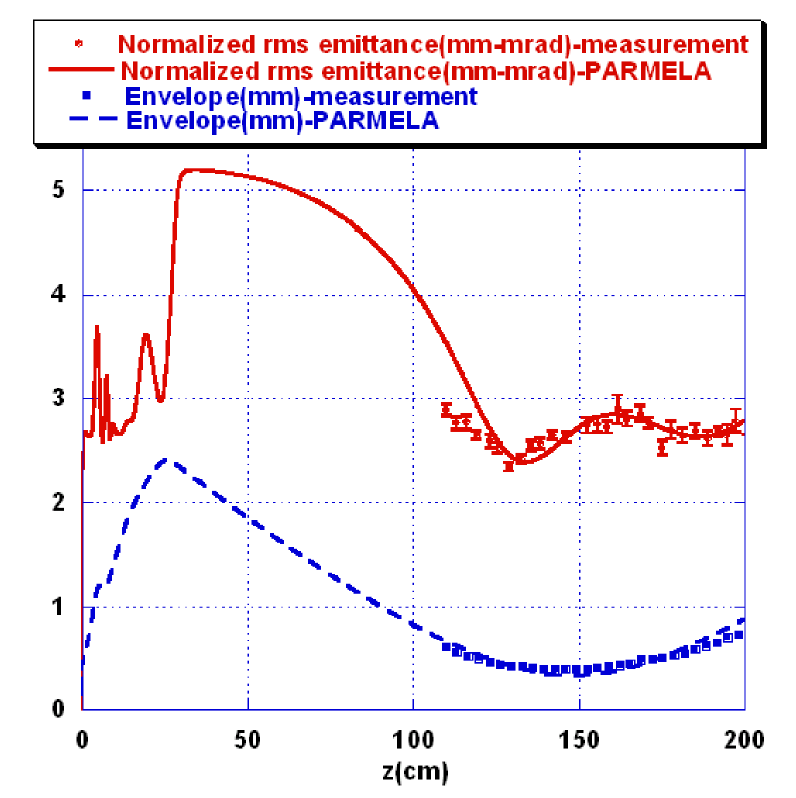


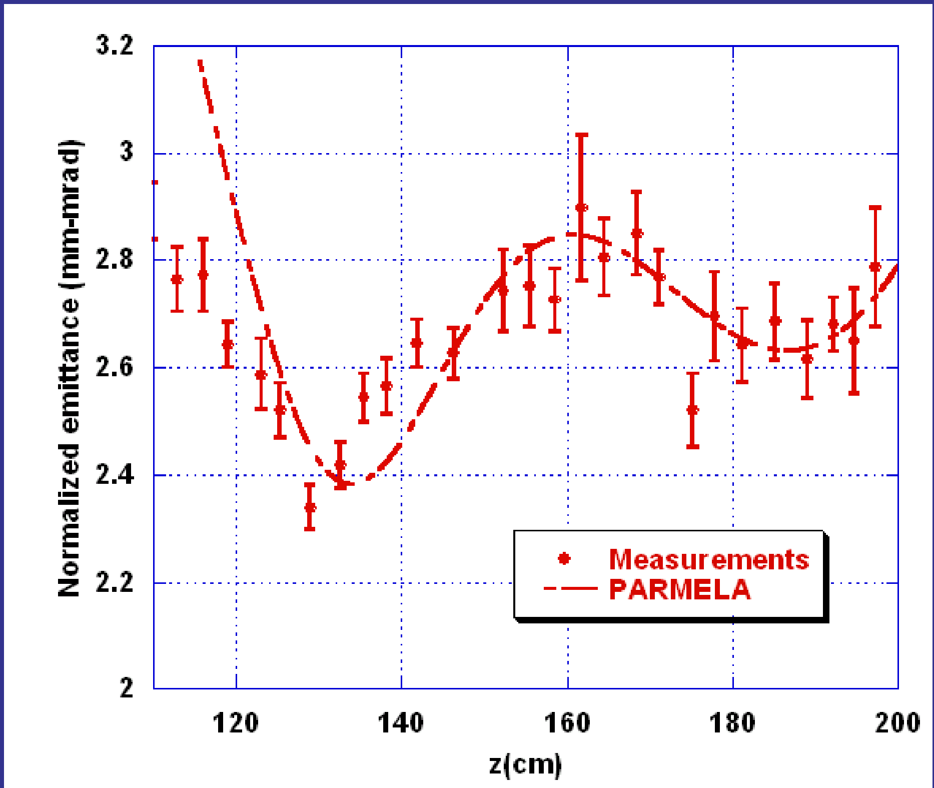
charge	0.74 nC
pulse length (FWHM)	8.7 ps
rise time	2.6 ps
rms spot size	0.31 mm
RF phase (φ-φ_{max})	-8°

PRL 99, 234801 (2007) PHYSICAL REVIEW LETTERS week ending 7 DECEMBER 2007

Direct Measurement of the Double Emittance Minimum in the Beam Dynamics of the Sparc High-Brightness Photoinjector

M. Ferrario,[1] D. Alesini,[1] A. Bacci,[3] M. Bellaveglia,[1] R. Boni,[1] M. Boscolo,[1] M. Castellano,[1] L. Catani,[2] E. Chiadroni,[1] S. Cialdi,[3] A. Cianchi,[2] A. Clozza,[1] L. Cultrera,[1] G. Di Pirro,[1] A. Drago,[1] A. Esposito,[1] L. Ficcadenti,[5] D. Filippetto,[1] V. Fusco,[1] A. Gallo,[1] G. Gatti,[1] A. Ghigo,[1] L. Giannessi,[4] C. Ligi,[1] M. Mattioli,[7] M. Migliorati,[5] A. Mostacci,[5] P. Musumeci,[6] E. Pace,[1] L. Palumbo,[5] L. Pellegrino,[1] M. Petrarca,[7] M. Quattromini,[4] R. Ricci,[1] C. Ronsivalle,[4] J. Rosenzweig,[6] A. R. Rossi,[3] C. Sanelli,[1] L. Serafini,[3] M. Serio,[1] F. Sgamma,[1] B. Spataro,[1] F. Tazzioli,[1] S. Tomassini,[1] C. Vaccarezza,[1] M. Vescovi,[1] and C. Vicario[1]





