Trend e Linee Guida Acceleratori-CSN5

C. Vaccarezza

Outline

- CSN5 2023 Overview
- 2023 Trends/New entries
- Some Experiment Details
- Guide Lines & work in progress

2019-2022 CSN5 - accelerator activity

	2019	2020	2021	2022
FTE (Tot)	118.26 (su 668.14)	102.84 (su 638.85)	100.1(su 696.4)	88.76(su 670.23)
FTE (%)	17.7 % (23% Quaranta slides)	16.0 % (22% Quaranta slides)	14 %	13.2 %
Budget (Tot)	1002 k€	1135 k€	867 k€	865 k€
Budget (%)	25 %	28 %	19 %	18 %
Experiments	1. **ASIDI 2018-2020** 2. **BISCOTTO 2019-2021** 3. **ELIOT 2019-2020** 4. **E_PLATE 2018-2019** 5. **L3IA 2016-2019** 6. **MAPS3D 2018-2019** 7. **MICA 2016-2018** 8. **MOPEA 2018-2020** 9. **NUCLEAAR 2019-2020** 10. **PLANETA 2017-2020** 11. **PLASMA4BEAM 2017-2020** 12. **PROMOD2 2016-2019** 13. **SL_COMB2FEL2019-2023** 14. **SL_EXIN 2012-2017** 15. **TEFEN 2019-2021** 16. **TERA (Call) 2018-2021** 17. **PANDORA (INT) 2017-2018**	1. **ACTIS 2020-2021** 2. **ARYA 2020-2023** 3. **ASIDI** 4. **BISCOTTO** 5. **ELIOT** 6. **ION2NEUTRAL2020-2023** 7. **LEMMAACC 2019-2020** 8. **LPA2 2020-2022** 9. **MOPEA** 10. **NUCLEAAR** 11. **PLANETA** 12. **PROMOD2** 13. **SHERPA 2020-2021** 14. **SINGULARITY2020-2022** 15. **SL_COMB2FEL** 16. **SL_EXIN** 17. **TEFEN** 18. **TERA** 19. **TRAMM 2020-2022** 20. **TUAREG 2020-2022**	1. **ACTIS** 2. **ARYA** 3. **ASIDI (PR)** 4. **ASTRACT 2021-2023** 5. **BISCOTTO** 6. **ION2NEUTRAL** 7. **IONS 2021-2023** 8. **LEMMAACC** 9. **LPA2** 10. **MOPEA** 11. **NUCLEAAR (PR)** 12. **SALVIA 2021-2022** 13. **SHERPA** 14. **SINGULARITY** 15. **SL_COMB2FEL** 16. **SL_EXIN** 17. **STORM 2021-2022** 18. **TEFEN** 19. **TERA** 20. **TRAMM** 21. **TUAREG**	1. **ACTIS (PR)** 2. **ARYA** 3. **ASTRACT** 4. **ETHIOPIA 2022-2024** 5. **GALORE 2022-2023** 6. **HSMDIS 2022-2024** 7. **IMPACT 2022-2023** 8. **ION2NEUTRAL** 9. **IONS** 10. **LPA2** 11. **MOPEA (PR)** 12. **SALVIA** 13. **SAMARA 2022-2024** 14. **SHERPA (PR)** 15. **SIG (Call) 2022-2024** 16. **SINGULARITY** 17. **SL_COMB2FEL** 18. **SL_EXIN** 19. **STORM** 20. **TRAMM** 21. **TUAREG** 22. **FRIDA (INT)2022-2024**

2023

	2023
FTE (Tot)	116.2. (su 622.9)
FTE (%)	18.6 % (↑ 1.4)
Budget (Tot)	1543 k€ (over 4762 k€)
Budget (%)	32 % (↑ 1.8)
Experiments	**1. Alpha_DTL_BETA 2023-2025** **2. ARYA 2020-2023** **3. ETHIOPIA 2022-2024** **4. FUSION 2023-2025** **5. GALORE 2022-2024** **6. H2BTF (Call) 2023-2025** **7. HISOL 2023-2024** **8. HSMDIS 2022-2024** **9. IMPACT 2022-2023** **10. ION2NEUTRAL 2020-2023** **11. IONS 2021-2023** **12. MICRON 2022-2024** **13. PBT 2022-2024** **14. SAMARA 2022-2024** ***15. SINGULARITY 2020-2022*** **16. SL_COMB2FEL 2019-2023** ***17. TUAREG 2020-2022*** **18. FRIDA (INT) 2022-2024**

ON APRIL 7-8 2022 MORE DETAILS ON:

- MAGNETS: BISCOTTO, ASTRACT
- IONS: PANDORA, IONS, ION2NEUTRAL
- COLLIDERS-BD-EM: ARYA, ACTIS
- RF: TUAREG, MICRON
- PLASMA ACCELERATION: SL_COMB2FEL-EXIN
- THz RADIATION: TERA
- LASER PROTON SOURCE: LPA2
- ML: SINGULARITY
- 4-Research Lines: FRIDA

Today some Details on:

IONS: ALPHA_DTL_BETA*, HISOL

RF: H2BTF*

PLASMA REACTIONS: FUSION*

CHANNELING: STORM,GALORE

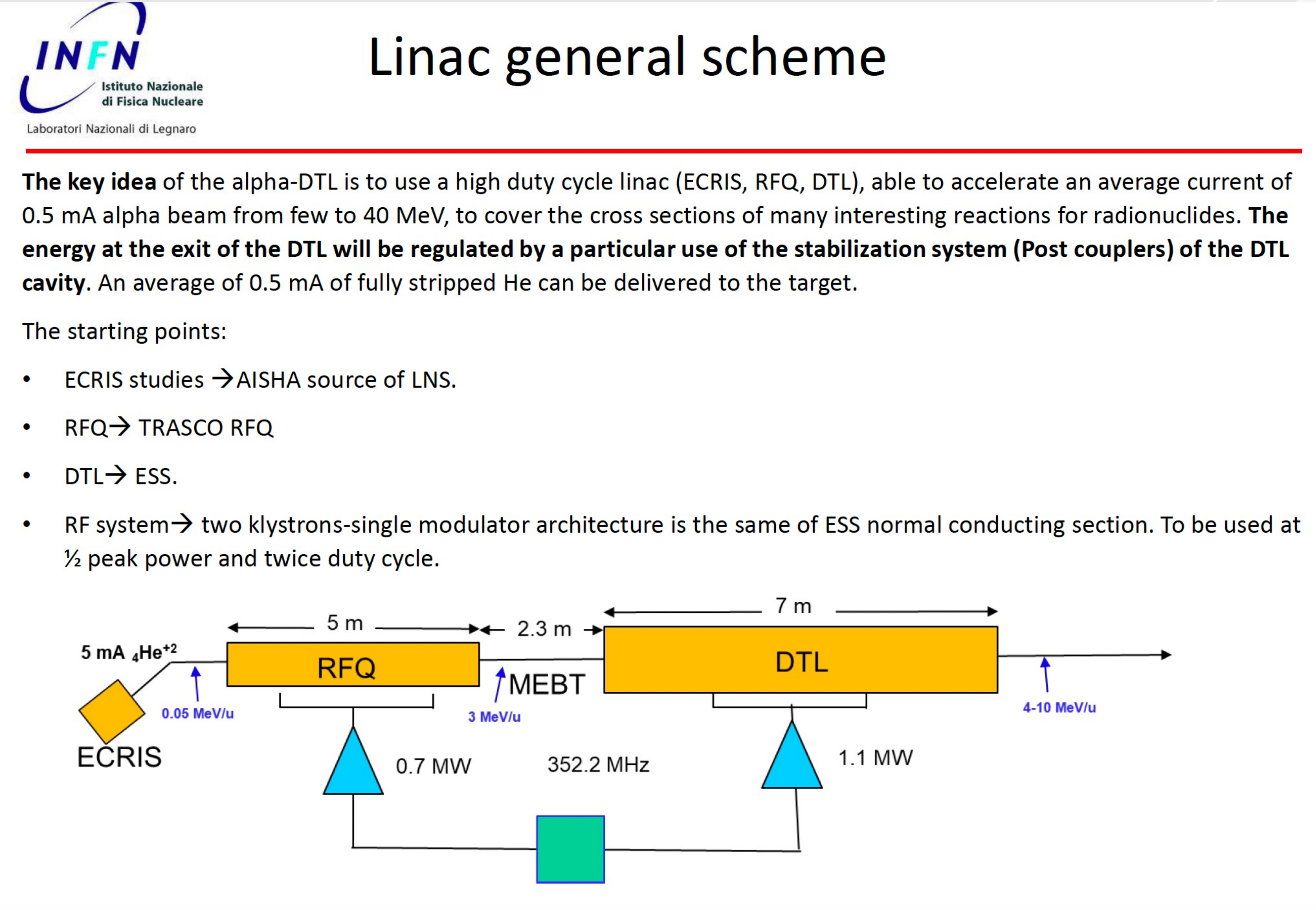
ALPHA-DTL-BETA

2022-2023 LNL, INFN-TO RN F. Grespan

ALPHA-DTL is a high perfomance linac for radioisotope production.
The approach of using alpha particles beams may allow to yield radionuclides hard to be obtained with more traditional nuclear reactors or by proton accelerators, by exploiting new reaction routes. This approach may lead to better radionuclide impurity profiles, simplifying the radiochemical separation and purification process. From the accelerator point of view, the use of cyclotron for α particles has an intensity limitation (mainly related to the extraction system.
The key idea of the alpha-DTL is to use a high duty cycle linac(ECRIS, RFQ, DTL), able to accelerate an average current of 0.5 mA alpha beam from few to 40 MeV, to cover the cross sections of many interesting reactions for radionuclides.
The energy at the exit of the DTL will be regulated by a particular use of the stabilization system (Post couplers) of the DTL cavity.

The goal of the experiment **“ALPHA-DTL_beta”** is to address the R&D activities recognized as critical during the evaluation of the “alpha-DTL” call and solve the feasibility of the accelerator for a future design report of the complete facility.

