Plans an perspectives for the INFN Frascati National Laboratory

Istituto Nazionale di Fisica Nucleare

Laboratori Nazionali di Frascati

Laboratori Nazionali di Frascati (LNF) is the oldest (1955) Italian research infrastructure for fundamental research. It is also the biggest lab of Istituto Nazionale di Fisica Nucleare (INFN), the institution that in Italy funds and coordinates the research for Nuclear and Particle Physics.

Frascati National Lab (LNF)

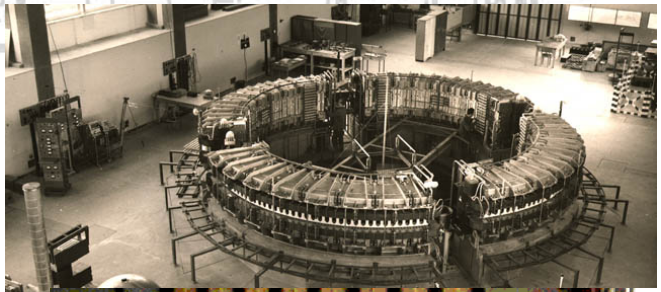
Total Staff of which: 293	Researchers 80	Technologist/ Engineers 38	Technicians 142	Administration/ Services 33
External Users 501	*Italian* 257		*Foreign* 244	
Visitors 3426	Stages 184	Conference Workshops 21	Participants to Seminars 765	Course for teachers of high school 172

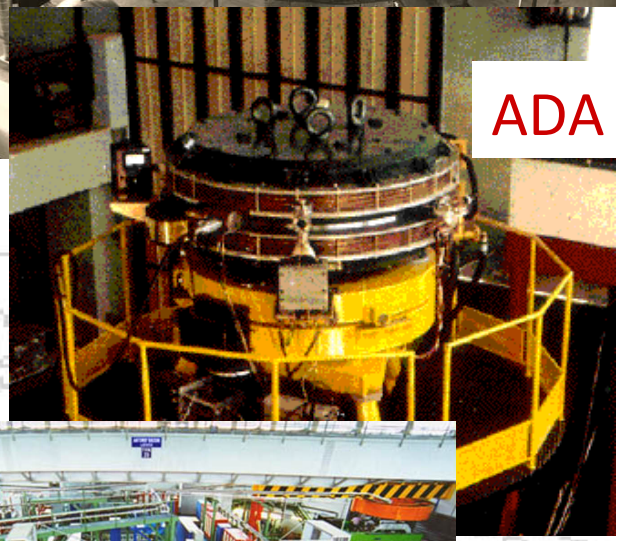
year 2012 numbers

LNF History

The tradition of the lab has been always in the field of hadronic physics:

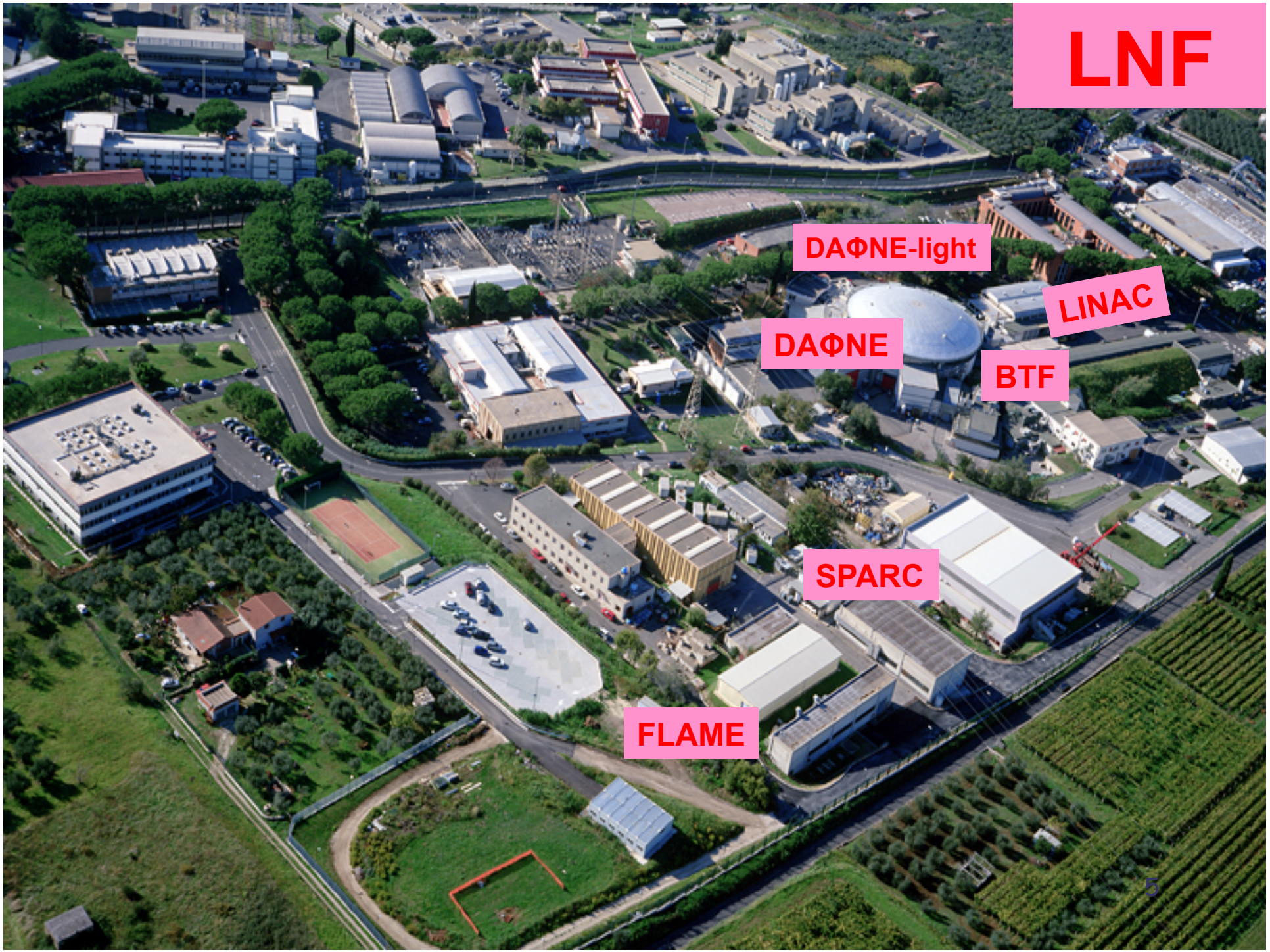
- 1959 – 1975 Electro-Syncrotron (max energy 1.1 GeV);
- 1960 Anello di Annichilazione First particle collider (beam energy 200 MeV);
- 1969 – 1993 ADONE e^+e^- collider (c.m. energy up to 3 GeV);
- 2001 – today DAΦNE e^+e^- collider (c.m energy 1.120 GeV);





ADA

DAΦNE


LNF
DAΦNE-light
LINAC
DAΦNE
BTF
SPARC
FLAME

LNF activities

Developments of new accelerator technique
CTF3
CLIC

Research and Developments of Detectors

Hadron therapy
CNAO

Medical Application

CABIBBOLAB
LABORATORIO NICOLA CABIBBO

DAΦNE

KLOE
upgrade on going

FINUDA
end of data taking in 2007

SIDDHARTA
end of data taking in 2009

Syncrotron light
LdS

X-ray Laboratory

Free Electron Laser (FEL)
SPARC

ATLAS-CERN
CMS-CERN
LHC-b-CERN
ALICE-CERN

Jlab12-JLab
Mambo-Bonn
PANDA-FAIR

NA62-CERN

CDF2-FermiLAB
BABAR-SLAC
.....