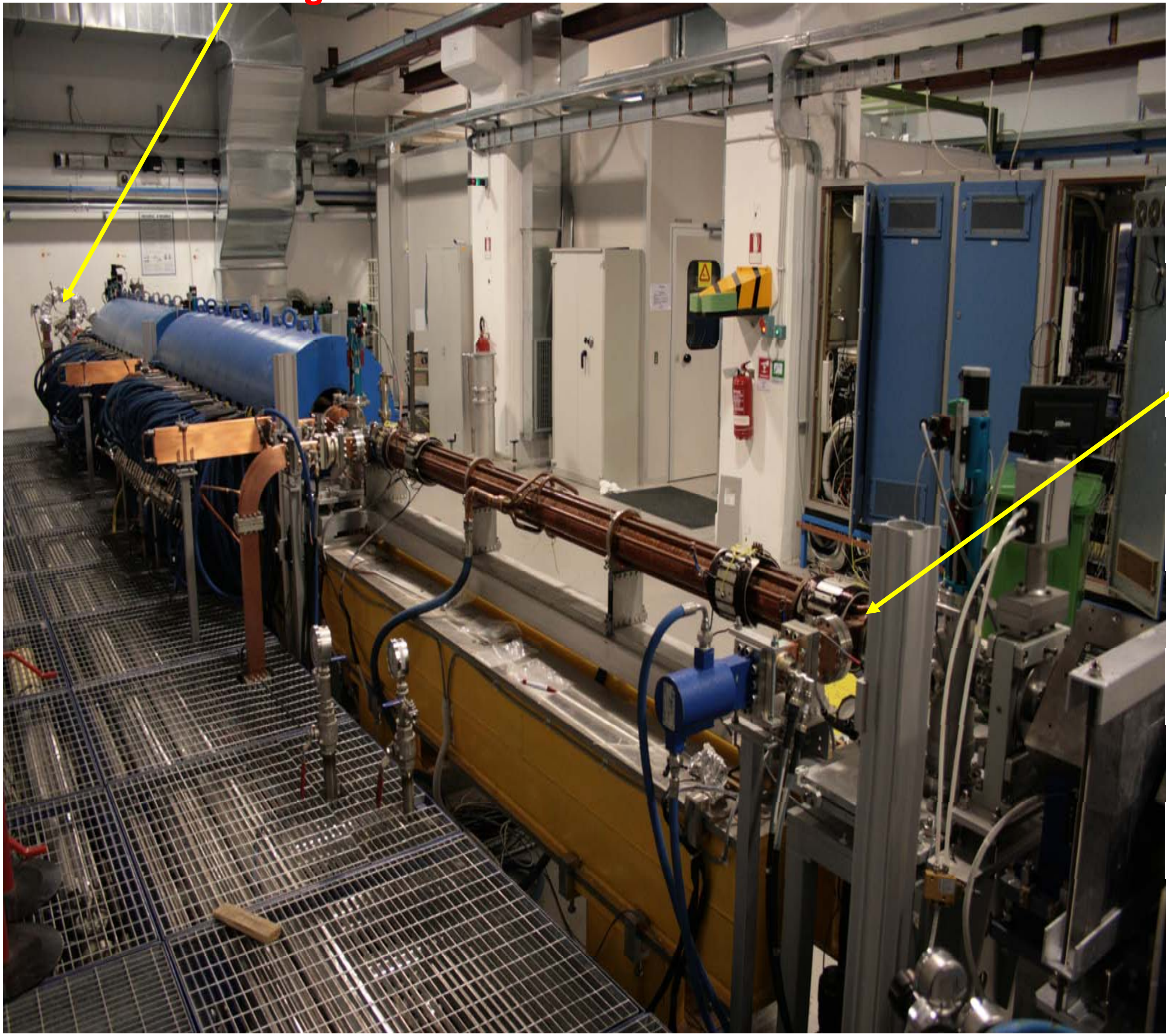
The LNF beam EMITTANZOMETER

- **BNL-SLAC-UCLA design 1.6 cells S-band rf-gun**

Electron gun

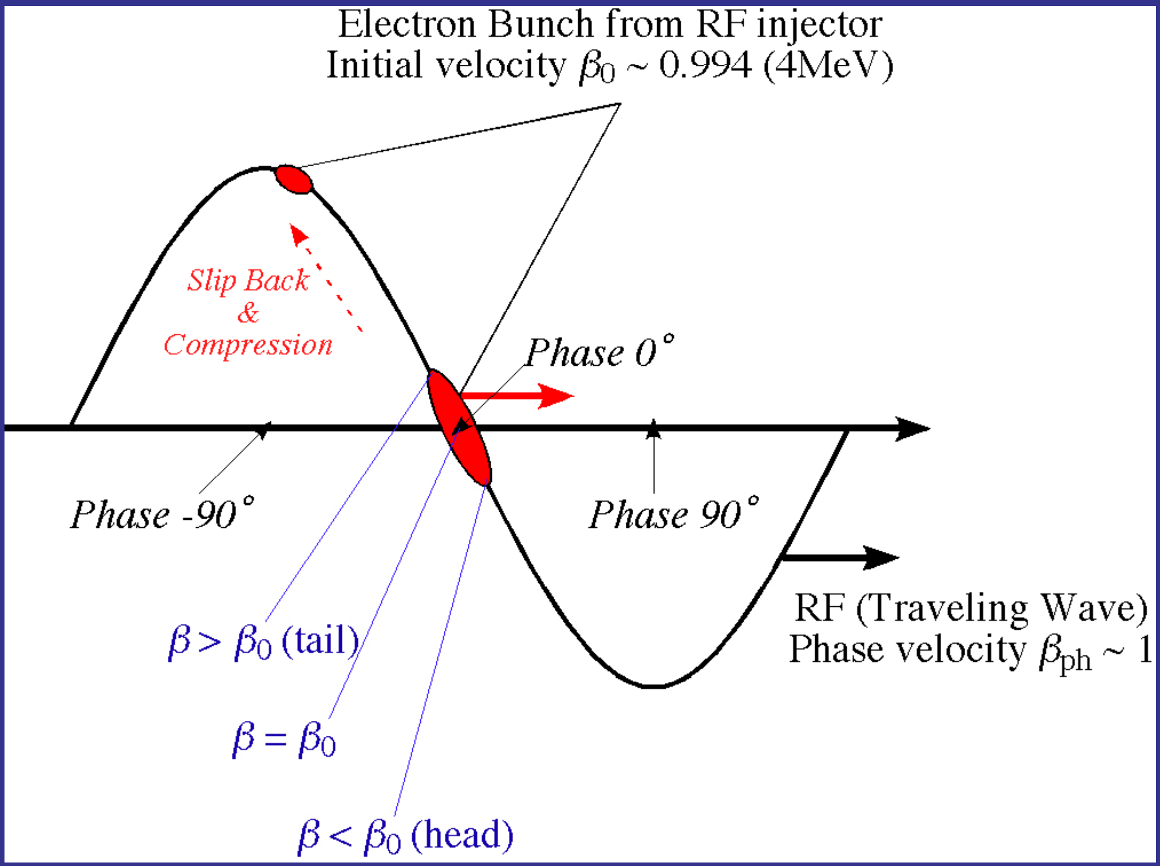
S-Band LINAC

SPARC



150 MeV

Velocity bunching scheme



$$E_z = E_0 \sin(\phi)$$

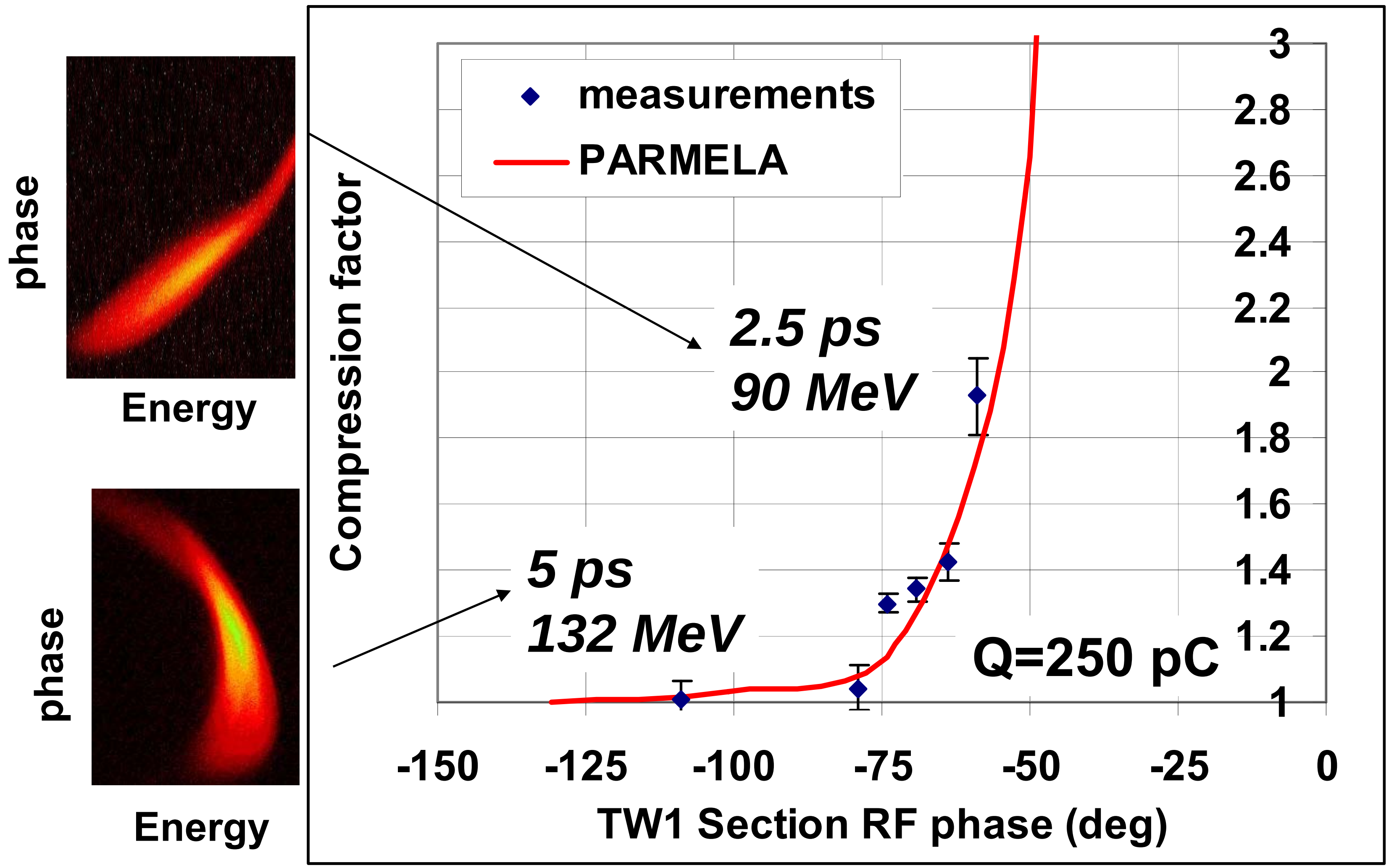
$$\phi = kz - \omega t + \phi_0$$

$$\frac{d\gamma}{dz} = -\alpha k \sin\phi,$$

$$\frac{d\phi}{dz} = k\left[1 - \frac{\gamma}{\sqrt{\gamma^2 - 1}}\right].$$

$$\alpha \equiv eE_0/mc^2k$$

Preliminary results in "velocity bunching" regime



A new Project : X-FEL SPARX

Very intense X-ray bursts for medical science, material science, biology …ecc
..it is like having a better microscope in space and time….