The Linac Scheme



INFN
Istituto Nazionale
di Fisica Nucleare
Laboratori Nazionali di Legnaro

Linac general scheme

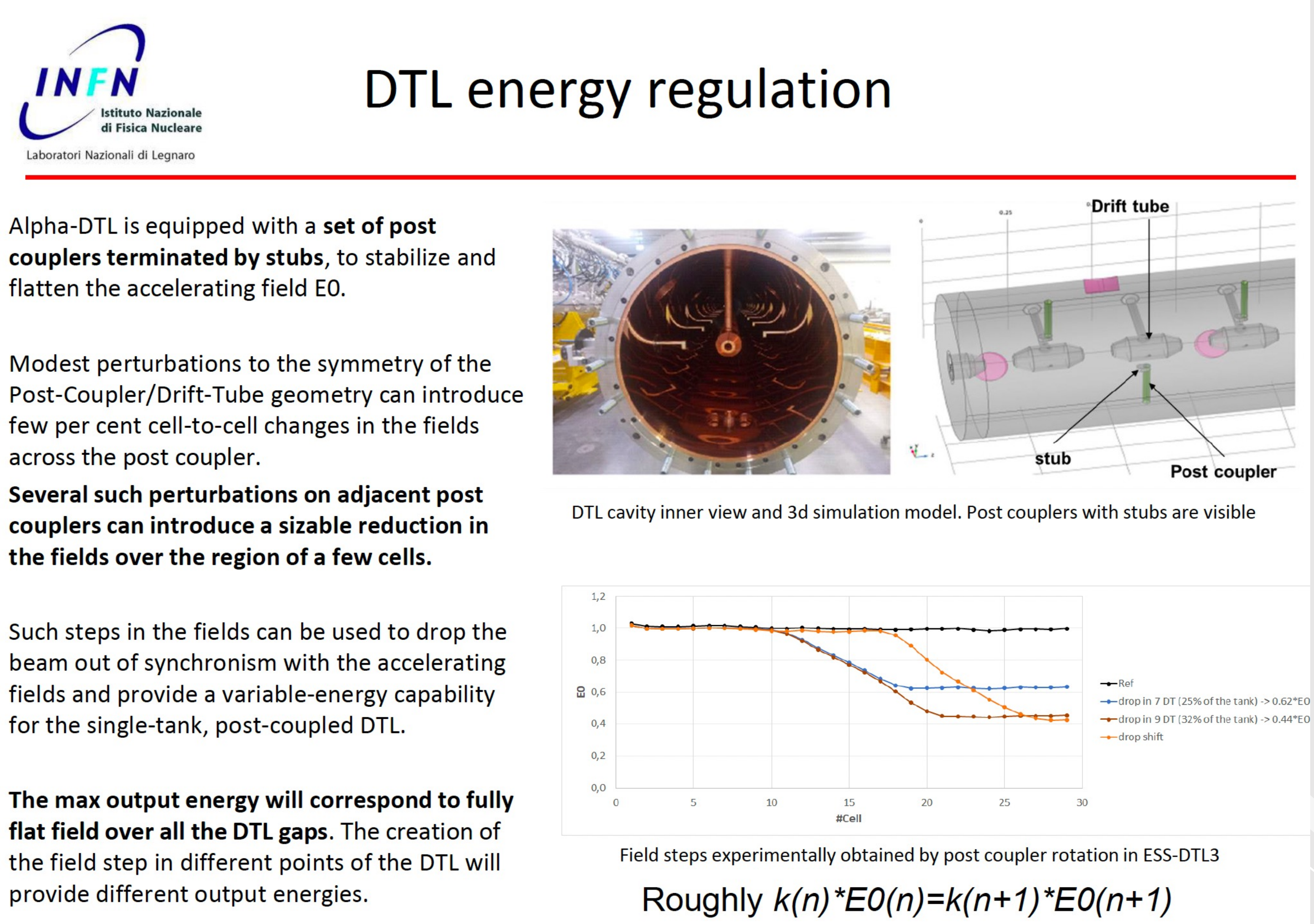
The key idea of the alpha-DTL is to use a high duty cycle linac (ECRIS, RFQ, DTL), able to accelerate an average current of 0.5 mA alpha beam from few to 40 MeV, to cover the cross sections of many interesting reactions for radionuclides. **The energy at the exit of the DTL will be regulated by a particular use of the stabilization system (Post couplers) of the DTL cavity**. An average of 0.5 mA of fully stripped He can be delivered to the target.

The starting points:

- ECRIS studies →AISHA source of LNS.
- RFQ→ TRASCO RFQ
- DTL→ ESS.
- RF system→ two klystrons-single modulator architecture is the same of ESS normal conducting section. To be used at ½ peak power and twice duty cycle.

Courtesy of F. Grespan

The key point



DTL energy regulation

Alpha-DTL is equipped with a **set of post couplers terminated by stubs**, to stabilize and flatten the accelerating field E0.

Modest perturbations to the symmetry of the Post-Coupler/Drift-Tube geometry can introduce few per cent cell-to-cell changes in the fields across the post coupler.

Several such perturbations on adjacent post couplers can introduce a sizable reduction in the fields over the region of a few cells.

Such steps in the fields can be used to drop the beam out of synchronism with the accelerating fields and provide a variable-energy capability for the single-tank, post-coupled DTL.

The max output energy will correspond to fully flat field over all the DTL gaps. The creation of the field step in different points of the DTL will provide different output energies.

DTL cavity inner view and 3d simulation model. Post couplers with stubs are visible

Field steps experimentally obtained by post coupler rotation in ESS-DTL3

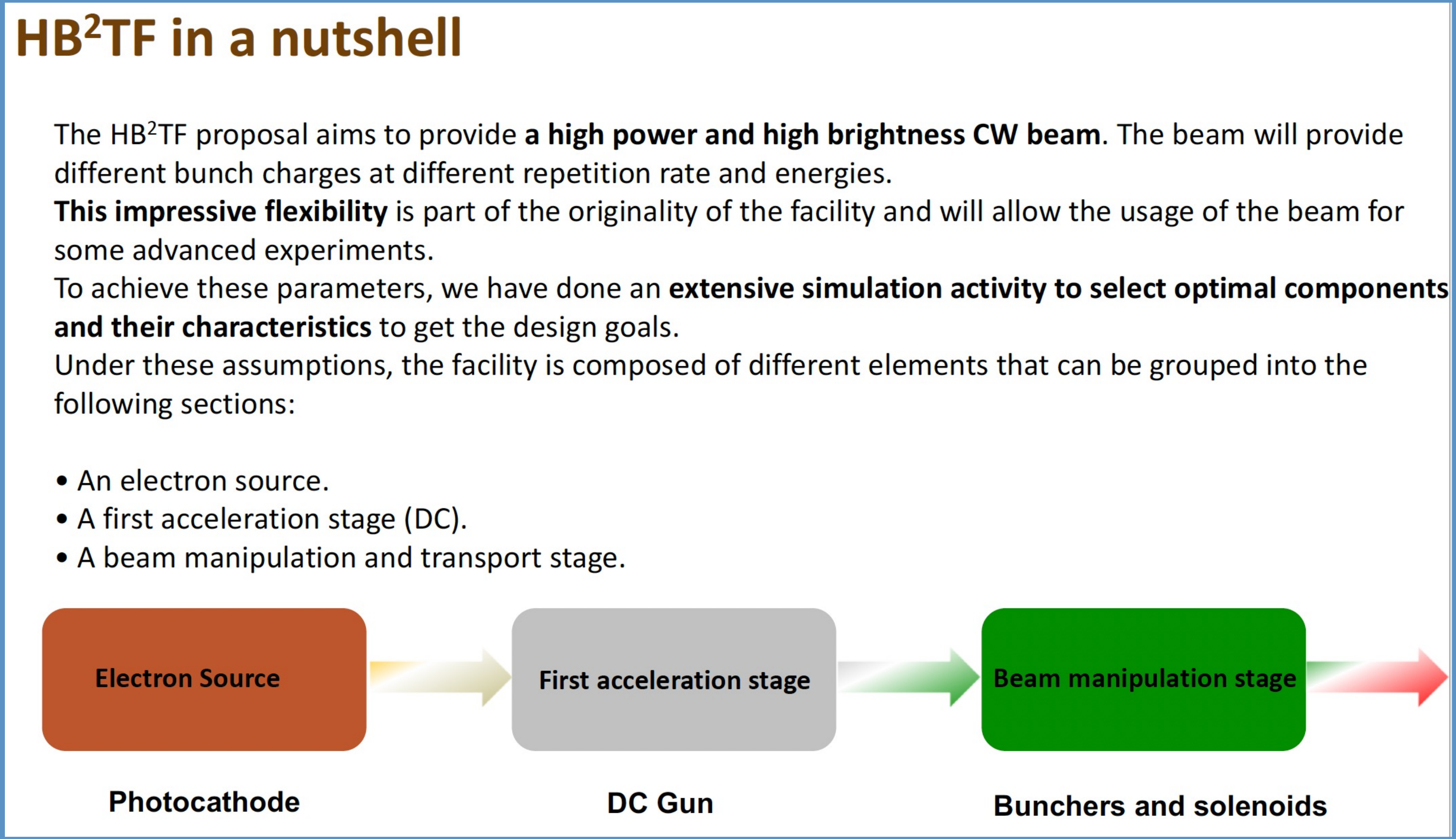
Roughly $k(n)*E0(n)=k(n+1)*E0(n+1)$

Courtesy of F. Grespan

WP1	Movable Post coupler prototyping	
MS# or DLV#	Description	Months from T0
MS2.1.a	Mech. Design of motorized post coupler	6
MS2.1.b	Production of 1 motorized post coupler and vacuum chamber	18
MS2.1.c	Test in vacuum of 1 motorized post coupler	24
DLV2.1	Report of test in vacuum of a motorized PC	24

High Brightness Beams Test Facility

2023-2025 INFN-MI-BO-NA,LNF,LNL,LNS RN D. Giove



HB^{2}TF in a nutshell

The HB^{2}TF proposal aims to provide **a high power and high brightness CW beam**. The beam will provide different bunch charges at different repetition rate and energies.
This impressive flexibility is part of the originality of the facility and will allow the usage of the beam for some advanced experiments.
To achieve these parameters, we have done an **extensive simulation activity to select optimal components and their characteristics** to get the design goals.
Under these assumptions, the facility is composed of different elements that can be grouped into the following sections:

- An electron source.
- A first acceleration stage (DC).
- A beam manipulation and transport stage.

Electron Source → **First acceleration stage** → **Beam manipulation stage** →

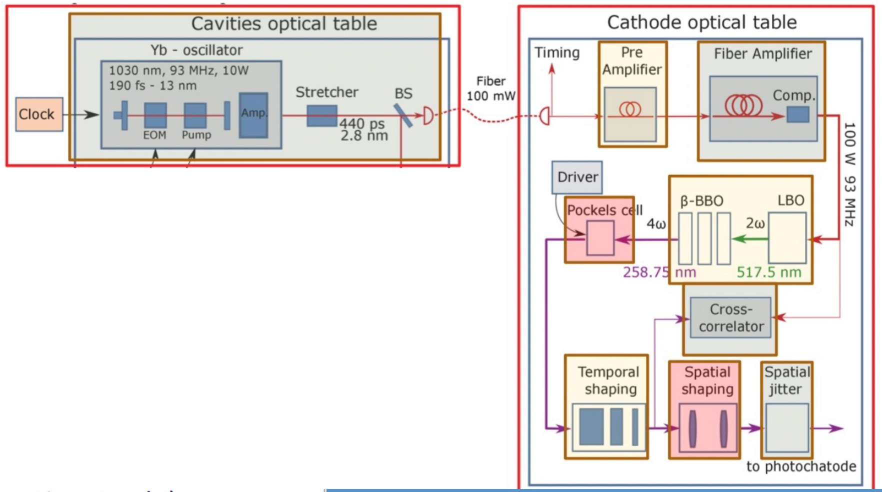
Photocathode

DC Gun

Bunchers and solenoids

Laser scheme

A UV laser running at 258.75 nm by fourth harmonic generation from a mode locked Yb laser will be used to have electron emission. The expected pulse length on the photocathode is planned to be 20-30 ps to mitigate the space charge effect in the emission and acceleration process in the DC gun. The long bunch generated in the DC gun is focused by solenoids magnets before injection into the sub harmonic bunchers.



Elements already available in the required configuration

Elements already available but requiring relevant modifications

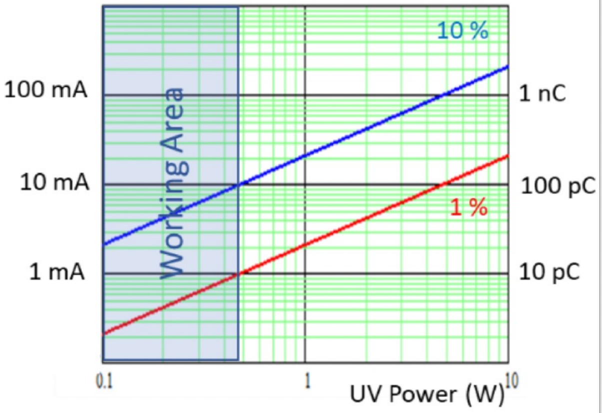
Elements to be acquired

Photocathodes for HB^{2}TF

- For HB^{2}TF Cs_2Te photocathodes will be used as electron sources
  - Average QE at the production ≥ 10% in UV range, in operation typically us
  - Vacuum quality: low 10^{-10} mbar (in the production stage), low 10^{-9} mbar (in operation mode)

- Laser system (Yb laser, λ^{fund} = 1035 nm, P = 10 W, Rep. Rate from 1 to 93 MHz, 190 fs):
  - UV is needed for the photocathode operation: λ^{4th} = 258.75 nm, P = 0.5 W

- Photocathode requirements in operation:
  - Q: up to 50 pC; I_{ave} up to 5 mA
  - Lifetime (as long as possible)
  - On-line: QE and reflectivity characterization
  - After operation, photocathodes will be analyzed in the production system (post-usage)