High intensity laser
FLAME

Cryogenic antenna
NAUTILUS

Physics in space

Astro-particles Physics

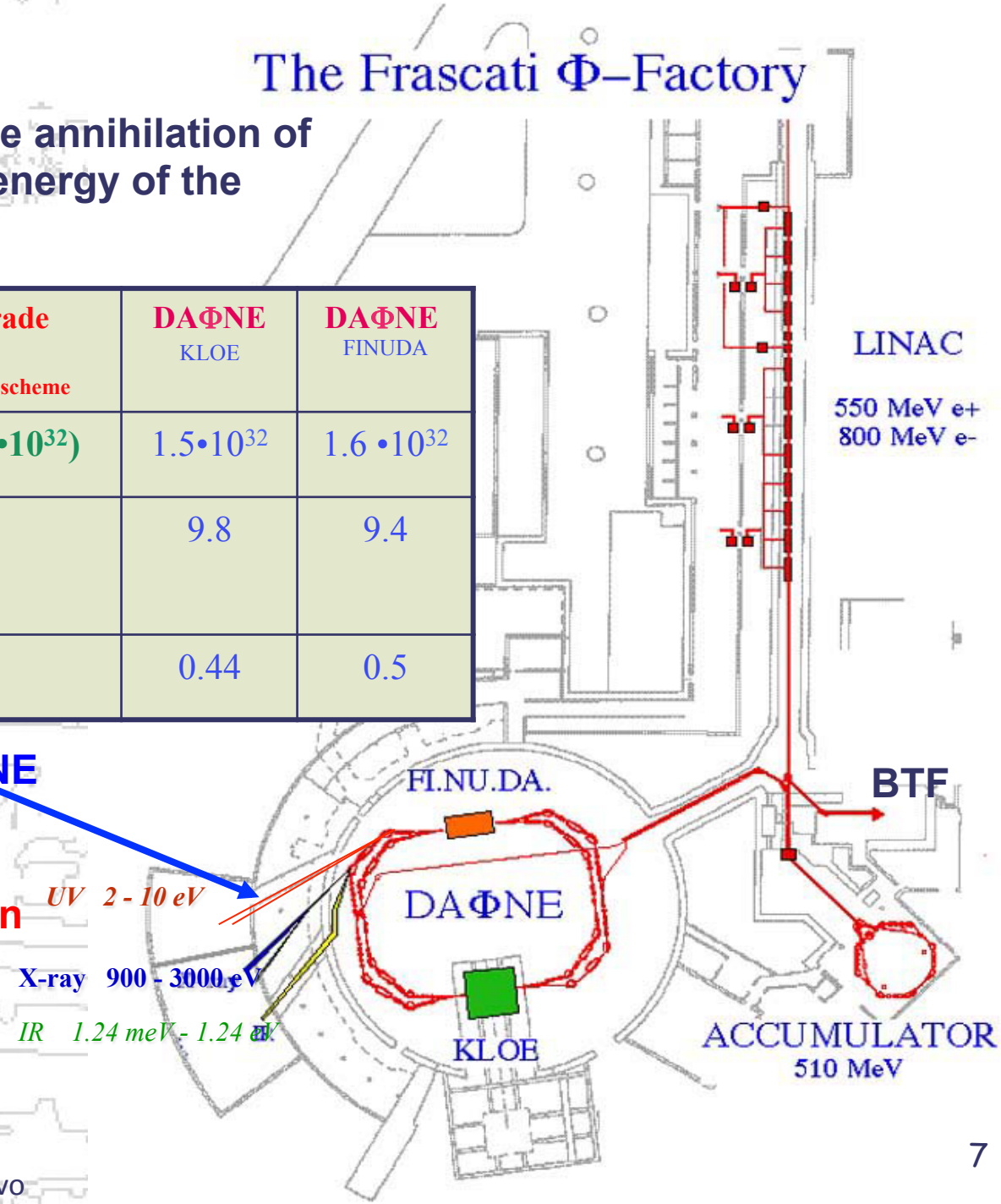
The Frascati Φ–Factory

Production of Φ particles via the annihilation of electrons and positrons at the energy of the resonance.

	DAΦNE upgrade SIDDHARTA Crab Waist collision scheme	DAΦNE KLOE	DAΦNE FINUDA
L_{peak} [$cm^{-2}s^{-1}$]	$4.53 \cdot 10^{32}$ ($5.0 \cdot 10^{32}$)	$1.5 \cdot 10^{32}$	$1.6 \cdot 10^{32}$
$L_{\int day}$ [pb^{-1}]	14.98	9.8	9.4
$L_{\int 1\ hour}$ [pb^{-1}]	1.033	0.44	0.5

Syncrotron ligth from DAΦNE

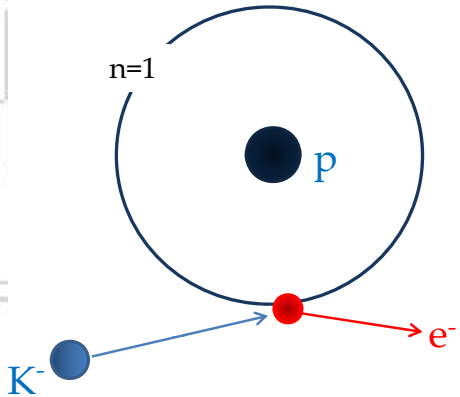
LNF are part of the European Infrastructure for syncrotron light



Kaonic Atoms

The study of Kaonic-atoms is a doorway for the determination of the ***isospin dependent KN scattering lengths***.

This is done through a *precision measurement of the shift* and *of the width* ***(induced by the strong interaction)*** of the $1s$ line of **kaonic hydrogen** and the of **kaonic deuterium**



$$n \approx \sqrt{\frac{m_{\mathrm{red}}}{m_e}}$$

SIDDHARTA measurements in 2009:

-Kaonic Hydrogen: 400 pb^{-1}

-Most precise measurement in the world

-Phys. Lett. B 704 (2011) 113, Nucl. Phys. A. (2012)