but also accelerator R&D

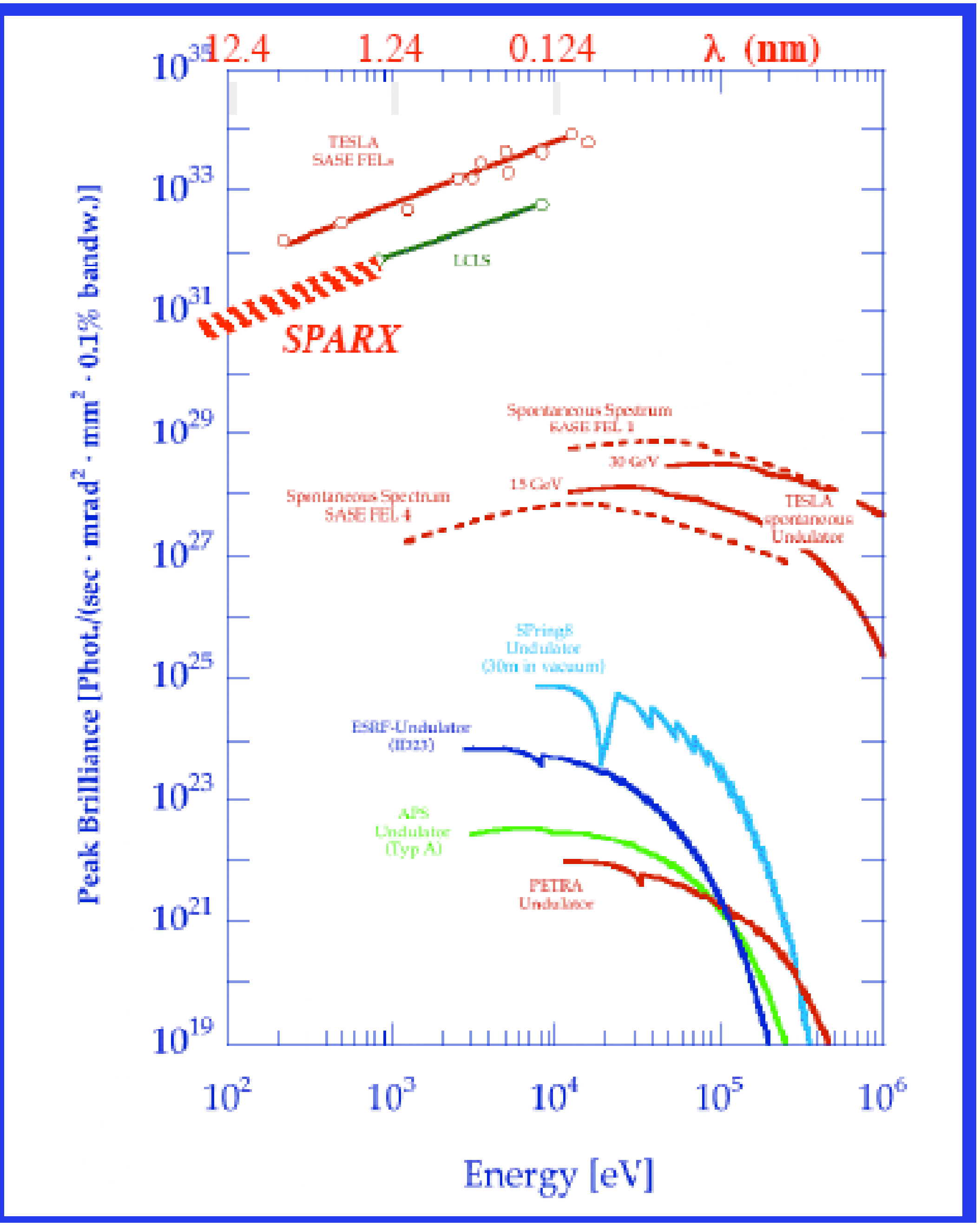
2008-2013

X rays Free Electron Laser

SASE RADIATION

A new project for the LNF:

A X-FEL in the Tor Vergata Campus

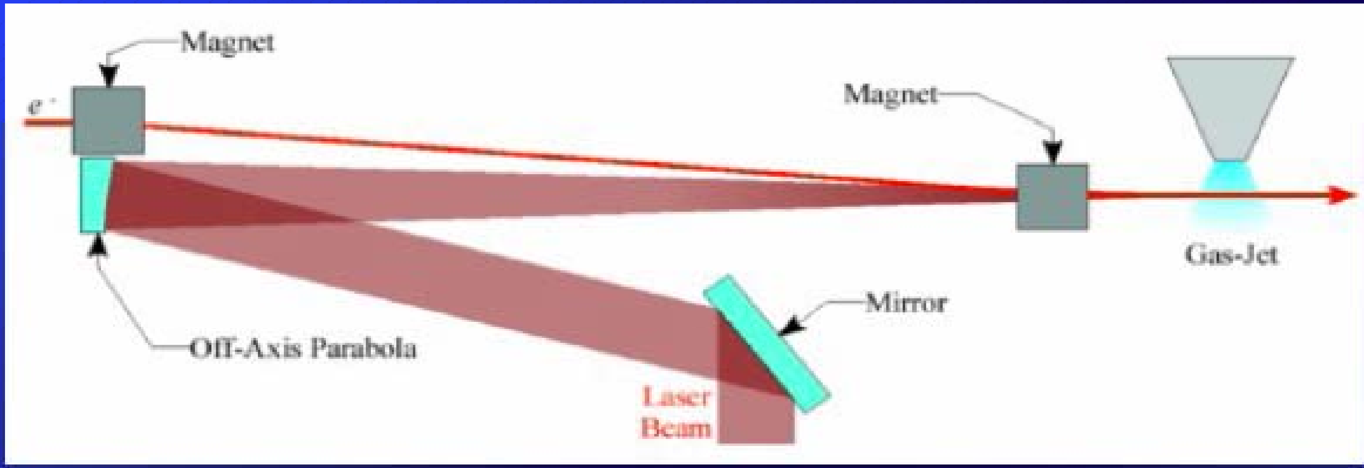


Again……..:

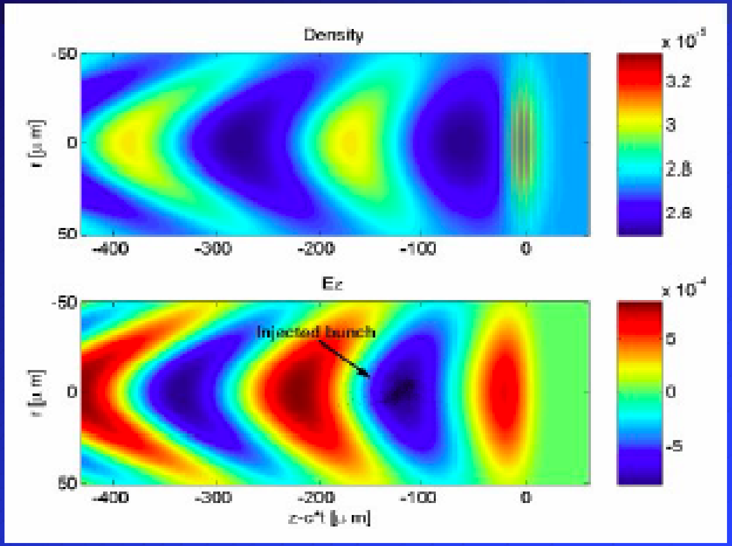
The future will profit from your fantasy and creativity

For example: Plasma Wake Field Acceleration

Wakefield Laser-Plasma Acceleration (WLPA) of externally injected electron bunches