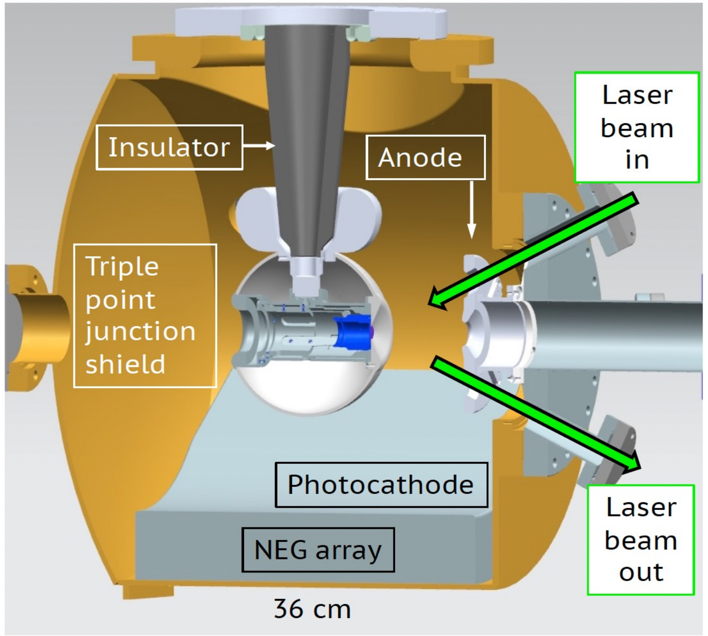


Courtesy of D. Giove

A »Good Gun»

A «good gun» may be defined according to 3 different parameters:

- Ultrahigh vacuum
- No field-emission
- Maintenance-free



1) Extreme-high vacuum conditions required for obtaining long-photocathode lifetime

- Static and Dynamic vacuum
- Ion-bombardment limits operation

2) High photocathode gradient for injector transmission and for generating bright electron beams in electron microscopy, ultra-fast electron diffraction and free electron lasers

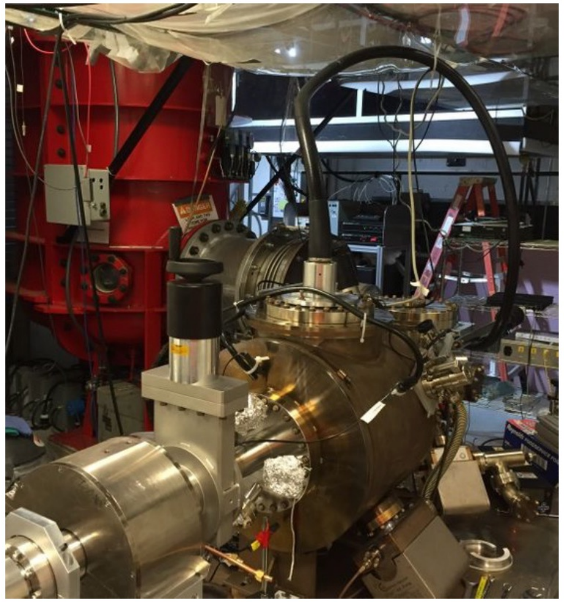
- Very low field emission from cathode electrode

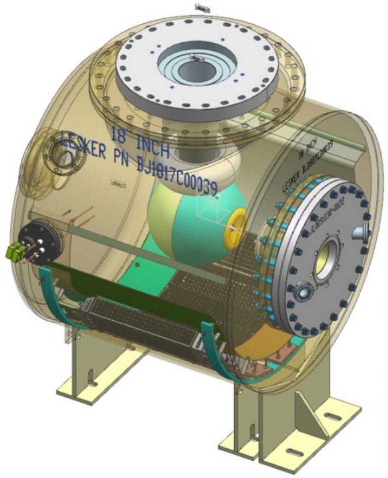
3) Maintenance Free

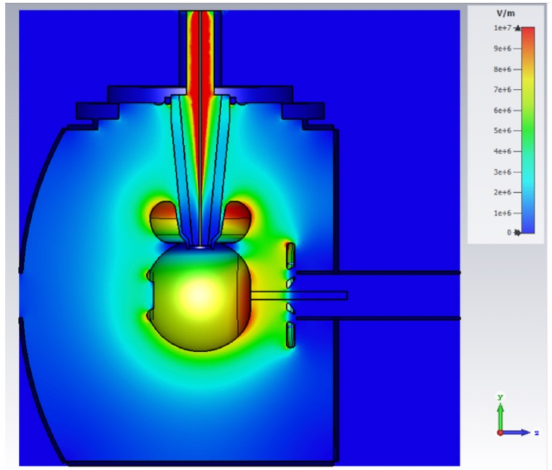
- Vent and Bake vs. Load locked

4) High CW beam current : tens of milli-Amperes beams for electron coolers, energy recovery linacs and free electron lasers

DC Gun







Courtesy of
C. Hernandez Garcia
J-Lab

Courtesy of D. Giove

HISOL

High performance ISOL systems for the production of radioactive ion beams

Principal Investigator: Mattia Manzolaro*

Research Fields
Particle Accelerators, Radioactive Ion Beams,
Isotope Separation On Line, Targets, Ion Sources

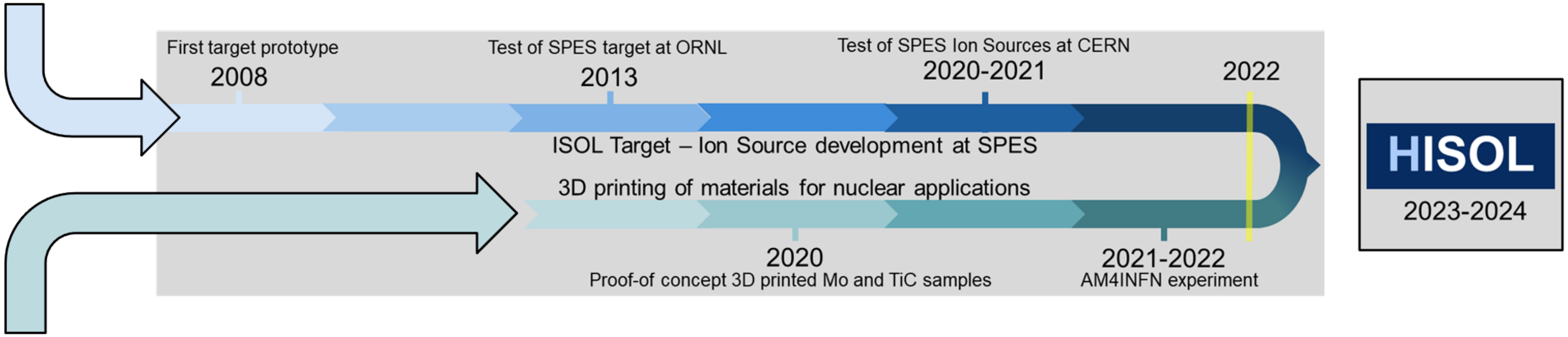
Duration
2 years

INFN Research Units
LNL, Padova, Pavia

Radioactive Ion Beams (RIBs) are fundamental for basic research in nuclear physics (@ **SPES**) and for high-level applications such as nuclear medicine (@ **ISOLPHARM**)

HISOL main objective: improvement of **ISOL Targets** and **Ion Sources** to increase the **RIBs intensity** and the **purity**

INFN-SPES project: the LNL ISOL group developed a considerable amount of **know-how** (on targets, ion sources, molecular beams, …) benefitting of presigious **international collaborations** (ISOLDE-CERN, ORNL, …).



First target prototype
2008

Test of SPES target at ORNL
2013

Test of SPES Ion Sources at CERN
2020-2021

2022

ISOL Target – Ion Source development at SPES

3D printing of materials for nuclear applications

2020
Proof-of concept 3D printed Mo and TiC samples

2021-2022
AM4INFN experiment

HISOL
2023-2024

AM4INFN (supported by INFN_E): 3D printing of high temperature materials such as **SiC**, **TiC (Target)**, **Ta**, **W**, and **Mo (Ion Source)** (for ISOL systems).

Courtesy of M Manzolaro

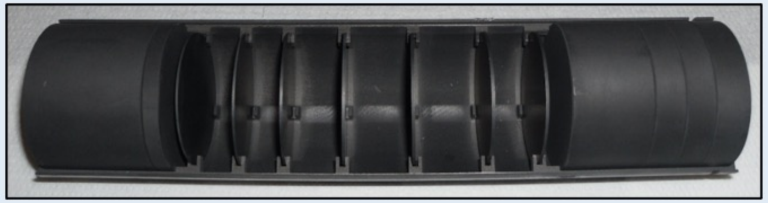
A dedicated INFN-CSN_5 Experiment is a great opportunity to define a **New Generation of High Performance ISOL Targets and Ion Sources**

Courtesy of M Manzolaro

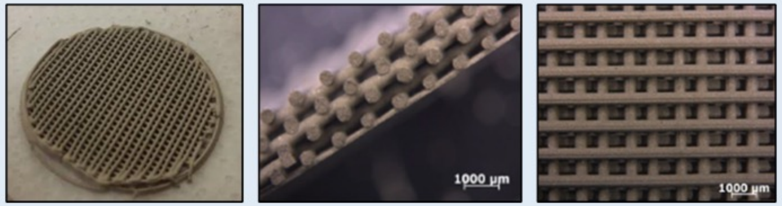
Project Organization: WP1, WP2 and WP3

Work Package 1:
Development of High Performance ISOL Targets (**S. Corradetti**)

Production of **TiC/SiC samples** with **regular structures** for **characterization** activities



Development of **TiC/SiC disks** with regular structures for **ISOL Targets**



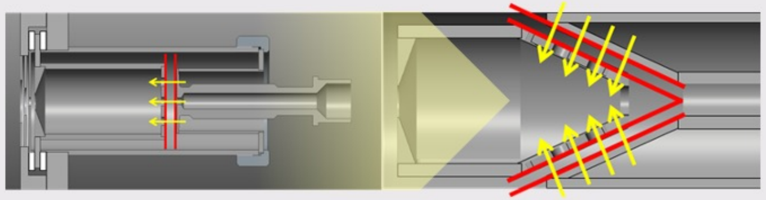
Long term **high temperature test** of a TiC/SiC ISOL Target prototype

Aim: maximize heat transfer and release

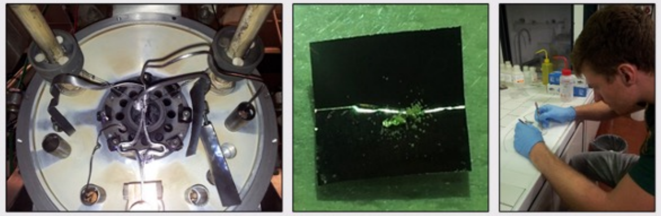
Work Package 2:
Development of High Performance ISOL Ion Sources (**A. Monetti**)

Production and test of **W, Ta and Mo Ion Source components** with **complex shapes**

Alternative anode-cathode interfaces



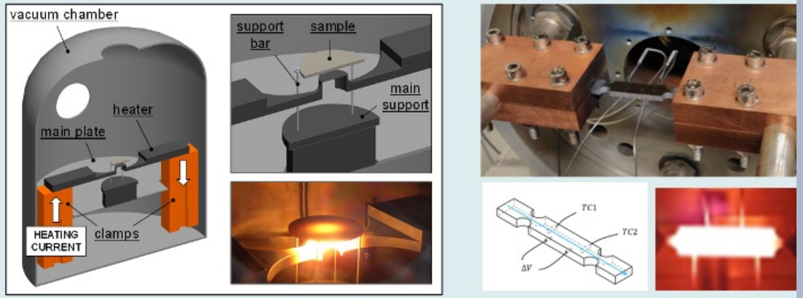
Production of ion beams with the Ion Source prototype (also **molecular beams**)



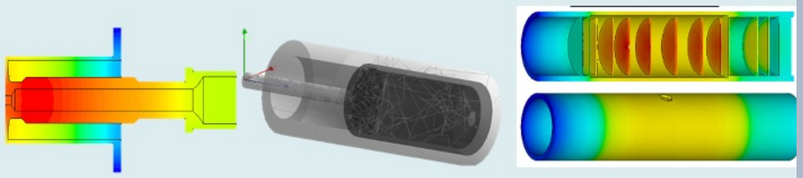
Aim: improve the ionization efficiency, the source stability and reproducibility

Work Package 3:
Materials Characterization and Multiphysics Simulation (**M. Ballan**)