- Kaonic helium 4: 30 pb^{-1}

- first measurement in the world in gas

-Phys. Lett. B 681 (2009) 310

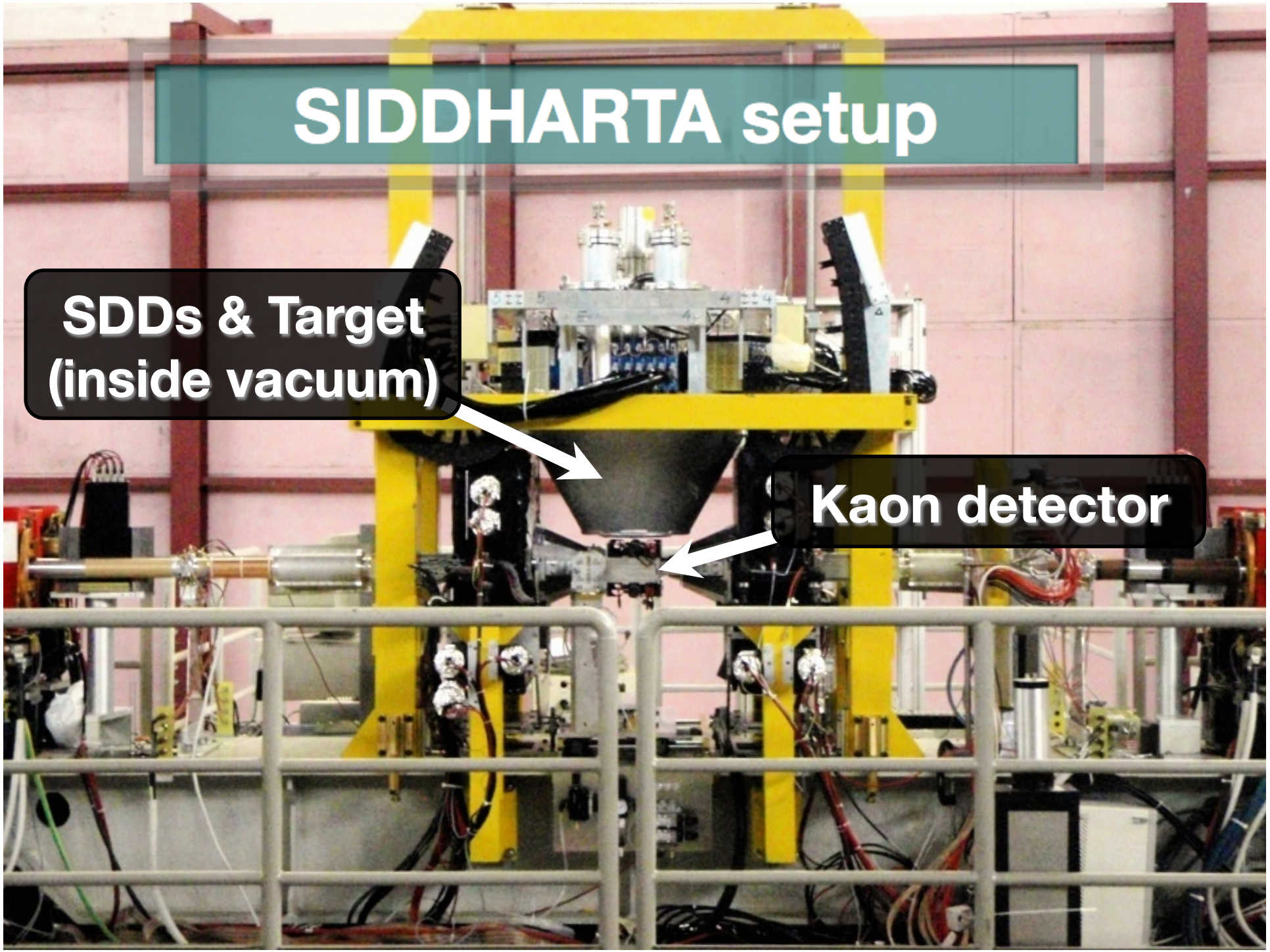
-Kaonic helium 3: 10 pb^{-1}

- first measurement in the world

Phys. Lett. B 697 (2011) 199

- Kaonic deuterium 100 pb^{-1},

- first exploratory measurement, small signal, significance ~ 2σ, paper in preparation.


SIDDHARTA setup
SDDs & Target
(inside vacuum)
Kaon detector

SIDDHARTA Future Plans

SIDDHARTA Physics program will continue for next years with SIDDHARTA-2.
The detector will be placed in the IP2 after the KLOE-2 data taking.

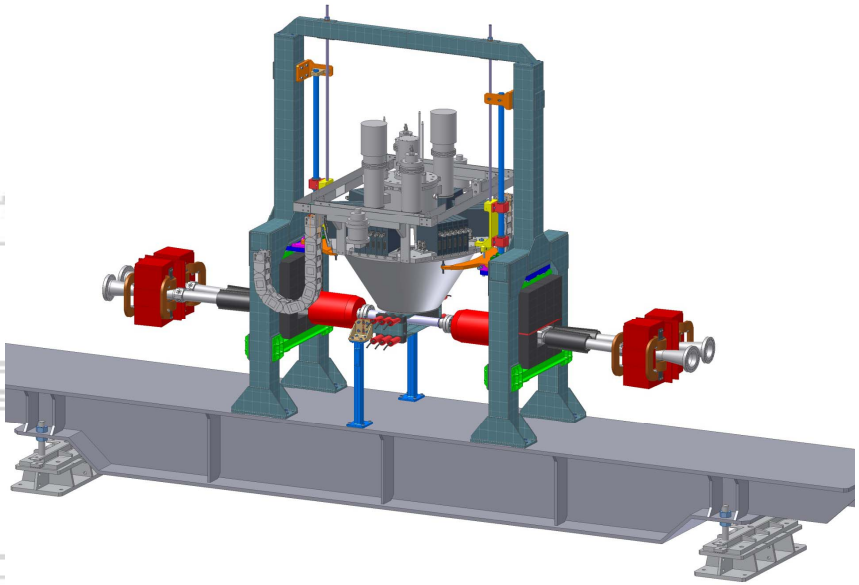
1) **Kaonic deuterium measurement - 1st measurement**

2) **Kaonic helium transitions to the 1s level**

3) **Other light kaonic atoms (KO, KC,…)**

4) **Heavier kaonic atoms measurement (Si, Pb…)**

5) **Kaon radiative capture – Λ(1405) study**



6) **Investigate the possibility of the measurement of other types of hadronic exotic atoms (sigmonic hydrogen?)**

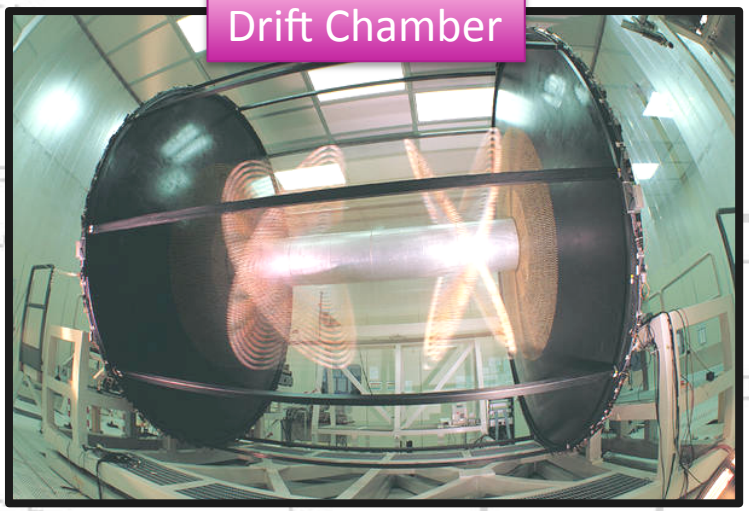
7) **Kaon mass precision measurement at the level of <10 keV**

KLOE at DAΦNE

The experiment has taken data from 2000 to 2006, collecting 2.5 fb^{-1} at the Φ peak, plus additional 0.25 fb^{-1} at 1000 MeV.

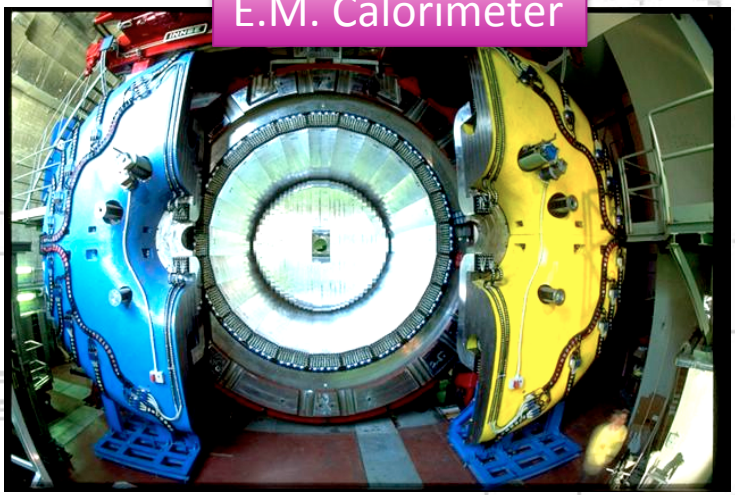
KLOE is multi-purpose detector optimized for KL physics

Drift Chamber



- Huge, transparent Drift Chamber in 5.2 kGauss field of a SC coil;
- Carbon fiber walls, 55000 stereo wires, 2 m radius, 4 m long, He/CO2 gas mixture;
- Momentum resolution: $\sigma(pT)/pT \sim 0.4\%$.

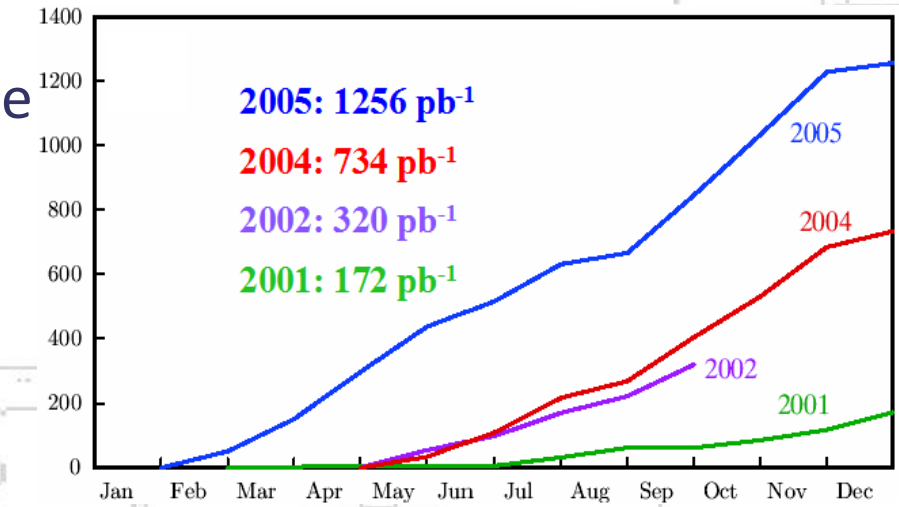
E.M. Calorimeter



- Pb-Scintillating Fiber Calorimeter with excellent timing performance
- 24 barrel modules, 4 m long and C-shaped End-Caps for 98% solid angle coverage
- Time resolution = 54 ps / $\sqrt{E(GeV)} \oplus$ 50 ps;
- Energy resolution = 5.7% / $\sqrt{E(GeV)}$