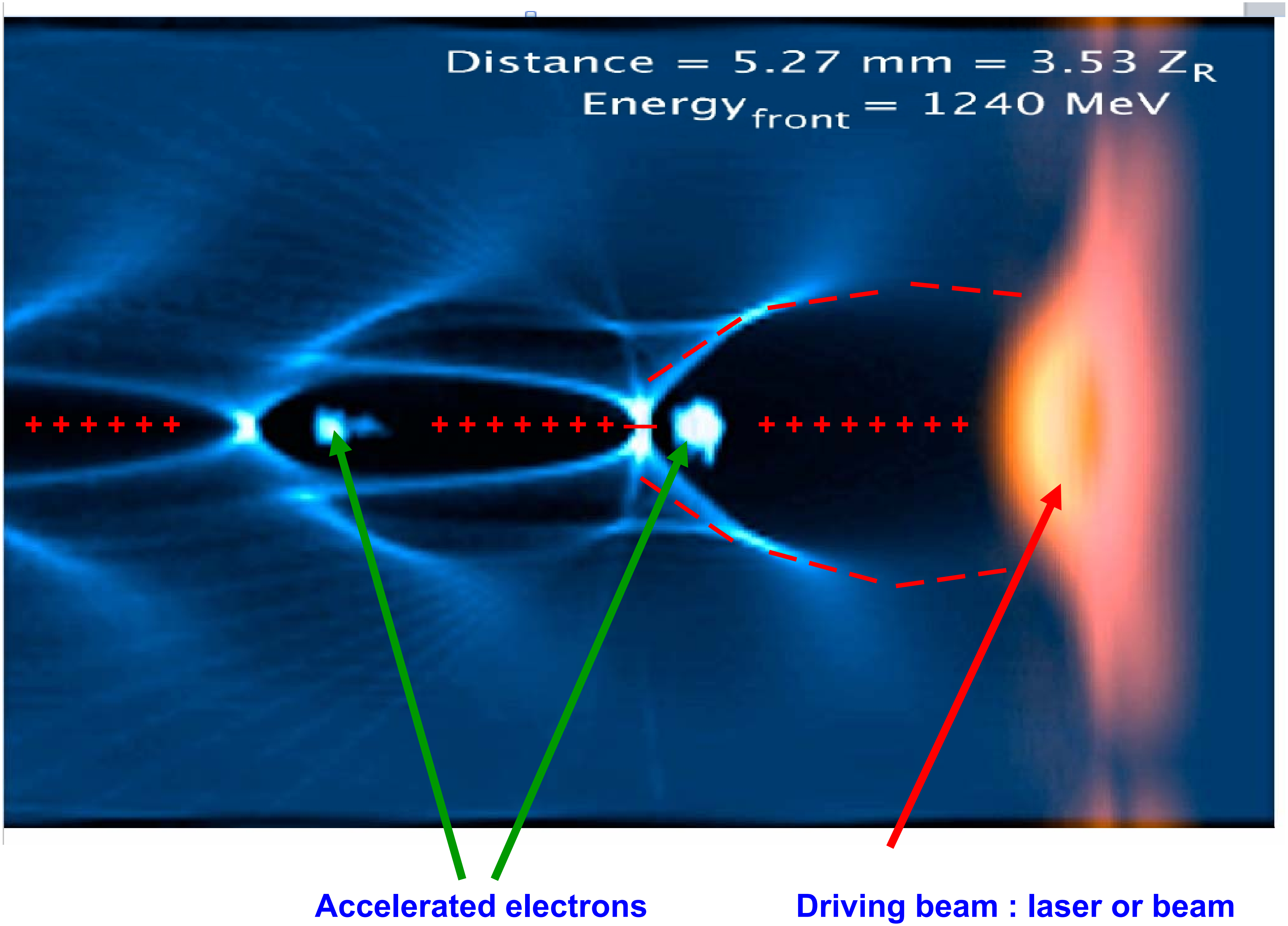


Acceleration of electron bunches injected in laser excited longitudinal electron plasma waves requires synchronization at the level of the period of the electron plasma wave.