Microstructural, thermal, electrical and structural **characterization**



Multiphysics Simulation of High Performance ISOL Targets and Ion Sources

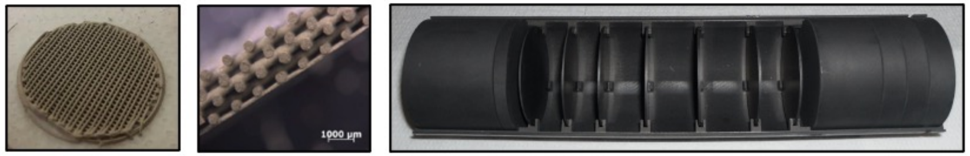


Aim: component characterization

Courtesy of M Manzolaro

Project Objectives

Production of TiC and SiC samples with fine structures

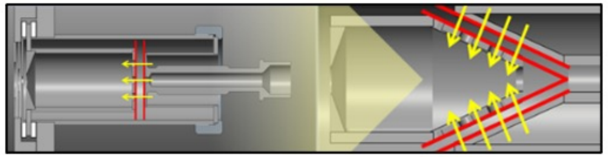


Microstructural, thermal and mechanical characterization

Development of High Performance ISOL Targets

Multiphysics simulations (FLUKA, ANSYS, …)

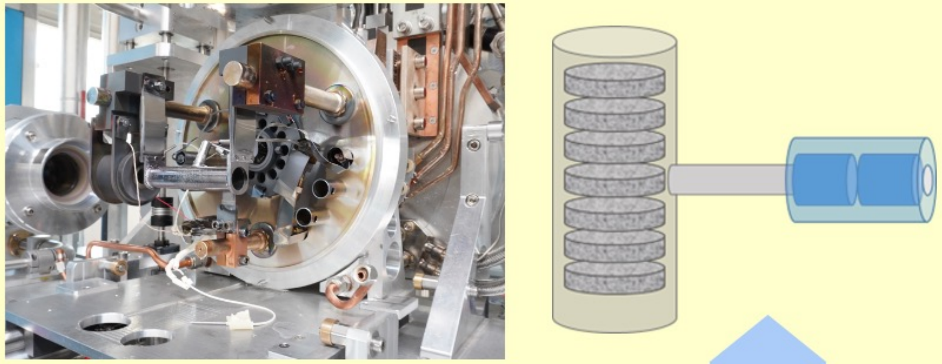
R&D of complex shape Ion Source components



Thermal, electric and mechanical characterization

Development of High Performance ISOL Ion Sources

Development and test of High Performance ISOL Target – Ion Source Systems

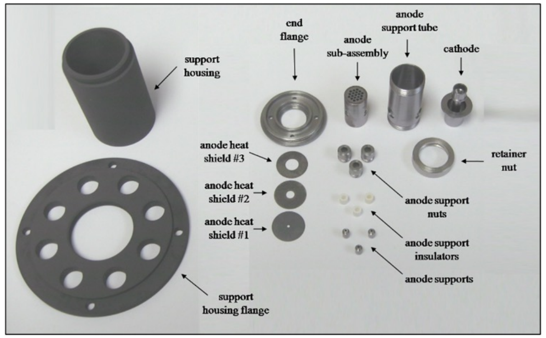


Courtesy of M Manzolaro

The Standard FEBIAD Ion Source

- more than **20 components** ⬇
- long procedure for alignment (manual operation) ⬇
- **performance variation** and **reduced reproducibility** ⬇

(max. electron current oscillating between **100** mA and **250** mA)



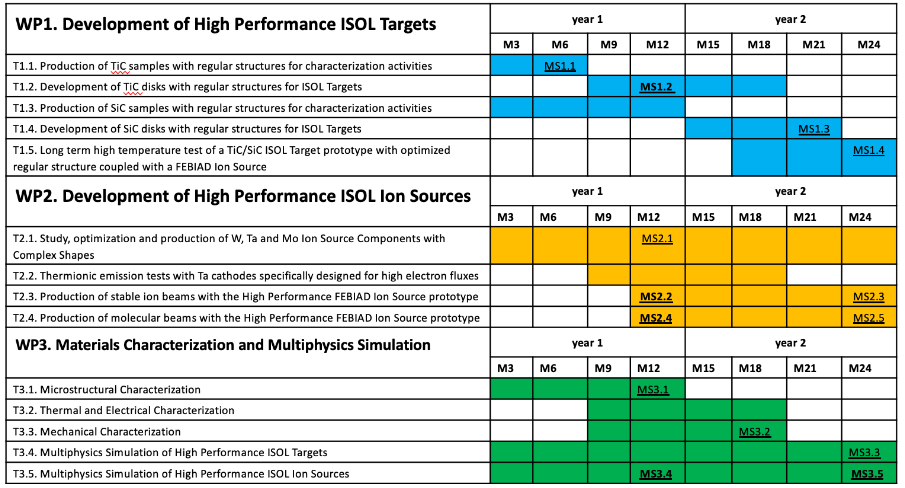
The New FEBIAD Ion Source

some innovative solutions to improve

stability and reproducibility

Stable performance ⬆ and **strong reproducibility** ⬆ can be obtained! Additive Manufacturing of **8 self-centering components**:

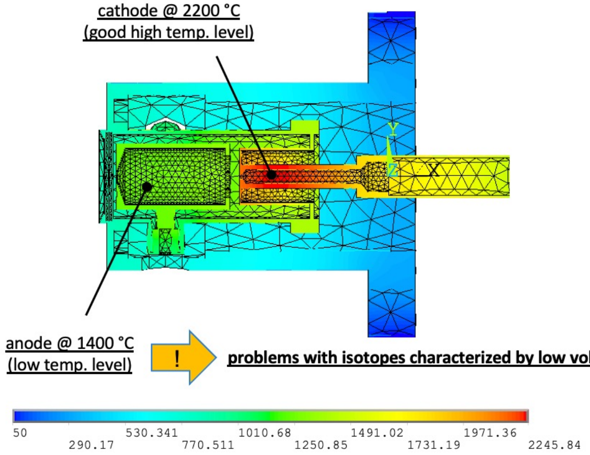
- AlSi10Mg protoype ready
- Ta prototype: **WIP**
- Ta prototype testing @ 2200 °C: **to be done**



WP1. Development of High Performance ISOL Targets	year 1				year 2			
	M3	M6	M9	M12	M15	M18	M21	M24
T1.1. Production of TiC samples with regular structures for characterization activities	🟦	🟦 MS1.1						
T1.2. Development of TiC disks with regular structures for ISOL Targets			🟦	🟦 **MS1.2**	🟦	🟦		
T1.3. Production of SiC samples with regular structures for characterization activities	🟦	🟦	🟦	🟦				
T1.4. Development of SiC disks with regular structures for ISOL Targets					🟦	🟦	🟦 MS1.3	
T1.5. Long term high temperature test of a TiC/SiC ISOL Target prototype with optimized regular structure coupled with a FEBIAD Ion Source						🟦	🟦	🟦 MS1.4
WP2. Development of High Performance ISOL Ion Sources	year 1				year 2			
	M3	M6	M9	M12	M15	M18	M21	M24
T2.1. Study, optimization and production of W, Ta and Mo Ion Source Components with Complex Shapes	🟧	🟧	🟧	🟧 MS2.1	🟧	🟧	🟧	🟧
T2.2. Thermionic emission tests with Ta cathodes specifically designed for high electron fluxes			🟧	🟧	🟧	🟧		
T2.3. Production of stable ion beams with the High Performance FEBIAD Ion Source prototype				🟧 **MS2.2**	🟧	🟧	🟧	🟧 MS2.3
T2.4. Production of molecular beams with the High Performance FEBIAD Ion Source prototype				🟧 **MS2.4**	🟧	🟧	🟧	🟧 MS2.5
WP3. Materials Characterization and Multiphysics Simulation	year 1				year 2			
	M3	M6	M9	M12	M15	M18	M21	M24
T3.1. Microstructural Characterization	🟩	🟩	🟩	🟩 MS3.1				
T3.2. Thermal and Electrical Characterization			🟩	🟩	🟩	🟩		
T3.3. Mechanical Characterization			🟩	🟩	🟩	🟩 MS3.2		
T3.4. Multiphysics Simulation of High Performance ISOL Targets	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩 MS3.3
T3.5. Multiphysics Simulation of High Performance ISOL Ion Sources	🟩	🟩	🟩	🟩 **MS3.4**	🟩	🟩	🟩	🟩 **MS3.5**

Study and production of **Ta, W** and **Mo Ion Source Components (**in particular **cathode** and **anode)** with **Complex Shapes** (making use of the Additive Manufacturing Technology for refr metals developed in the context of AM4INFN/INFN_Energia) to **improve the temperature field, the electron flux** and consequently **the ionization efficiency of FEBIAD Ion Sources.**

FEBIAD Ion Source (standard version)

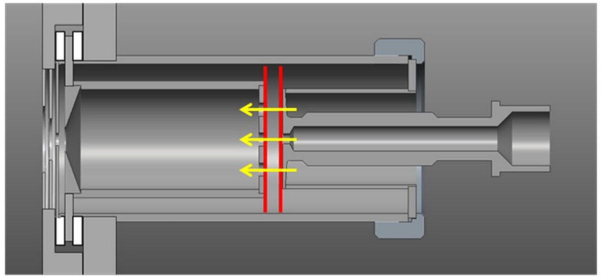


cathode @ 2200 °C
(good high temp. level)

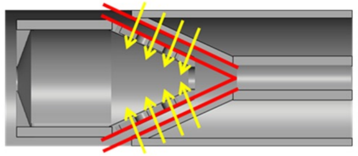
anode @ 1400 °C
(low temp. level)

! **problems with isotopes characterized by low volatility**

planar interface and electron beam in the axial direction (STANDARD)



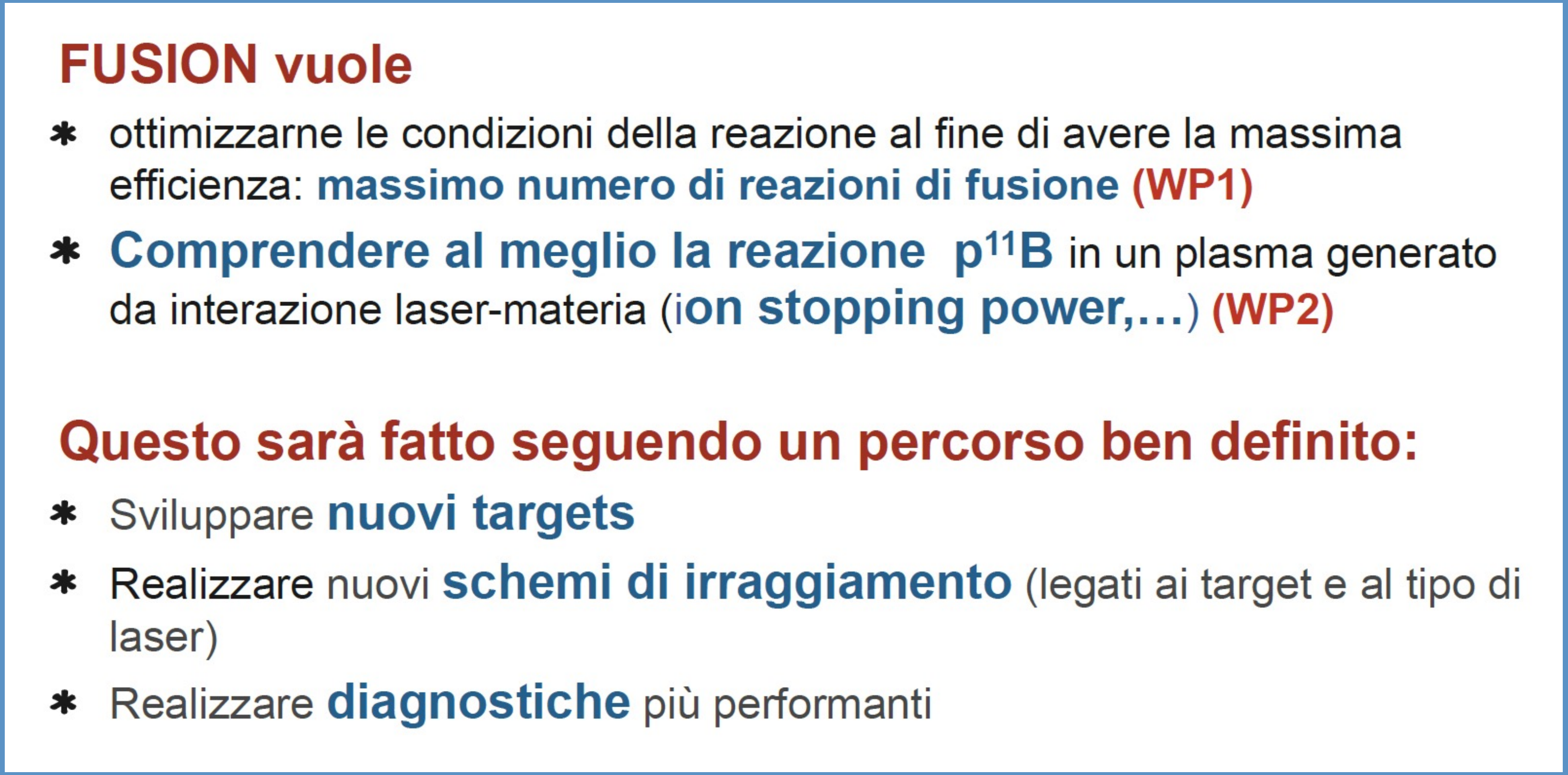
conical/spherical/free-form interface to improve the temperature field and the electron flux