KLOE at DAΦNE

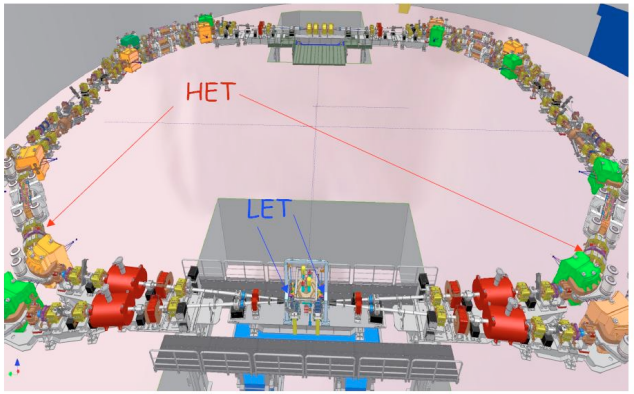
KLOE has produced in the last decade several physics results in the fields of:



- Flavour physics ($K_{L,S}$, $K^{\pm}$ decays);
- Hadron physics (light scalar and pseudoscalar meson decays);
- Discrete symmetries (P, C, CP, CPT) conservation;
- Tests of quantum mechanics.

KLOE-2 at upgraded DAΦNE

With an upgraded machine capable of delivering ~ 4 fb^{-1}/yr, the goal is to have the present KLOE statistics increased by ~ an order of magnitude (20-40 fb^{-1}) in the next years.

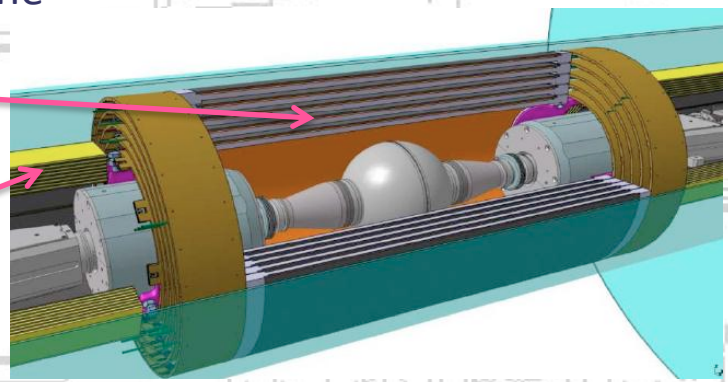


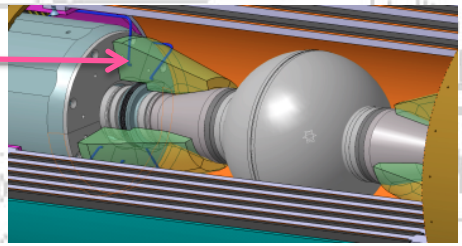
KLOE-2 detector upgrades:

- Tagger for γγ physics: to detect off-momentum **e**$^{\pm}$ from:

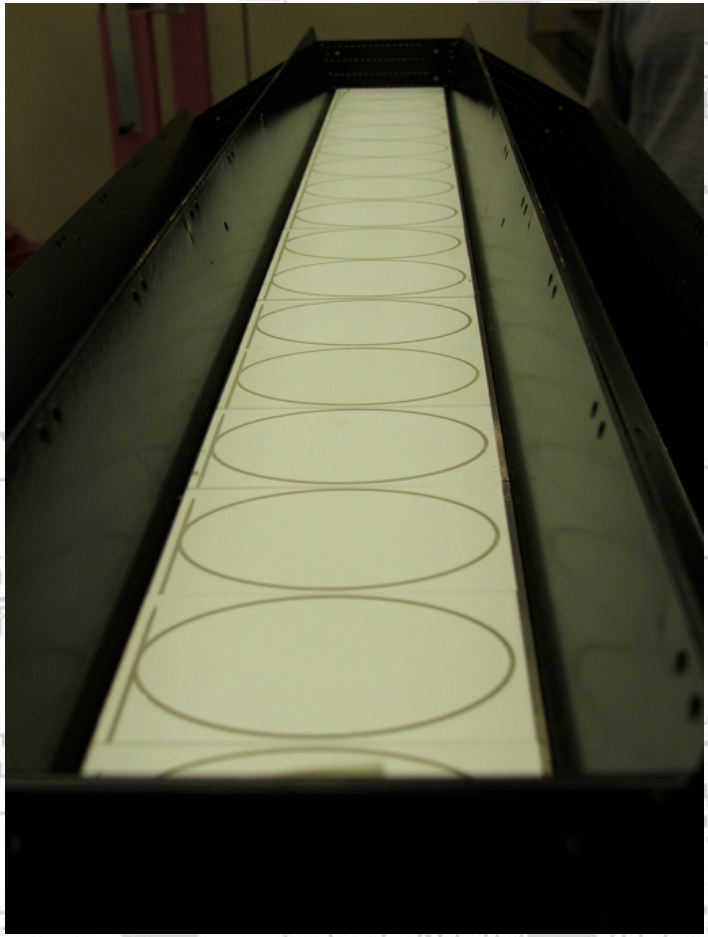
$$e^+e^- \rightarrow e^+e^-\gamma^*\gamma^* \rightarrow e^+e^-X$$

- Low Energy Tagger (130-230 MeV) calorimeters, LYSO + SiPM
- High Energy Tagger (E > 400 MeV) position sensitive detectors (strong energy-position correlation⇒ use the DAΦNE magnets as **e**$^{\pm}$ spectrometer
- Inner tracker: 5 layers of cylindrical triple GEM to improve vertex reconstruction near the IP
- QCALT: W + scint. tiles readout by SiPM via WLS fibers
- CCAL: LYSO crystals + APD; close to IP to increase acceptance for photons coming from the IP (min. angle: 21°→ 9°)





Assembly of the cylindrical GEM chamber:
2 layers are ready and under test.



Construction of a module of the new calorimeters with scintillating tiles

KLOE-2 Physics Program

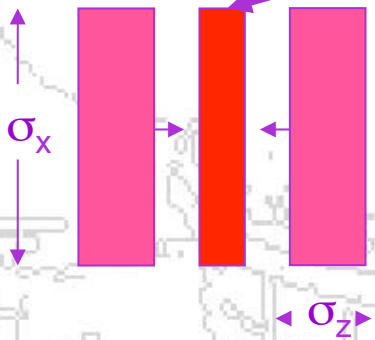
- Kaon Physics
  - Test of CPT (and QM) in correlated kaon decays and test of CPT in KS semileptonic decays
  - Test of SM (CKM unitarity, lepton universality)
  - Test of χ_{PT} (K_S decays)
- Spectroscopy of light mesons
  - $\eta,\eta',f_0,a_0,\sigma$ in ϕ radiative decays
- Hadronic cross section from $2m_\pi$ to 2.4 GeV
  - $\alpha_{em}(M_Z)$ and $(g-2)_\mu$
- $\gamma\gamma$ Physics
  - Study of $\Gamma(S/PS\rightarrow\gamma\gamma)$, test of χ_{PT}, existence and properties of σ meson, PS Transition FF
- Dark Matter searches (light bosons at at O(1 GeV))