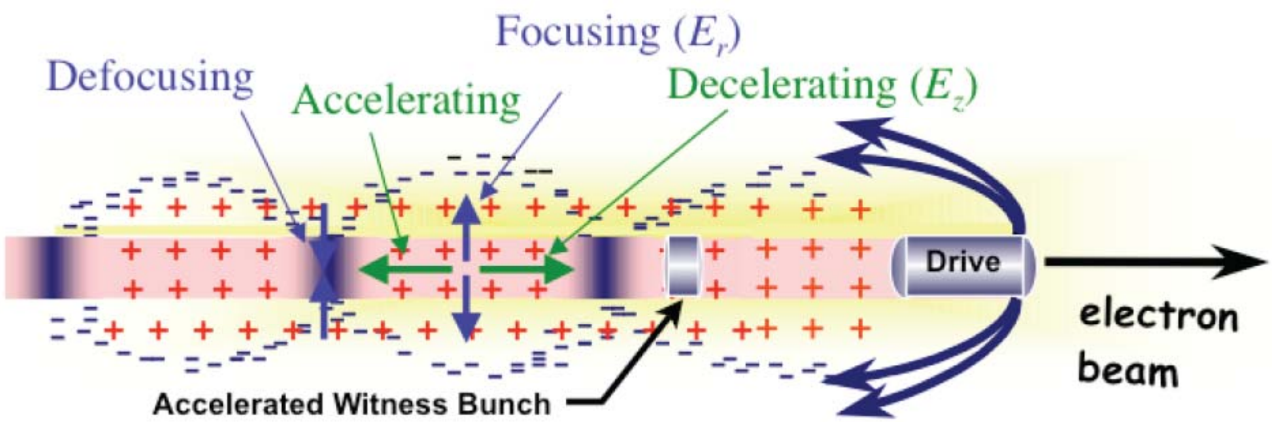


Stability required <100 fs

PlasmonX

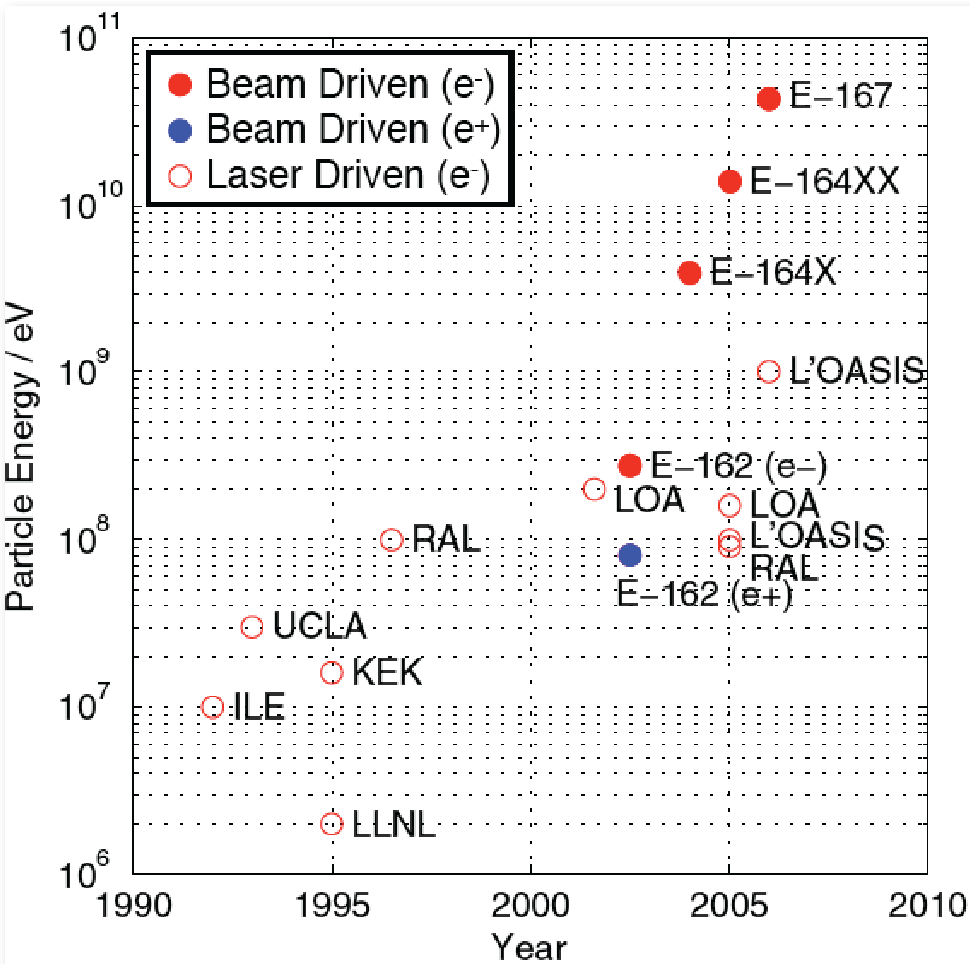

Distance = 5.27 mm = 3.53 Z_R
$Energy_{front}$ = 1240 MeV
Accelerated electrons
Driving beam : laser or beam

How does it work ?