- anode @ higher temp. levels
- bigger surface @ high temperature for electron emission
- magnetic field (coil) not required
- simplified vacuum chamber design (coil not required)

***FU**sion **S**tud**I**es of pr**O**ton boron* *
Neutron-less reaction in laser-generated plasma*

2023-2025 RN G.A.P Cirrone-F. Consoli



FUSION vuole

- ottimizzarne le condizioni della reazione al fine di avere la massima efficienza: **massimo numero di reazioni di fusione** **(WP1)**
- **Comprendere al meglio la reazione p^{11}B** in un plasma generato da interazione laser-materia (i**on stopping power,…**) **(WP2)**

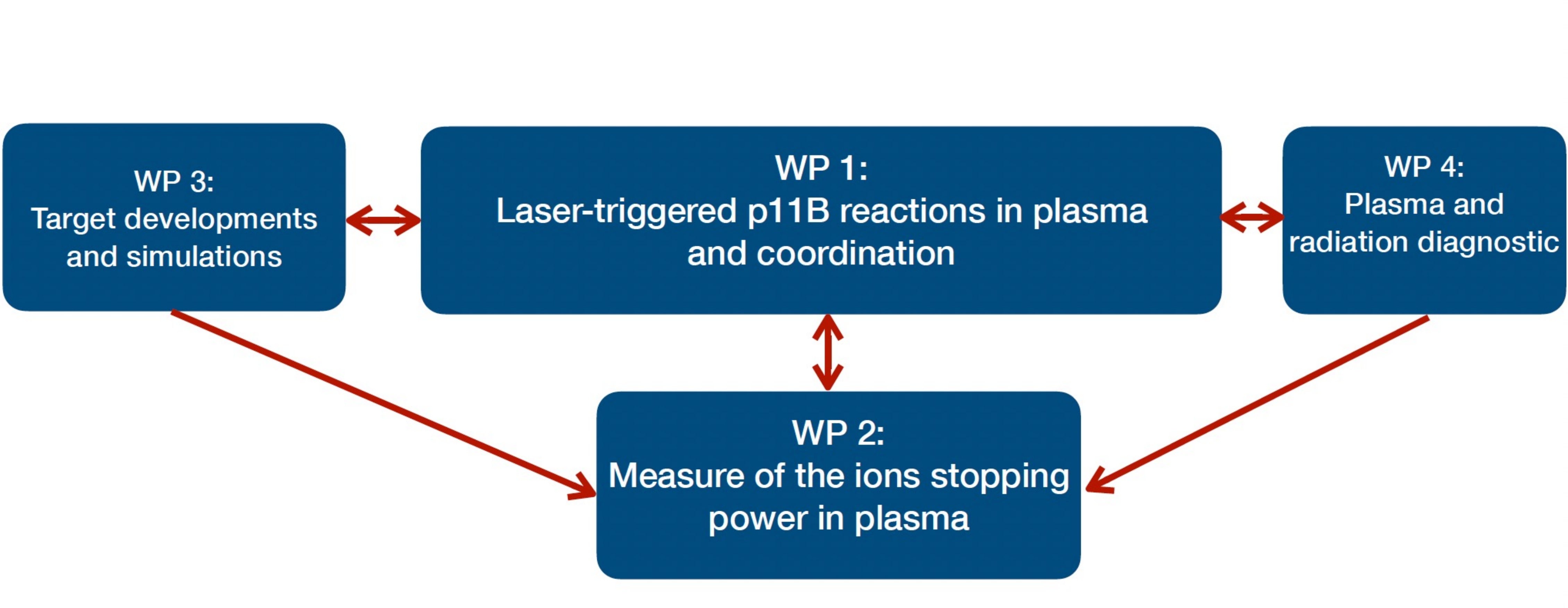
Questo sarà fatto seguendo un percorso ben definito:

- Sviluppare **nuovi targets**
- Realizzare nuovi **schemi di irraggiamento** (legati ai target e al tipo di laser)
- Realizzare **diagnostiche** più performanti

Courtesy of GAP Cirrone e F. Consoli

Courtesy of GAP Cirrone e F. Consoli

Obiettivi e metodologia



WP 3:
Target developments and simulations

WP 1:
Laser-triggered p11B reactions in plasma and coordination

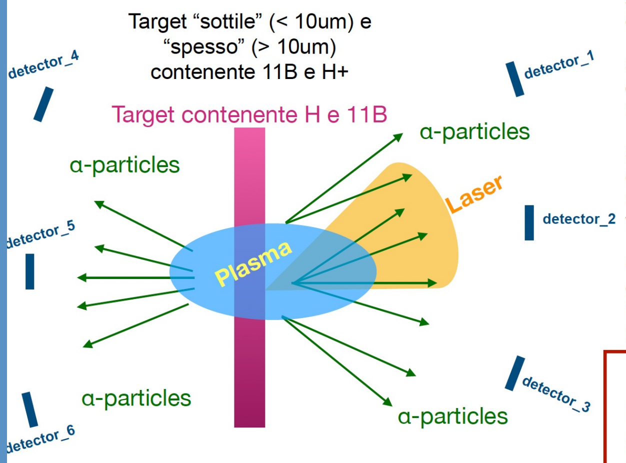
WP 4:
Plasma and radiation diagnostic

WP 2:
Measure of the ions stopping power in plasma

WP's

WP1: reaction study in plasma;

Responsabili: GAP Cirrone (INFN) e F Consoli (RM2-ENEA);
FTE: 3.35; **Sezioni:** LNS, RM2 e TIFPA



Schema di una reazione p-^{11}B attivata in un plasma generato da laser

Si producono e caratterizzano dei **targets** contenenti Boro e Idrogeno in specifiche configurazioni e si irraggiano con un **laser**

Si definisce la tipologia e la posizione delle diagnostiche (**d1, …)** sia della radiazione generata che del plasma

Si misurano, **per ogni sparo laser**: le **caratteristiche del plasma e la radiazione** (alfa e protoni) emessa ai vari angoli

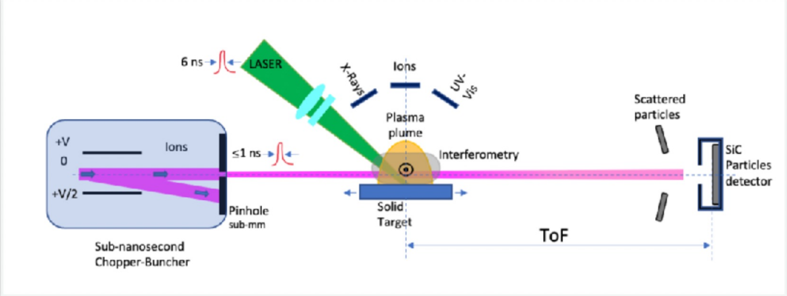
Ottimizzazione della interazione e delle capacità diagnostiche al fine di incrementare il numero di reazioni p-11B

Laser pulse characteristics

Duration: 300 ps
Contrast: 10E-7
Energy: up to 1000 J
Power on target: 3 TW
Intensity on target: 10^{16} W/cm2

WP2: stopping power in plasma;

Responsabili: S Tudisco (LNS), G Pasquali (FI); **FTE:** 1.99 **Sezioni**: LNS, RM2, CT, BO, LNGS, TO, FI



Si producono e caratterizzano dei targets contenenti Boro che poi vengono colpiti da un laser cosicché da produrre un **plasma “borato”**

Bunches di protoni e alfa verranno **sincronizzati** con il plasma generato

Le diagnostiche permetteranno, ad ogni sparo laser, di **caratterizzare il plasma**

Verrà misurata la **perdita di energia** degli ioni nel plasma

Laser pulse characteristics

Duration: 6 ns
Energy: 2 J
Power on target: 10E8
Pulse intensity: 10^{12} W/cm2

Ion-beam characteristics

Spot diameter: < 1mm
Energy: 0.5 - 3 AMeV (protons, alfa)
Bunch duration: 1 ns

WP3: target and simulations;

Responsabili: A Picciotto (TIFPA), S Mirabella (UNICT), M Cipriani (RM2-ENEA)
FTE: 4.8; **Sezioni**: TIFPA, CT, RM2, CT, LE, MI, BO, LNS, TO

- High-energy, long-pulse, low repetition rate (Prague Asterix Laser System, PALS, CZ)
- Low-energy, long pulse, high repetition rate (INFN-LNS laser)

	Target typologies	Thick (bulk)	Thin (5 - 20 µm)	Group/Institutes	Facility	Motivation
a	**BN (boron nitride)**	V	V	FBK-TIFPA-Trento **(WP1,WP2)**	**PALS e Catania**	Aumento di concentrazione di B, usando un mezzo host che ne ha abbondante. H fornita nel processo di fabbricazione
b	**Si:H,B doped**	V	V	FBK-TIFPA/UNI-Catania **(WP1,WP2)**	**PALS e Catania**	Target di riferimento per confronto con precedenti risultati ma con tecniche di drogaggio più efficienti (UNICT)
c	**C:H NPs/B-polymer doped**	V	V	ELI Beamlines, Prague **(WP1,WP2)**	**PALS e Catania**	Aumento di concentrazione di H, usando un mezzo host che ne ha abbondante.Aumento assorbimento energia laser dale nano strutture
d	**Foam**	V	V	INFN-RM2 INFN-Lecce **(WP1,WP2)**	**PALS e Catania**	Aumento larghezza di scala del plasma e aumento elettroni liberi
e	**Multilayer B polymers**	_	V	UNI-Catania **(WP1)**	**PALS**	Possibilità di gestire le configurazioni e le dimensioni dei singoli layer

Già irraggiati al PALS ma non in condizioni controllate (a, b)

Targets completamente nuovi (c, d, e)

Tutti i target (eccetto c) sono stati già preliminarmente simulati con simulazioni di tipo idrodinamico

WP4: diagnostic;

Responsabili: C Verona (RM2), M Scisciò (RM2-ENEA);
FTE: 5.36; **Sezioni:** RM2, LE, LNS, MI, BO, LNGS

✓Ogni diagnostica sarà progettata, realizzata e caratterizzata/calibrata dalle diverse sezioni coinvolte come riportato in tabella

✓Alcuni rivelatori (TOF SiC e diamante, Telescopio al Si, CR-39) sono già disponibili “in kind” per la diagnostica

✓Tutti i sistemi diagnostici verranno impiegati negli esperimenti organizzati nel WP1 e nel WP2 per misure delle caratteristiche del plasma (temperature e densità) e della radiazione emessa dall'interazione laser-target (protoni, particelle alpha, ioni e neutroni)