Large Crossing Angle, Small x Size

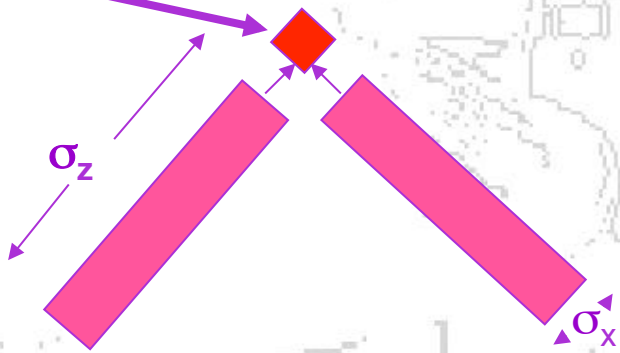
1) Head-on,
Short bunches

Overlap region

2) Large crossing angle,
long bunches



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



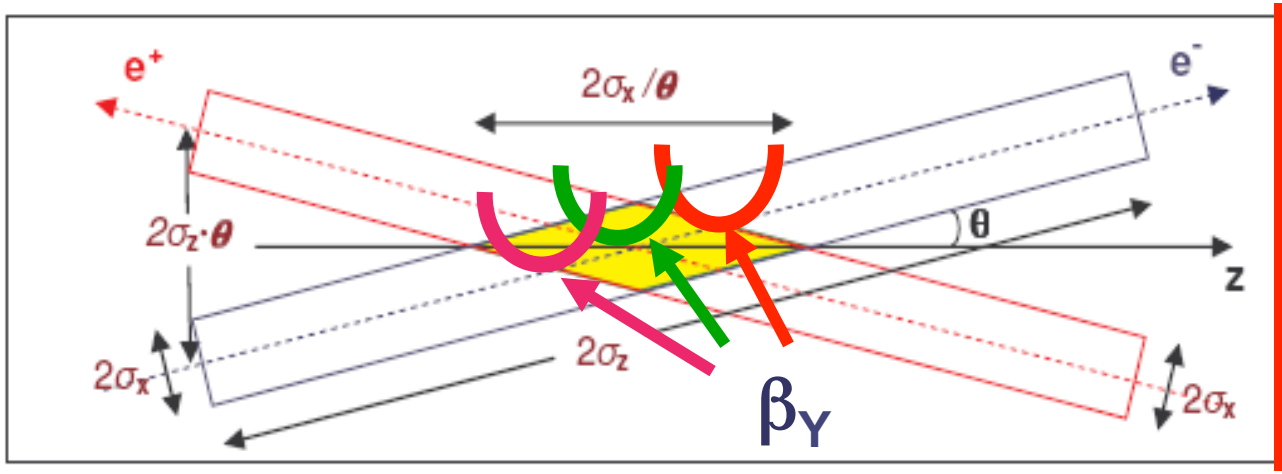
Vertical waist has to be a function of x:

Z = 0 for particles at $-\sigma_x$ ($-\sigma_x/2\theta$ at low current)

Z = σ_x/θ for particles at $+\sigma_x$ ($\sigma_x/2\theta$ at low current)

Large Piwinski angle:

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



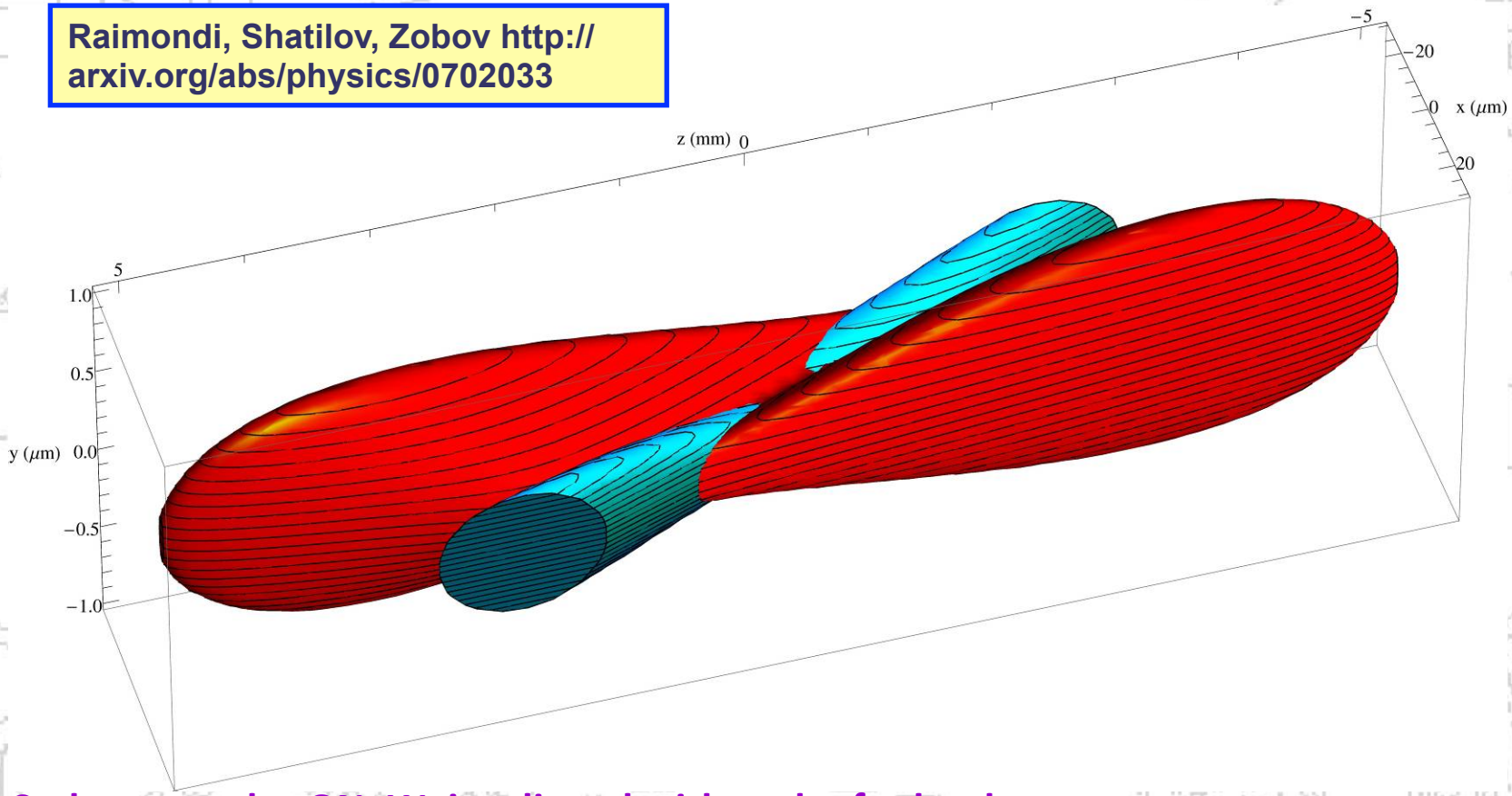
y waist can be moved along z with a sextupole on both sides of IP at proper phase

"Crab Waist"