1979 Tajima & Dawson Paper

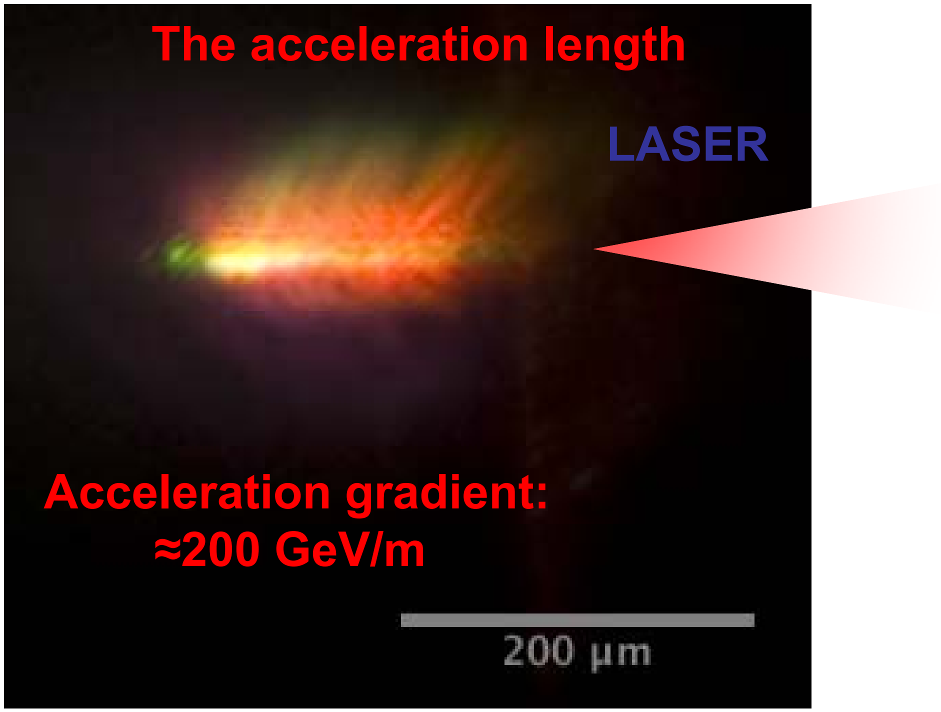
Plasma Weak-Filed Acceleration

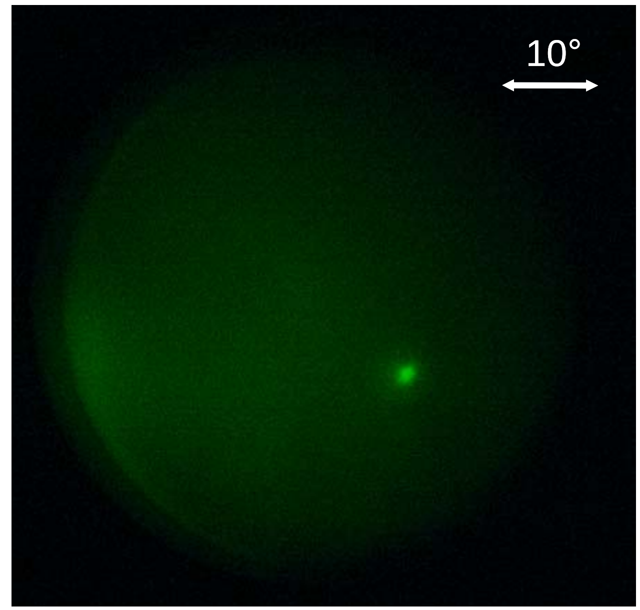


Time evolution of electron energy gain

THE “FLAME” LAB at LNF

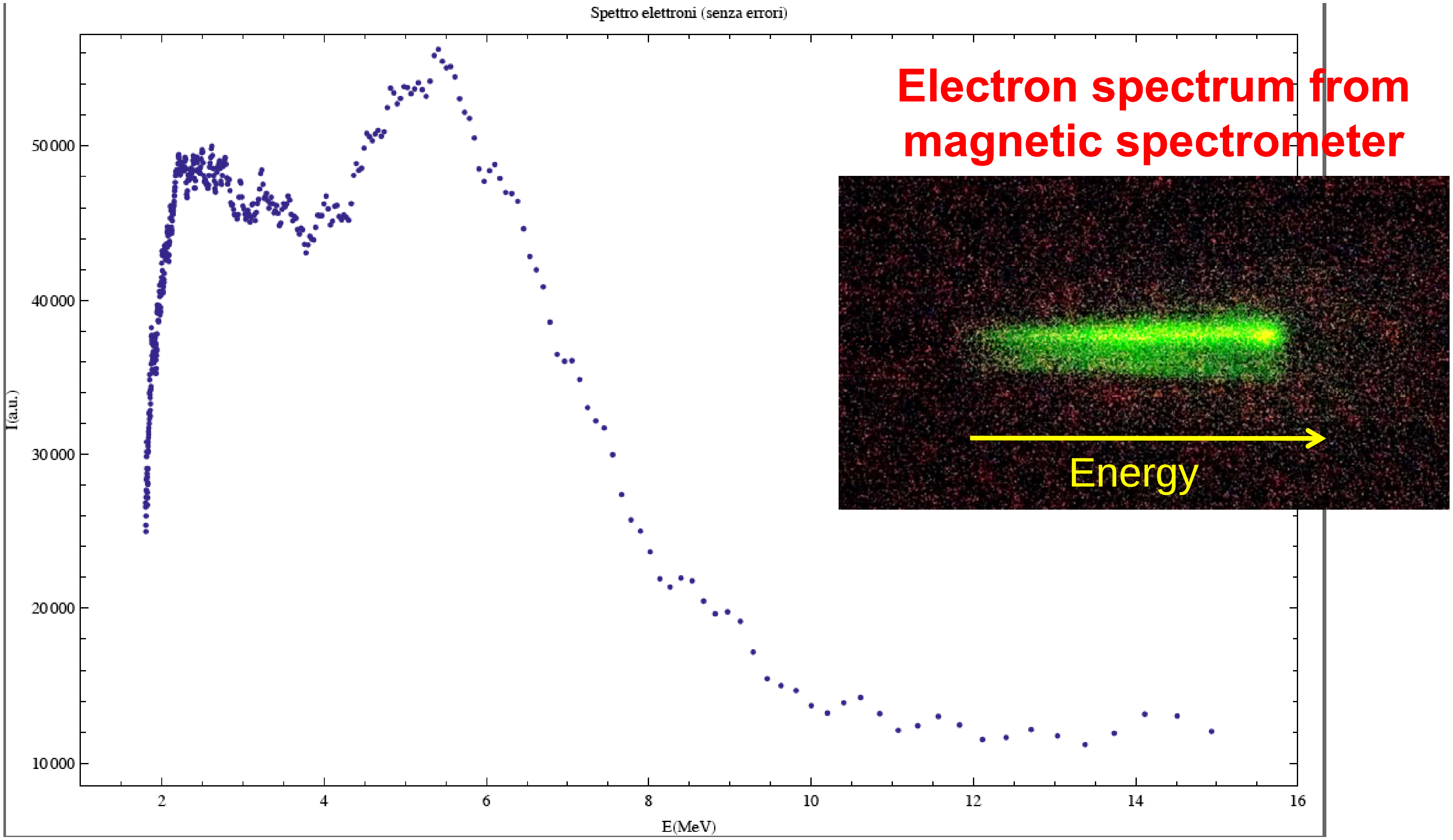
FIRST EXPERIMENTS @ CNR-INFN PISA





La diffusione Thomson della radiazione laser mostra il canale di bassa densità in cui gli elettroni sono accelerati . Sullo schermo LANEX è visulalizzato lo spot degli elettroni accelerati.

PLASMONX: first electron spectra



Electrons bunch up to about 15 MeV.

At SLAC:

- ~50GeV/m acceleration in one meter of plasma at SLAC , with electrons as the driving beam

* High efficiency of energy transfer (1/3)

- Is a linear collider possible?

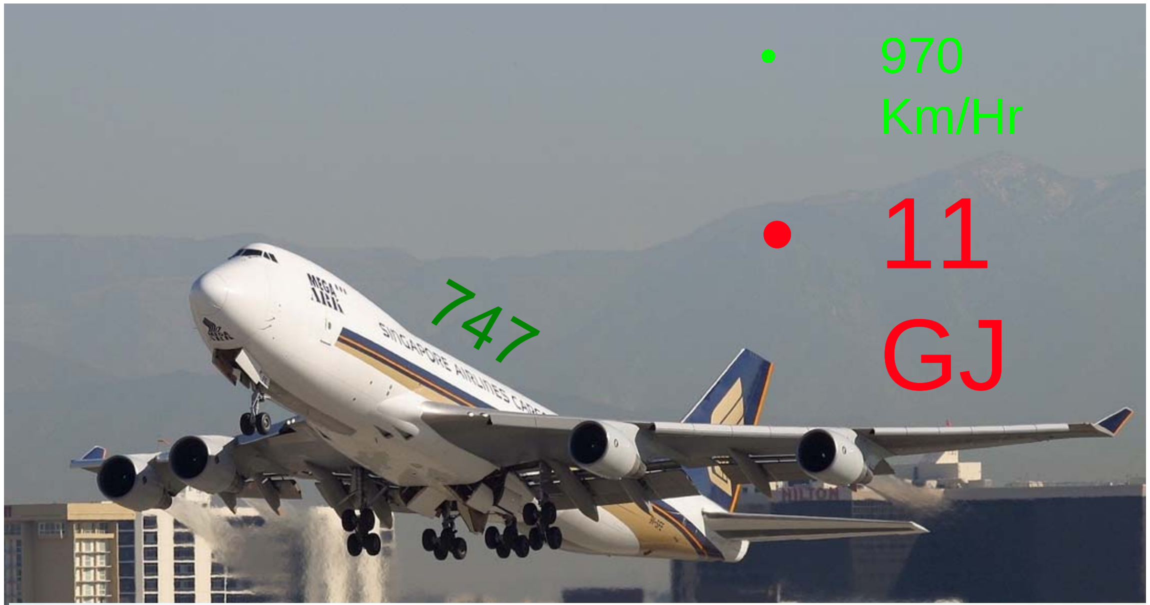
LHC is a formidable machine

Stored energy in the beam: 300 MJ (Tevatron is 1 MJ)

Stored energy in the guide field:

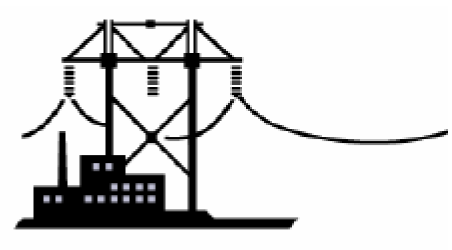
10.6 GJ (Tevatron is 0.3 MJ)

So….why not to try?