Diagnostic type	Description	Advantages	Section
High-sensitivity spectrometer device	Thomson Spectrometry + advanced adaptive filtering + track discrimination in CR39. Compact structure with enhanced shielding to X and RF-microwaves	Efficient discrimination of alpha particles; detection of low particle fluxes with good resolution in the ion energy ranges of p-11B fusion reaction	Roma2, MI, LNS
Ion Collector	System able to measure the energy spectra in Time Of Flight configuration	Charged particle detection at high intensity rate	LNS, MI
Pixelated-TOF diamond detectors	Matrix of diamond detectors nominally identical in terms of size and thickness, featuring different calibrated foil filters of different thicknesses for energy spectra reconstruction	Distinguish alpha particles from the protons and measurement of ions energy spectra in “real-time”	Roma2
EJ-309 liquid scintillators	100 mm diameter X 51 mm high + fast Hamamatsu R7725 PMT read out	Neutron detection in TOF configuration + alpha/gamma discrimination with Pulse Shape technique	LNS, ELI-beamlines
Time-resolved laser interferometer	Part of the same laser generating the plasma will be time-reduced by pockels cells and used to illuminate the plasma tangentially at some specific time instants. A pattern of parallel fringes will be set by a Wollaston prism.	Plasma density spatial profile in specific time instants will be retrieved by fringe deflection.	LNS, Roma2
X-ray spectrometer	X-ray Bragg's diffraction spectroscopy by two planar crystals. Ranges: 600-740 eV and 1500-1850 eV. Detector: linear CCD; Optimization of a device developed in the	Double X-ray crystal spectra, for description of the X-ray plasma emission and thus estimation of plasma temperature	BO, LNGS

Courtesy of GAP Cirrone e F. Consoli

STORM

STrOngcRystallineelectroMagneticfields

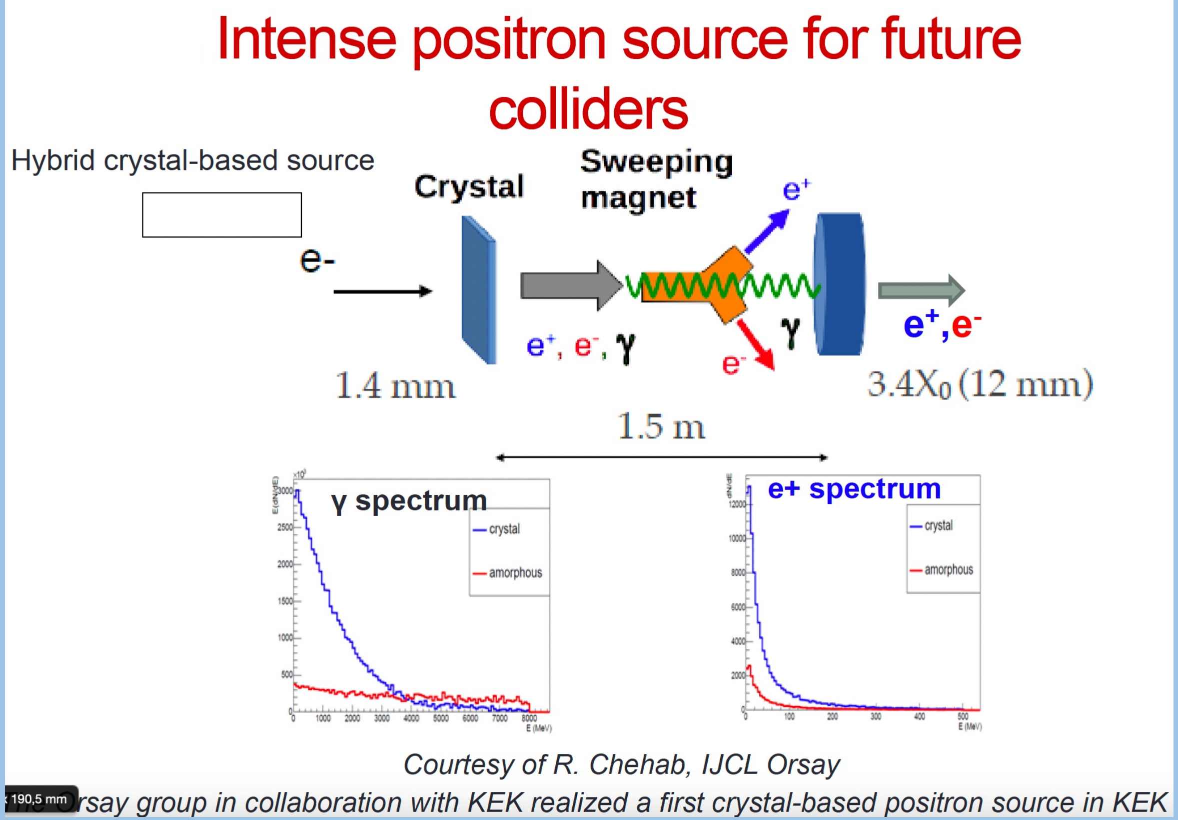
2021-2022 INFN-FE,LNL, MIB RN L. Bandiera

Goal

Investigation of beam interaction with strong crystalline electromagnetic fields to exploit the huge **enhancement of the photon emission** and **radiation length reduction** for applications in **accelerator and detector physics.**

Courtesy of L. Bandiera

Project Targets: 1



Intense positron source for future colliders

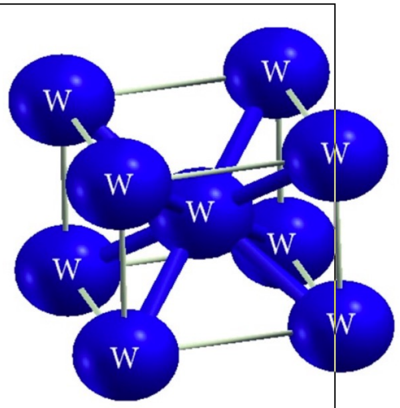
Courtesy of R. Chehab, IJCL Orsay

The Orsay group in collaboration with KEK realized a first crystal-based positron source in KEK

Courtesy of L. Bandiera

Crystalline materials: high-Z metals, **W and Ir** (Axial potential ≈1 keV vs. ≈ 100 eV for Si) .

- **Typically less perfect than Si or Ge, but already used in past channeling experiments.**



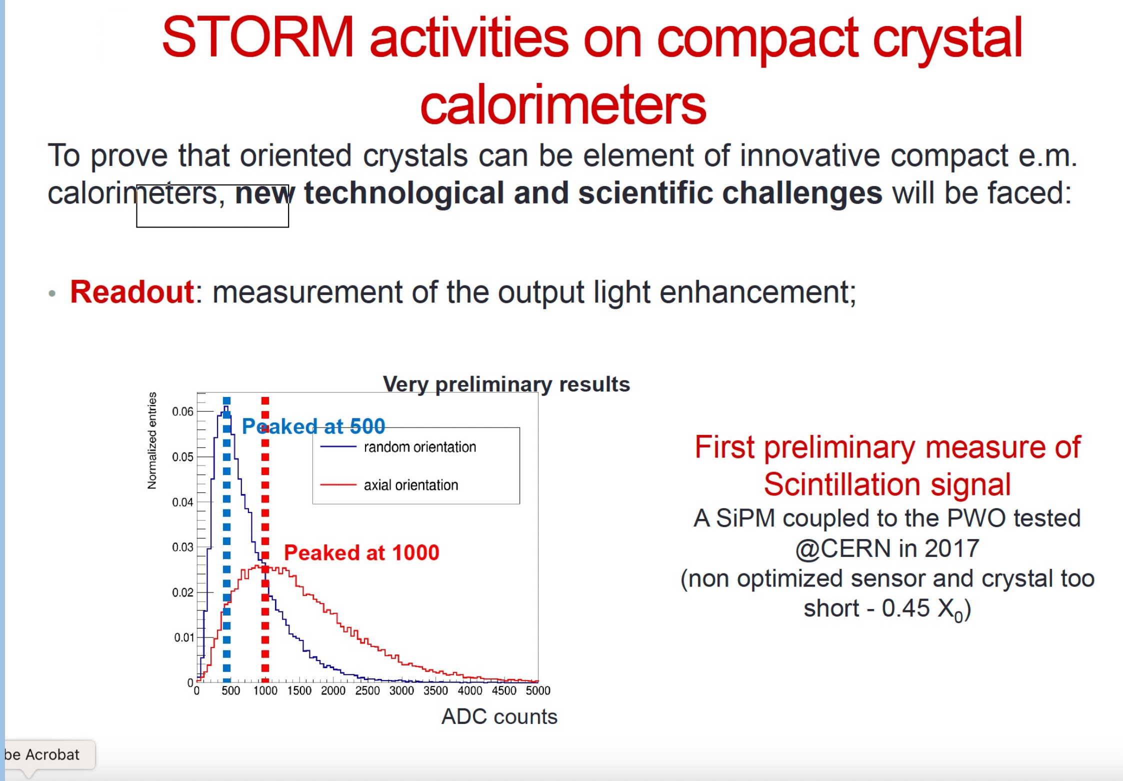
Measure the γ spectrum and other parameters needed for a crystal-based e+ source:

- **use e- beam of interest for FCCee: 6 GeV** (DESY) and **20 GeV** (CERN)

- **Main advantages**
  - **Enhancement of photon generation in crystals in channeling conditions ➔ enhancement of pair production in the converter target**
  - **Reduction of the *Peak Energy Deposition Density* (PEDD) in the target material** compared to conventional sources (more than 1 order of mag. less)

One of the two options for FCCee. Since July 2020 we are part of the Injector study group Task 3 Positron source – collaboration with IJCL Orsay.

Project Targets:2



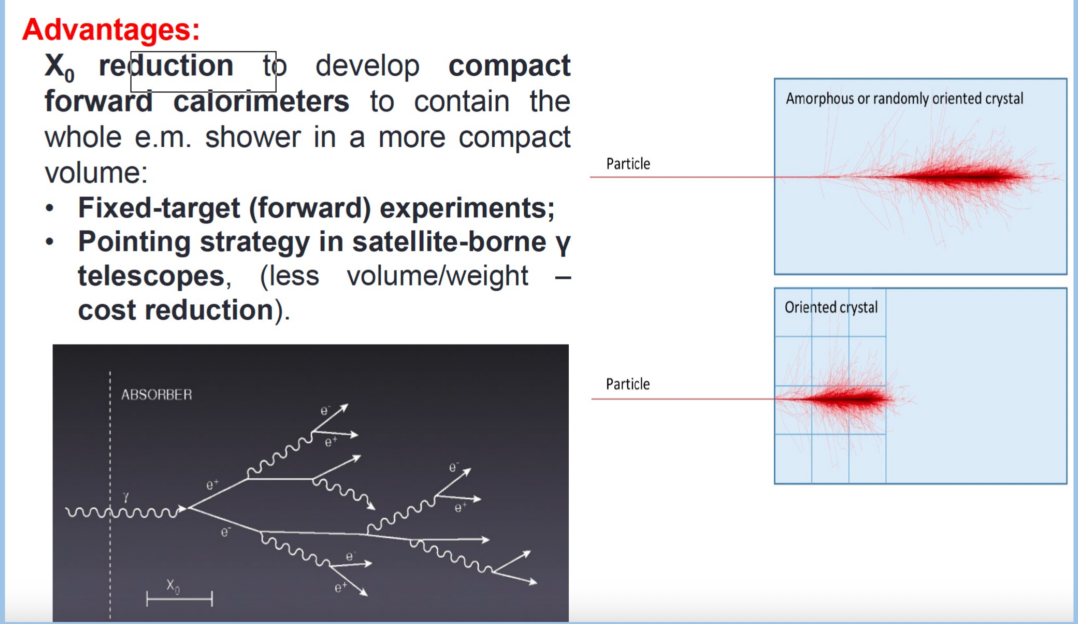
STORM activities on compact crystal calorimeters

To prove that oriented crystals can be element of innovative compact e.m. calorimeters, **new technological and scientific challenges** will be faced:

- **Readout**: measurement of the output light enhancement;