Crab-Waist Scheme

Crab sextupoles OFF: Waist line is orthogonal to the axis of other beam

Raimondi, Shatilov, Zobov http://arxiv.org/abs/physics/0702033



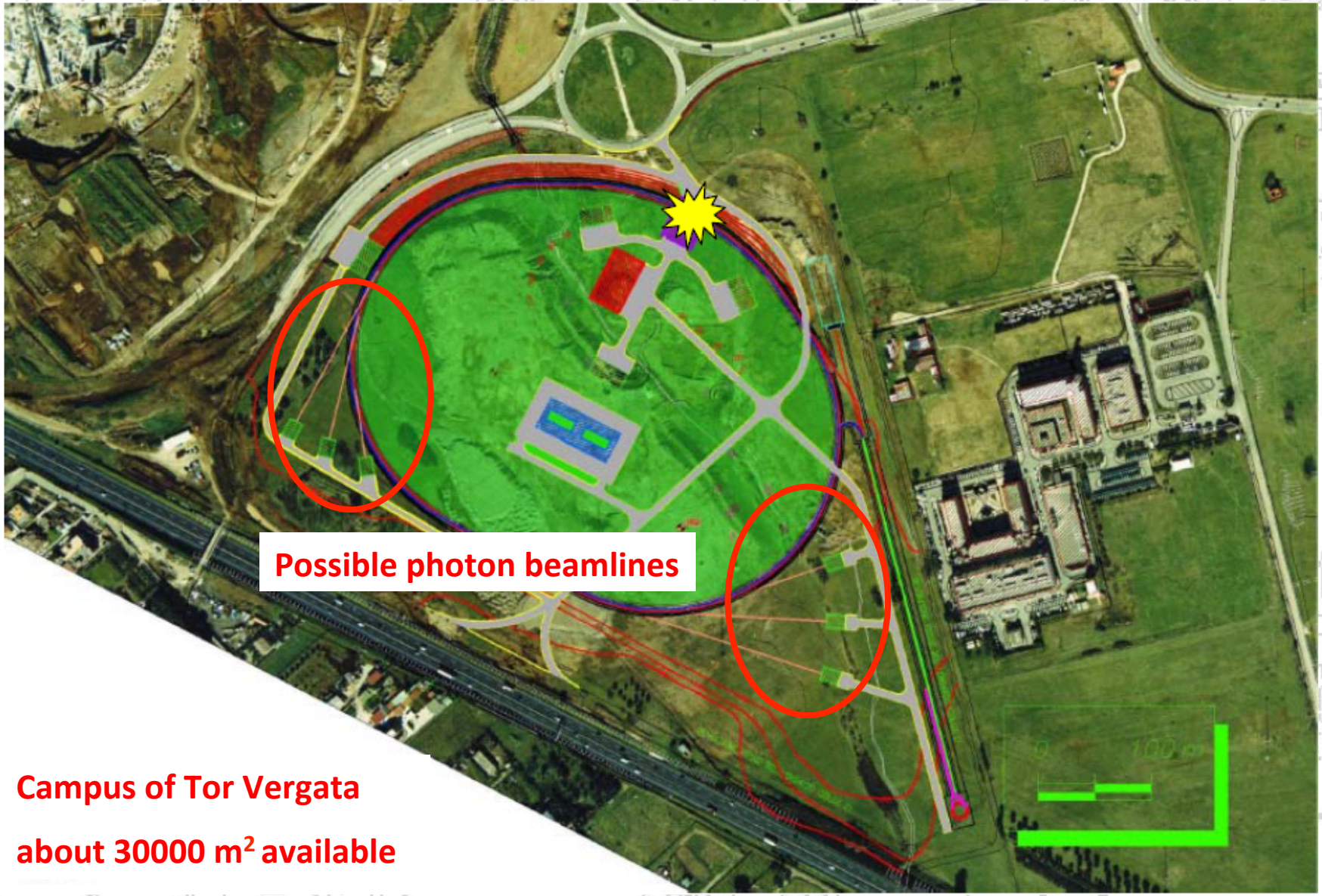
Crab sextupoles ON: Waist aligned with path of other beam

- **particles at higher ß do not see full field of other beam**
- **no excessive beam-beam parameter due to hourglass effect**

Future Super Flavour Factories

	SuperB	Super KEKB
Peak Luminosity	$>10^{36}$	0.8×10^{36}
Integrated Luminosity	75 ab^{-1}	50 ab^{-1}
Site	Tor Vergata	KEKB Laboratory
Collisions	end 2016	2015
Polarization	80% electron beam	No
Low energy running	10^{35} @ charm threshold	No
Approval status	Approved	Approved

SuperB Site at Tor Vergata

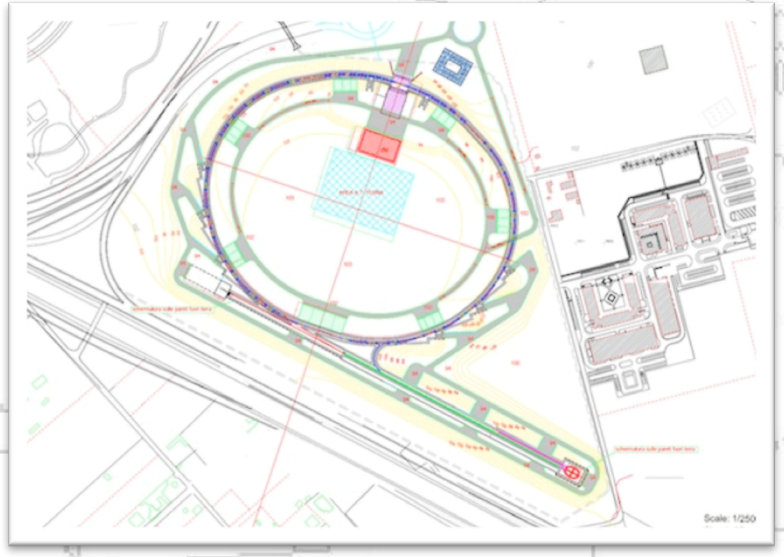


Campus of Tor Vergata

about 30000 m^2 available

Status of SuperB project

In Nov. 2012 presentation of the "SuperB technical evaluation Report". Italian Ministry of Education and Research set an international advisory committee to scrutinize the cost of the project.

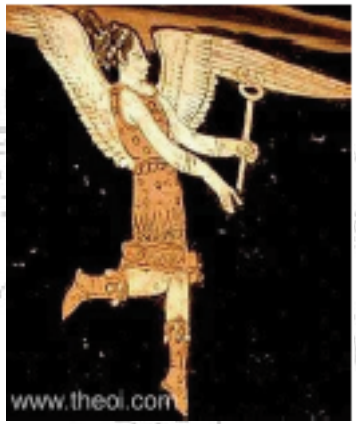


The cost of the SuperB facility amount to ~ 1B€.
The government is giving only 250 M€.

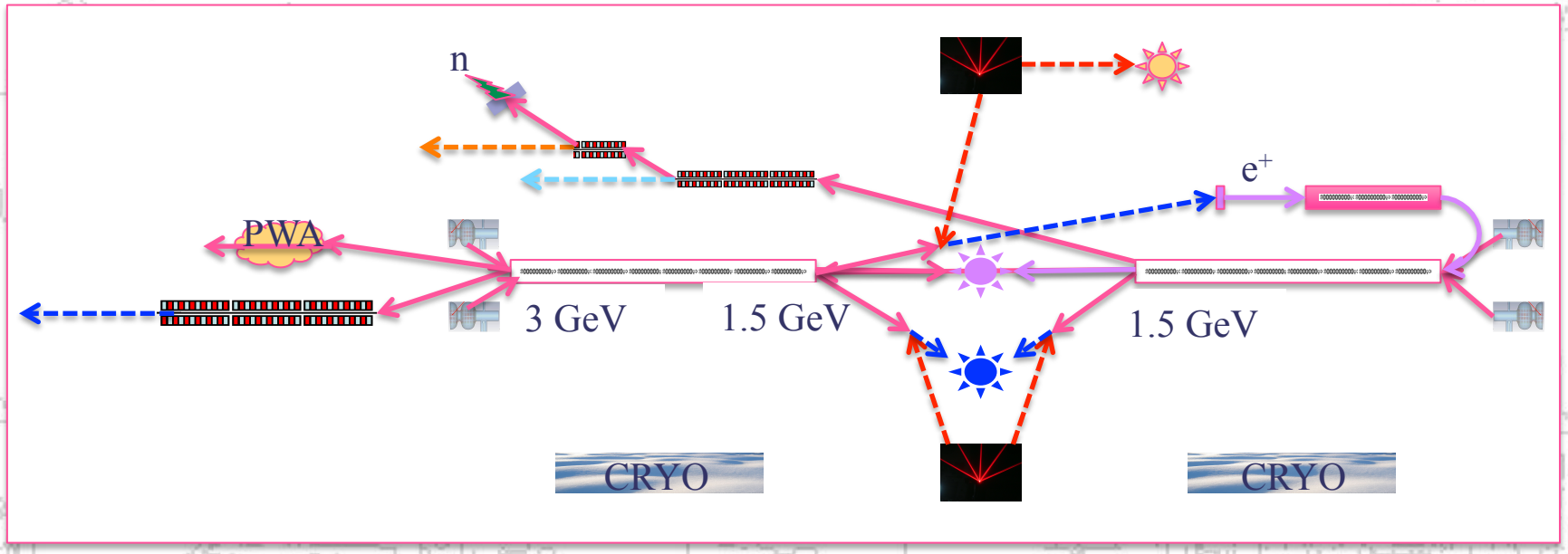
It is under study the possibility to downgrade the project to a tau-charm factory.