Plasma WF LC, Luminosity & Efficiency

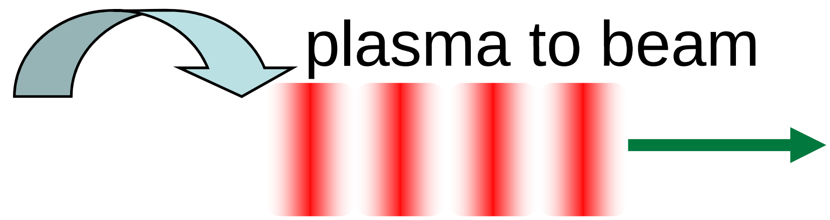
- **TeV collider call for P_{beam} ~10 MW of continuous power, small emittances and nanometer beams at IP**



Wall-plug

Mechanism to transfer energy to waves in plasma

plasma to beam



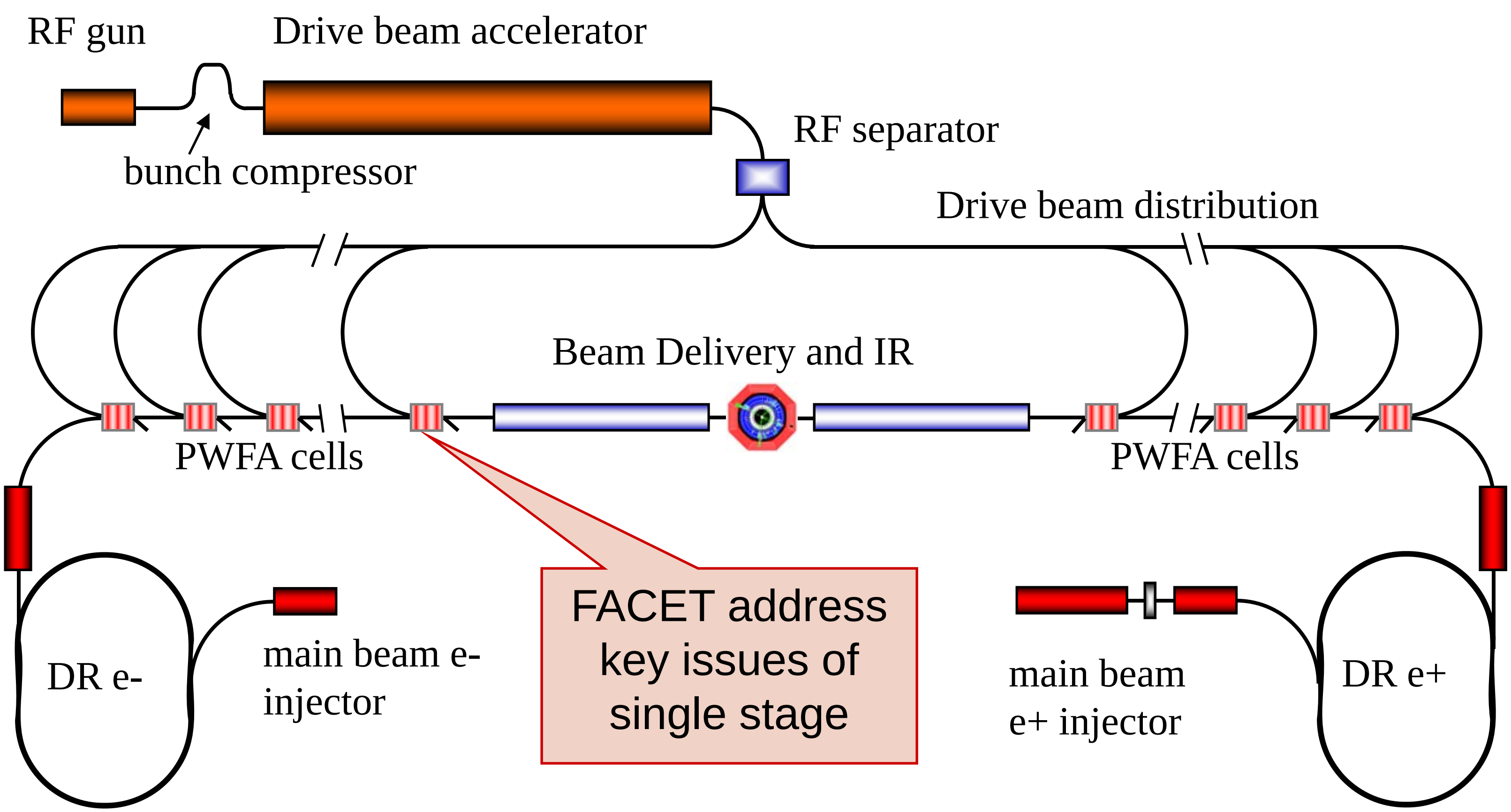
plasma wave

- **An efficient approach to transfer several tens of MW of continuous power to plasma is to use drive beam**

beam power ~ 20MW

A concept for Plasma Wake Field Acceleration 1TeV CM Linear Collider

10 M



Much less storage energy in the B field

conferenze, workshop, corsi 51
studenti ai LNF 2844

525 insegnanti ai LNF NEL 2007

VISITE AI LNF giornata europea della ricerca scientifica **4000 persone nei LNF**

LNF WORK IN PROGRESS:

1) TEST OF THE CRAB-WAIST METHOD
2) INCREASE OF THE DAFNE LUMINOSITY
3) RUN OF THE SIDDHARTA EXPERIMENT
4) RUNNING-IN OF KLOE, FALL 2009

5) SPARC LASERING
6) FLAME LASER COMMISSIONING
7) BEGINNING OF EXPERIMENTS WITH HIGH INTENSITY LASERS
8) COMMISSIONING OF CLIC-CTF3 AT CERN
9) COMMISSIONING OF THE CNAO SYNCROTRON
10) RUN OF OUR PART OF THE LHC EXPERIMENTS

I WISH YOU A PROFITABLE AND NICE WEEK HERE IN FRASCATI


Spring time at LNF