First preliminary measure of Scintillation signal

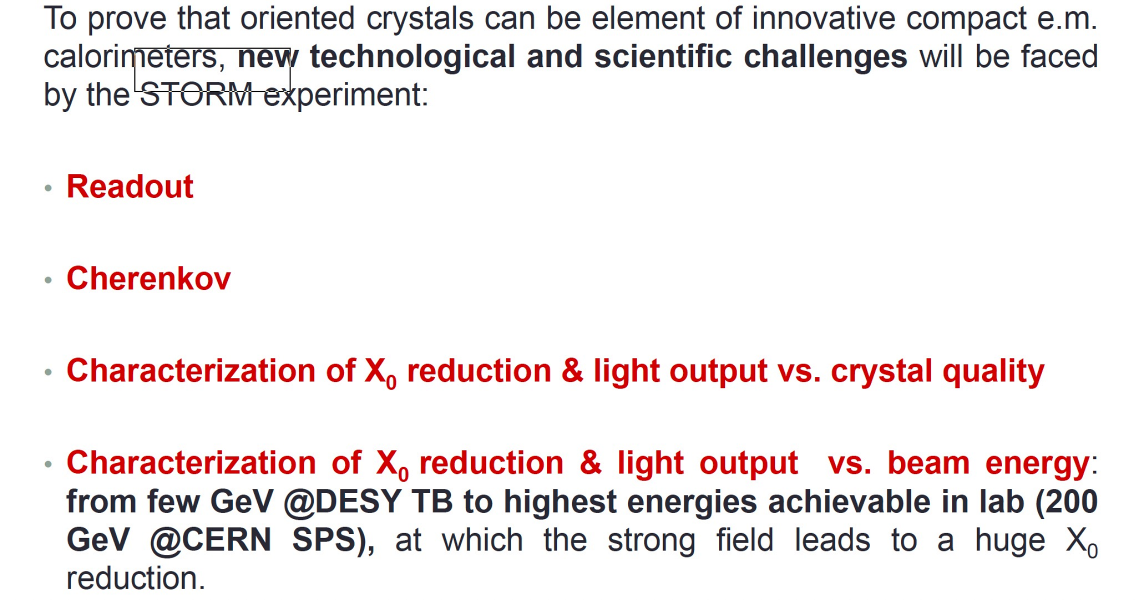
A SiPM coupled to the PWO tested @CERN in 2017 (non optimized sensor and crystal too short - 0.45 X_0)



Advantages:

X_0 reduction to develop **compact forward calorimeters** to contain the whole e.m. shower in a more compact volume:

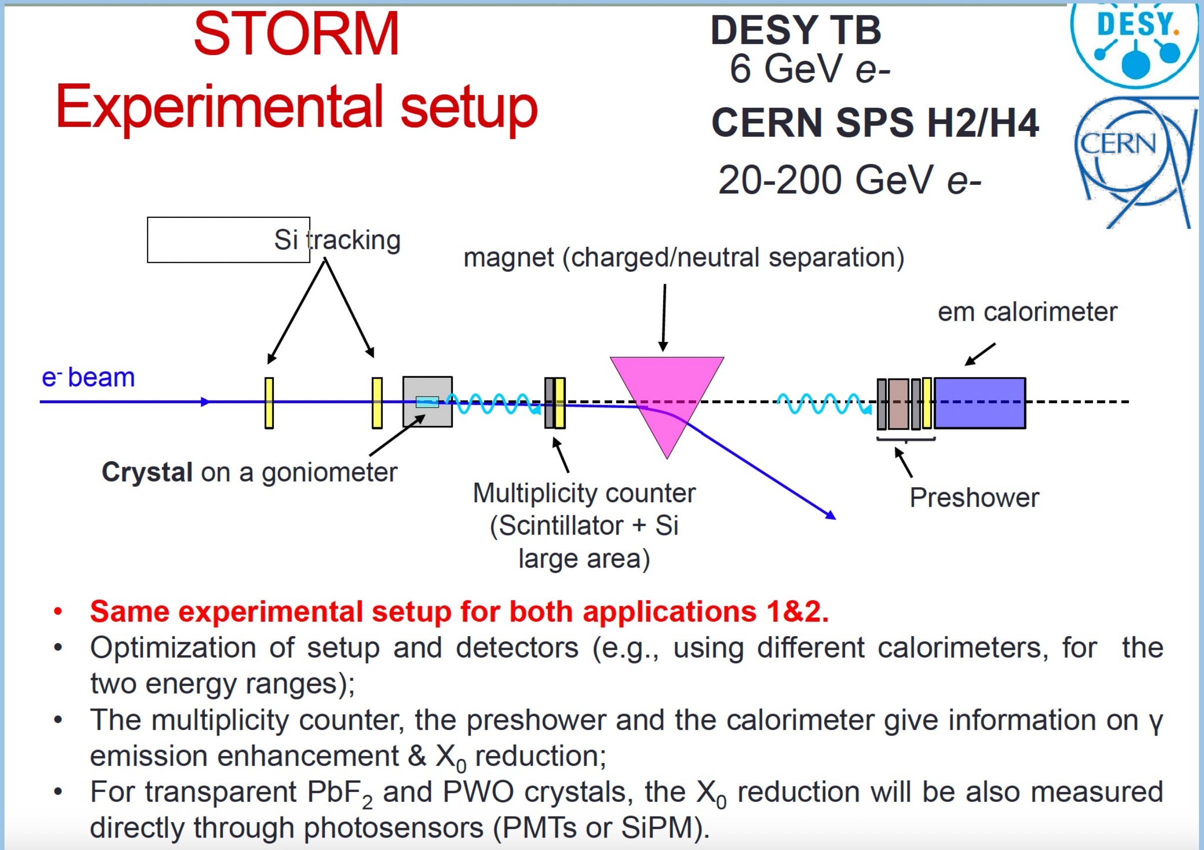
- **Fixed-target (forward) experiments;**
- **Pointing strategy in satellite-borne γ telescopes**, (less volume/weight – **cost reduction**).



To prove that oriented crystals can be element of innovative compact e.m. calorimeters, **new technological and scientific challenges** will be faced by the STORM experiment:

- **Readout**
- **Cherenkov**
- **Characterization of X_0 reduction & light output vs. crystal quality**
- **Characterization of X_0 reduction & light output vs. beam energy: from few GeV @DESY TB to highest energies achievable in lab (200 GeV @CERN SPS)**, at which the strong field leads to a huge X_0 reduction.

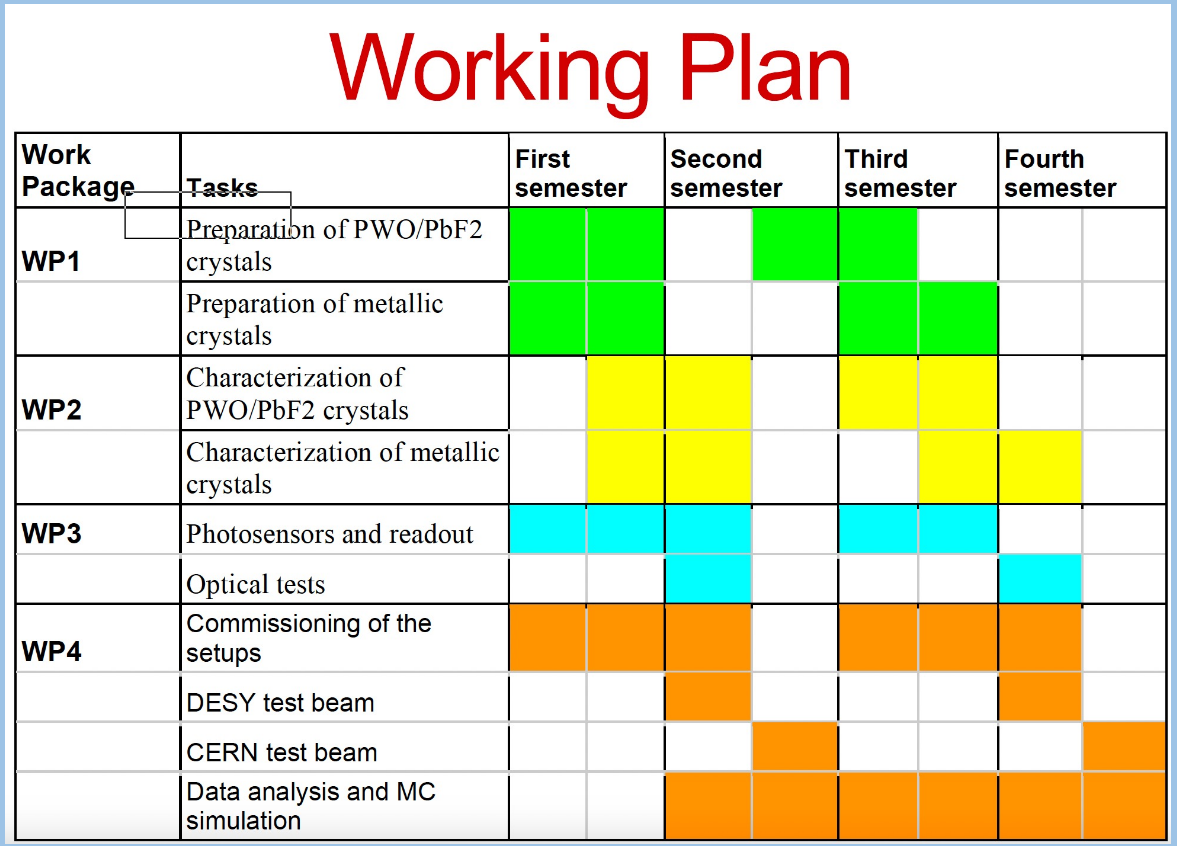
Courtesy of L. Bandiera



STORM Experimental setup

DESY TB
6 GeV *e-*
CERN SPS H2/H4
20-200 GeV *e-*

- **Same experimental setup for both applications 1&2.**
- Optimization of setup and detectors (e.g., using different calorimeters, for the two energy ranges);
- The multiplicity counter, the preshower and the calorimeter give information on γ emission enhancement & X_0 reduction;
- For transparent PbF_2 and PWO crystals, the X_0 reduction will be also measured directly through photosensors (PMTs or SiPM).



Working Plan

Work Package	Tasks	First semester		Second semester		Third semester		Fourth semester	
WP1	Preparation of PWO/PbF2 crystals	🟩	🟩		🟩	🟩			
	Preparation of metallic crystals	🟩	🟩			🟩	🟩		
WP2	Characterization of PWO/PbF2 crystals		🟨	🟨		🟨	🟨		
	Characterization of metallic crystals		🟨	🟨			🟨	🟨	
WP3	Photosensors and readout	🟦	🟦	🟦		🟦	🟦		
	Optical tests			🟦				🟦	
WP4	Commissioning of the setups	🟧	🟧	🟧		🟧	🟧	🟧	
	DESY test beam			🟧				🟧	
	CERN test beam				🟧				🟧
	Data analysis and MC simulation			🟧	🟧	🟧	🟧	🟧	🟧

Courtesy of L. Bandiera

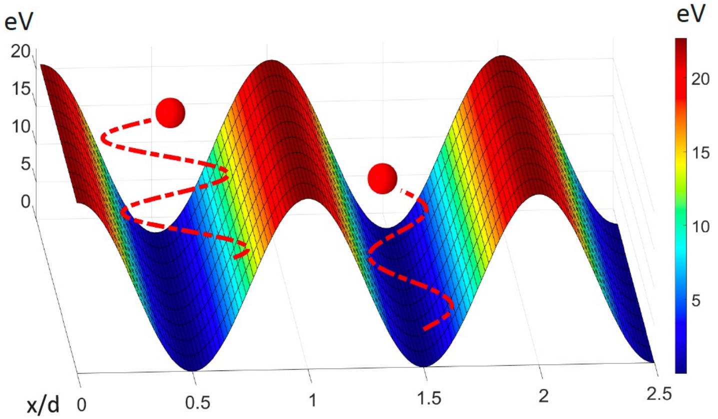
GALORE

hi**G**h-efficient be**A**m def**L**ector f**OR** acc**E**lerators

Proponente: M. Romagnoni (romagnoni@fe.infn.it)
Sezioni Partecipanti: Ferrara, Legnaro