Preliminary evaluations indicate that the cost of a this new project (~ 650M€) is still exceeding the available budget.

IRIDE project



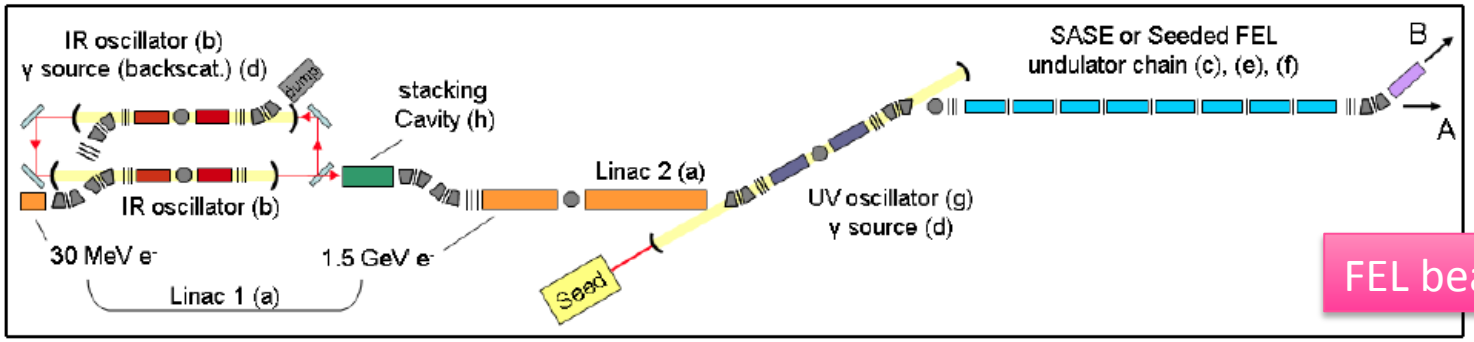
IRIDE (An Interdisciplinary Research Infrastructure based on Dual Electron linac&laser) is a project for a multi-disciplinary facility.
It will provide high flux of electrons, photons (from infrared to γ-rays), neutrons, protons and eventually positrons.
The backbone of the facility is a superconducting high duty cycle 1.5 GeV electron linear accelerator.
The second core device is a high energy cryogenically cooled Yb:YAG Laser system



By using a SCRF accelerating structures, that can accelerate beams in both longitudinal directions, the two linacs can be operated at a maximum energy of 1.5 GeV each when working in the collider mode, or used in cascade, as a single longer linac, to get electrons of energy up to 3 GeV.

FEL activities

The IRIDE project will provide a new concept of FEL facility by merging the two technologies of FEL oscillators and fourth generation radiation sources by developing a facility providing radiation from IR to EUV to the nm region down to Å level using a mechanism of emission already successfully tested at LNF SPARC lab.



FEL beam line

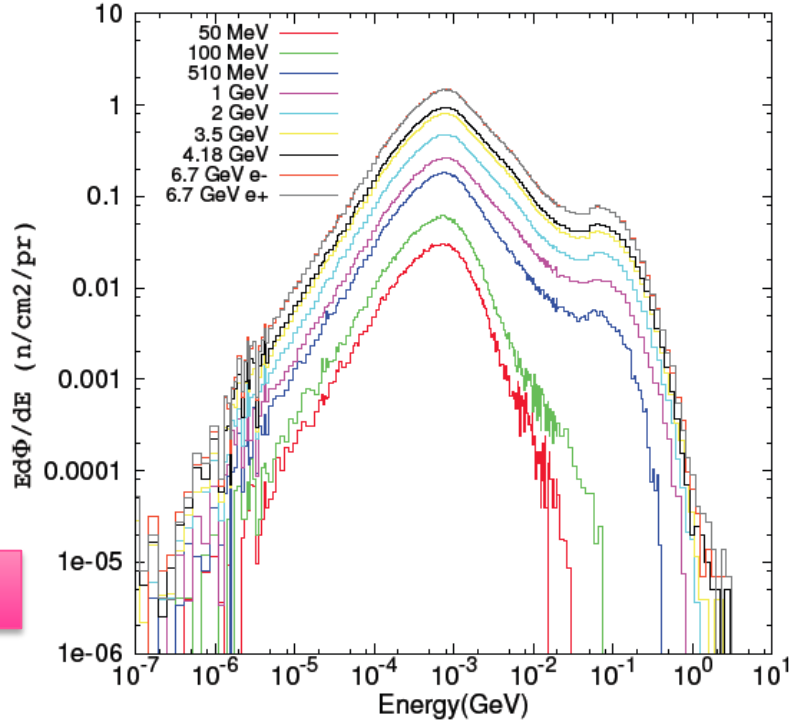
Electron beam energy	FEL osc_I	FEL osc_II	FEL osc_III	SASE&Seeding
50-100 MeV	10-0.1 X-ray intracavity generation			
750 Mev		120 nm+ Harmonics& Intracavity-scattering		30nm-10nm
2.28 GeV			13.5nm+ Harmonics &intracavity scattering	6-2 nm
3 GeV				1-0.1nm

Neutron Source

A Neutron Source can be realized by photo-production sending high energy e− on a high Z target.
Neutrons energy spectrum will span from few meV up to hundred of MeV

Deposited Power [kW]	Primary Electron Energy [GeV]	Expected Average Neutron Emission rate [n/s]
30	1	1.3 E+14
250	1	1.0 E+15
400	1	1.7 E+15
30	3	4.3 E+13
250	3	3.3 E+14
400	3	5.6 E+14

n expected form W traget



This source may be suitable for multiple applications: material analysis, cultural heritages studies, chip's irradiation and metrology. Properly beam lines with neutron moderation and possibly cold/thermal neutron transport systems will be realized.

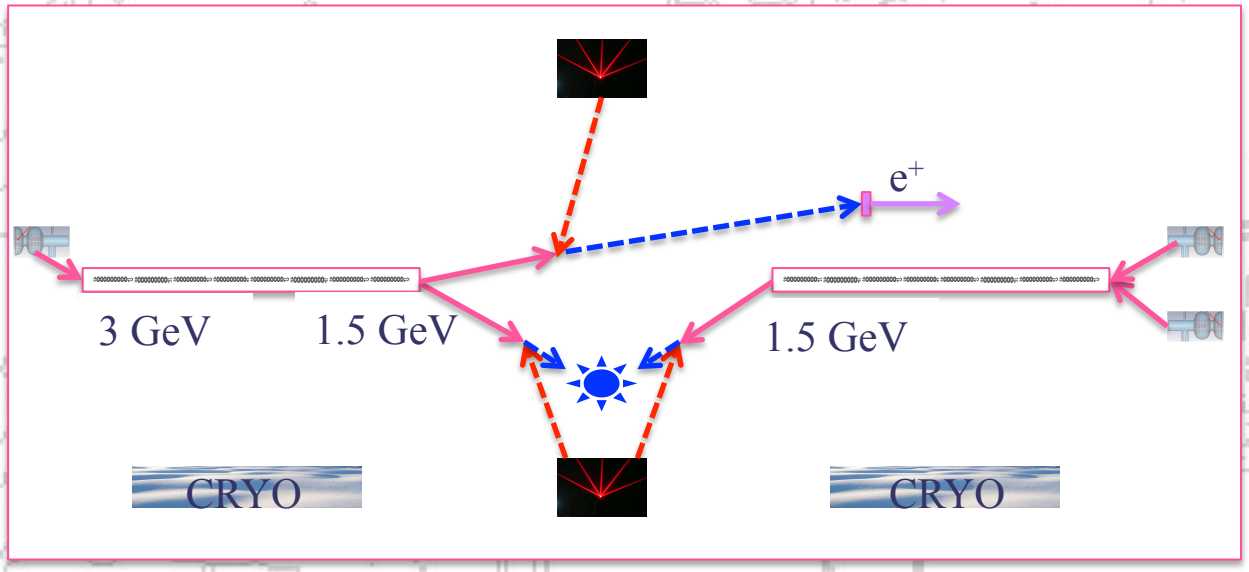
Advanced γ-ray Compton Source

The possibility to produce high brilliance/spectral density mono-chromatic *γ*-ray beams using Compton/Thomson back-scattering is stepping up rapidly thanks to several initiative world-wide.

Soon the threshold for Nuclear Photonics, *i.e.* a bandwidth of the *γ*-ray beam lower than 0.3% and a spectral density larger than 10^4 *photons/s·eV* will be reached.

Laser photons are converted by Compton back-scattering into high energy gamma photons.

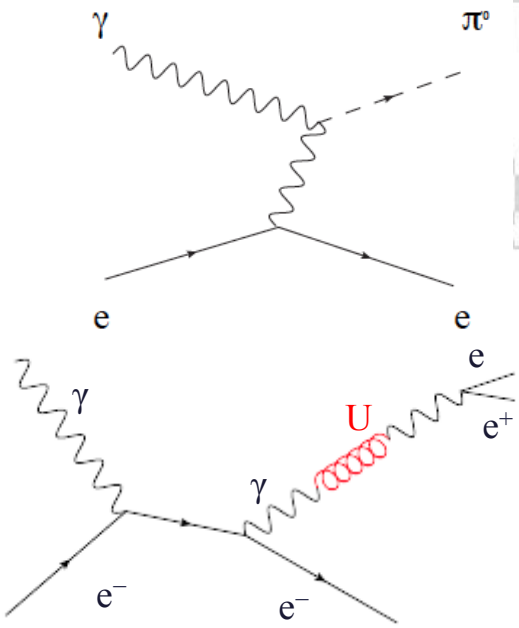
Spectral density up to 10^5 *photons/s·eV* with fluxes 10^9 *photons/s* with a narrow bandwith 0.3% will be acheived.

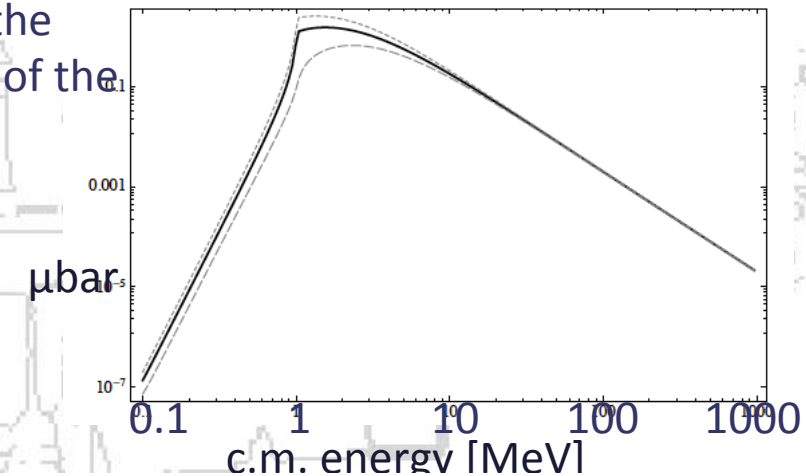


e-γ, γ-γ Collider options

Nuclear and Particle Physics will benefit from the availability of these new generation *γ*-ray beams for:

- studies of the nucleus structure at the Pigmy and Giant Dipole Resonance with unprecedented resolution in the reconstruction of the nuclear states;
- electron-photon collision can be a source of π^0 produced via the Primakoff effect having an electron as a "target" instead of a nucleus;
- search for beyond-standard-model (BSM), weakly interactin boson "U";
- The elastic photon-photon scattering offers unique opportunities to probe the nature of QED vacuum. An experiment to observe photon-photon scattering in the range 1 MeV – 2 MeV CM energy, i.e., near the peak of the QED cross-section will be performed.



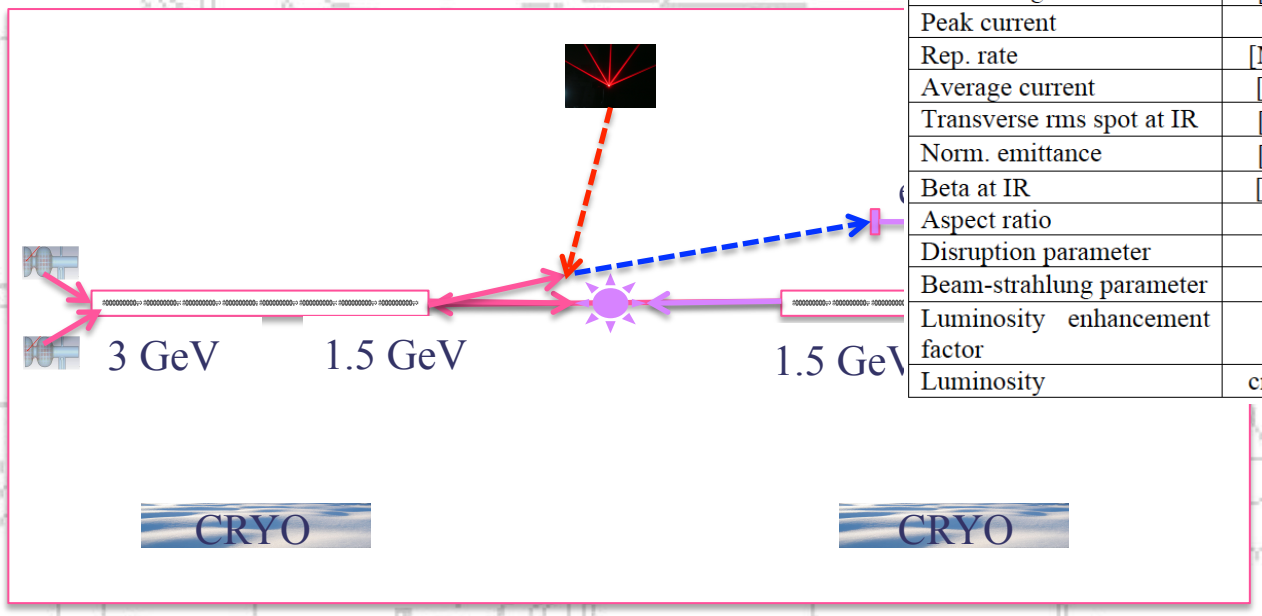


$e^+ e^-$ Linear Collider

An electron-positron collider with luminosity of 10^{32} $cm^{-2}s^{-1}$ with c.m. energy ranging from the the ϕ-resonance up to ~3.0 GeV, would allow many fundamental measurements.

- Precision measurement of muon (g-2);
- Precise measurement of the fine-structure constant α_S;
- Study of scalar resonances;
- Spectroscopy of baryon form-factors

Parameters	Units	Electrons >< Electrons	Electrons >< Positrons	Reduced Positron quality
Beam energy	[GeV]	1	1	1
Beam power	[MW]	1	1	0.4
AC power	[MW]	1.9	1.9	1.3
Charge	[nC]	0.2	2	0.8
Bunch length rms	[μm]	500	675	450
Peak current	[A]	120	888	533
Rep. rate	[MHz]	5	0.5	0.5
Average current	[mA]	1	1	0.4
Transverse rms spot at IR	[μm]	0.5	1.5	1.5
Norm. emittance	[μm]	1	2	10
Beta at IR	[mm]	0.5	2.6	0.45
Aspect ratio	A	1	0.3	1
Disruption parameter	D	-3.5	5.3	1.4
Beam-strahlung parameter	δ_ε	$\sim 10^{-7}$	$\sim 10^{-7}$	$\sim 10^{-7}$
Luminosity enhancement factor	H_D	(<) 1	5.8	1.3
Luminosity	$cm^{-2}s^{-1}$	$\sim 2.5\ 10^{32}$	$1.6\ 10^{33}$	$\sim 1.1\ 10^{32}$



Such a machine can easily collect an integrated luminosity of about 5 fb^{-1} in a few years of data taking.

Conlusions

- DAΦNE accelerator scientific life is almost at the end.
- LNF is looking for a future down-hill in the TorVergata area where a new scientific infrastructure named "Cabibbo Lab" has been settled.
- After the cancellation of the project of a Flavor-Factory, a new proposal of a Multi-disciplinary Facility for fundamental and applied research is under preparation.
- IRIDE accelerator complex combining 2 SC LINACS and a powerful laser source will be launched with a Kick-off meeting end of February and with a one day international meeting on June 2 during EAAC 2013.
- Conceptual Design Report will be ready for Summer.