Novel design for bent crystal based on silicon micromachining

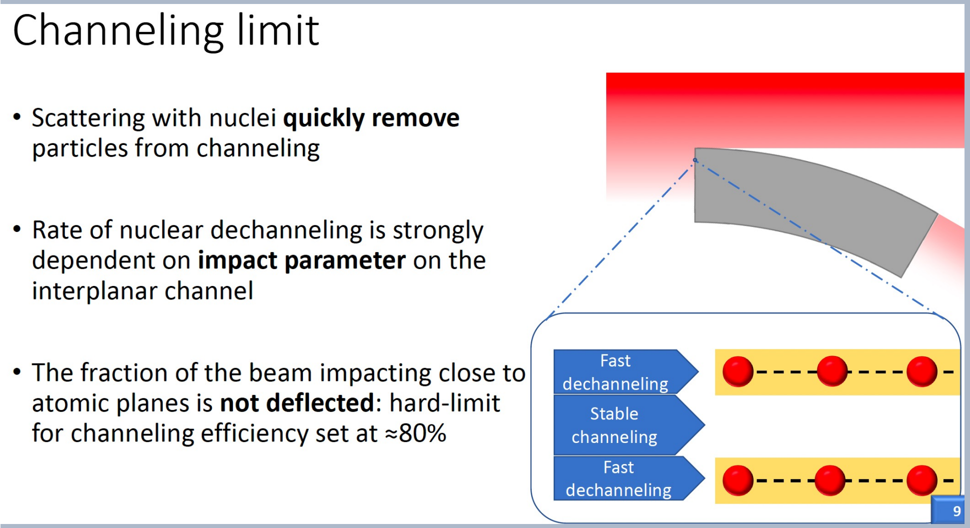
Remove upper efficiency limit: close to **100% efficiency possible**



Strong static potential (≈**GeV/cm**) can trap (*channel*) positive particles between two adjacent atomic planes angle

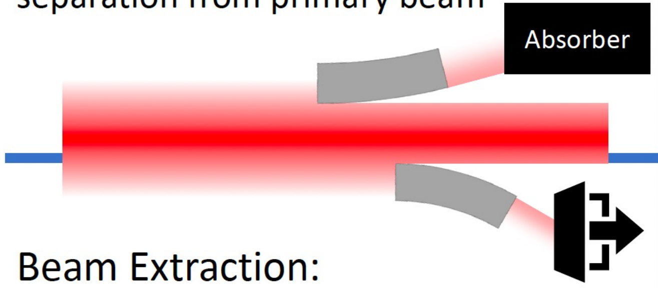
Channeled particles are forced to follow crystal curvature, with steering power ≈ **10^2T** magnetic dipole

for



Channeling limit

- Scattering with nuclei **quickly remove** particles from channeling
- Rate of nuclear dechanneling is strongly dependent on **impact parameter** on the interplanar channel
- The fraction of the beam impacting close to atomic planes is **not deflected**: hard-limit for channeling efficiency set at ≈80%

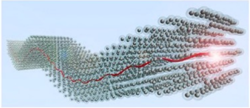


Beam Collimation:

With crystal high control of beam halo separation from primary beam

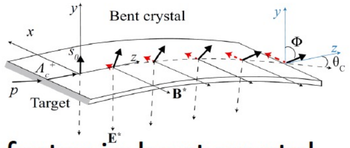
Novel radiation sources:

For channeled light particles (e+/e-) enhanced photon emission



Beam Extraction:

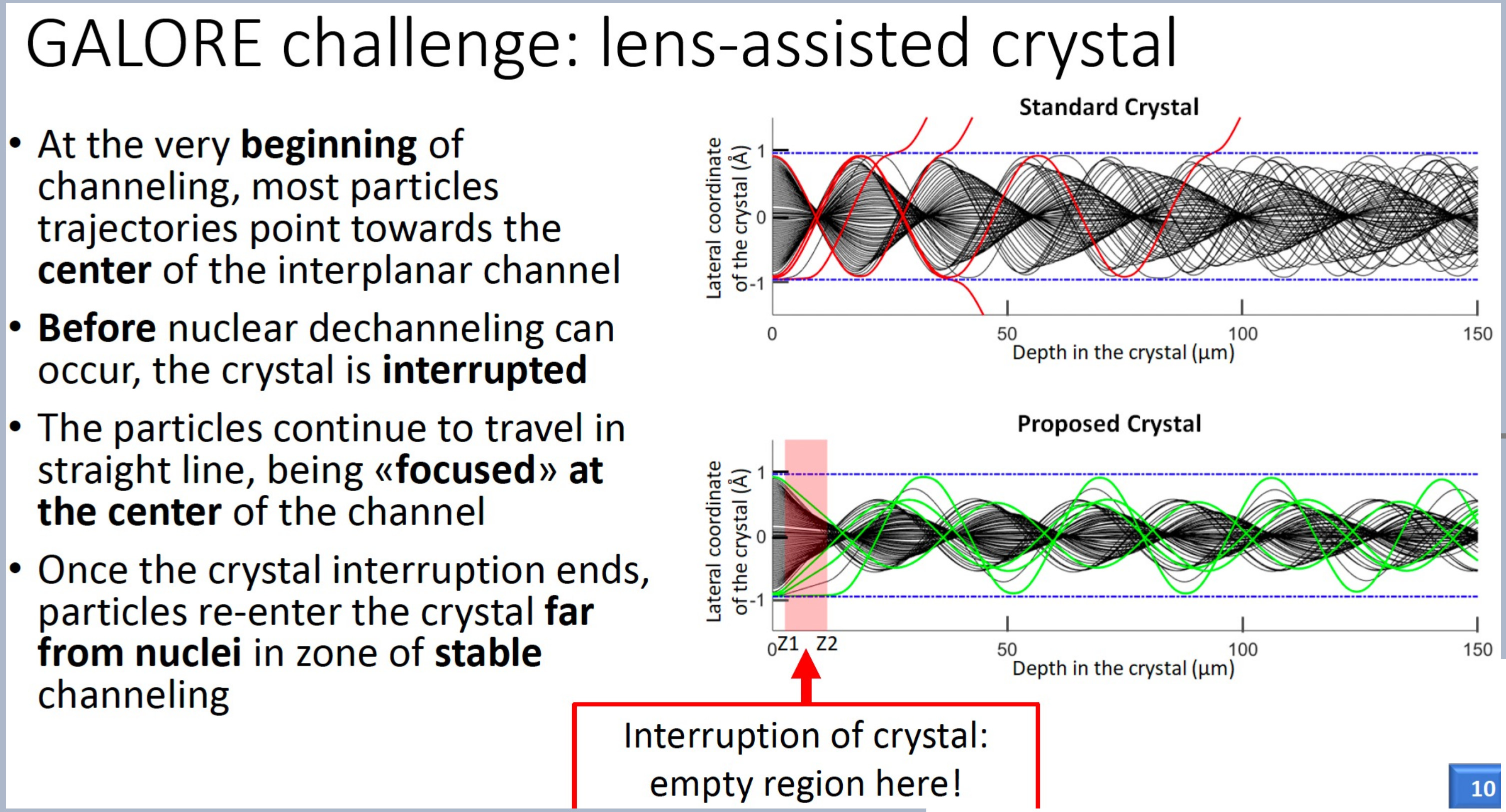
Surgical redirection of a beam portion, towards a precise location in the machine or in an external facility



Spin precession:

Spin precession much faster in bent crystal wrt existing dipoles→EDM & MDM study of fast decaying particles

Courtesy of M. Romagnoni



GALORE challenge: lens-assisted crystal

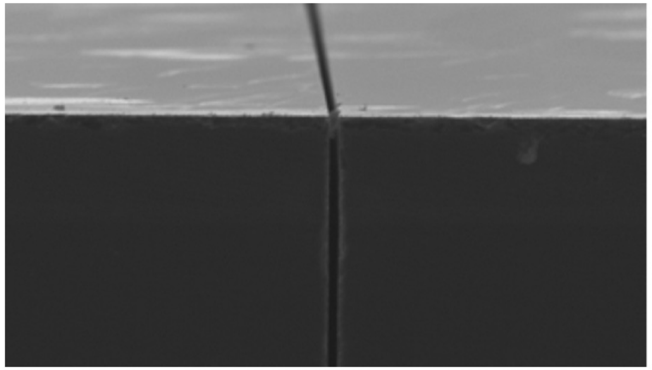
- At the very **beginning** of channeling, most particles trajectories point towards the **center** of the interplanar channel
- **Before** nuclear dechanneling can occur, the crystal is **interrupted**
- The particles continue to travel in straight line, being «**focused**» **at the center** of the channel
- Once the crystal interruption ends, particles re-enter the crystal **far from nuclei** in zone of **stable** channeling

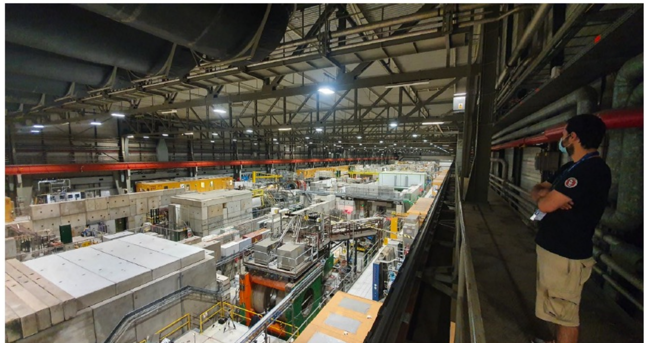
Interruption of crystal: empty region here!

Courtesy of M. Romagnoni

GALORE GOALS

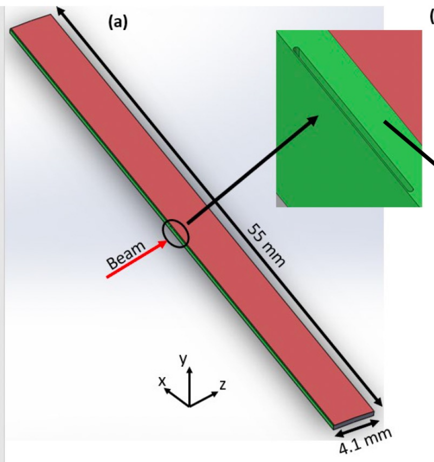
- ✓ To develop a **reliable procedure** to fabricate this type of bent crystals
- ✓ To manufacture and characterize a **first prototype**
- ✓ To **test** a first prototype with 180 GeV/c hadronic beam

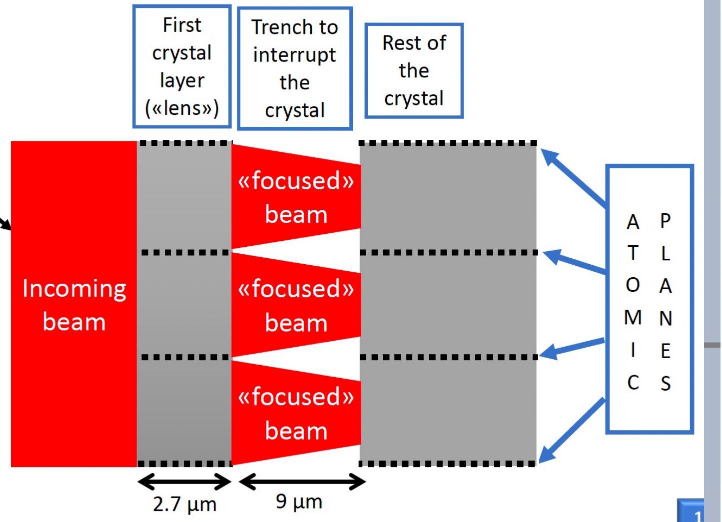




Success of GALORE would prove the **feasibility** of this new design and unlock application for **wide energy range**

Schematic of GALORE prototype





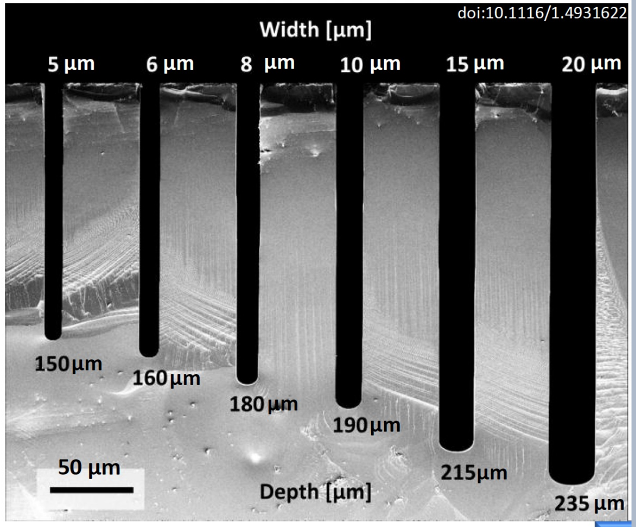
New techniques from semiconductors industry

Deep Reactive Ion Etching (DRIE)

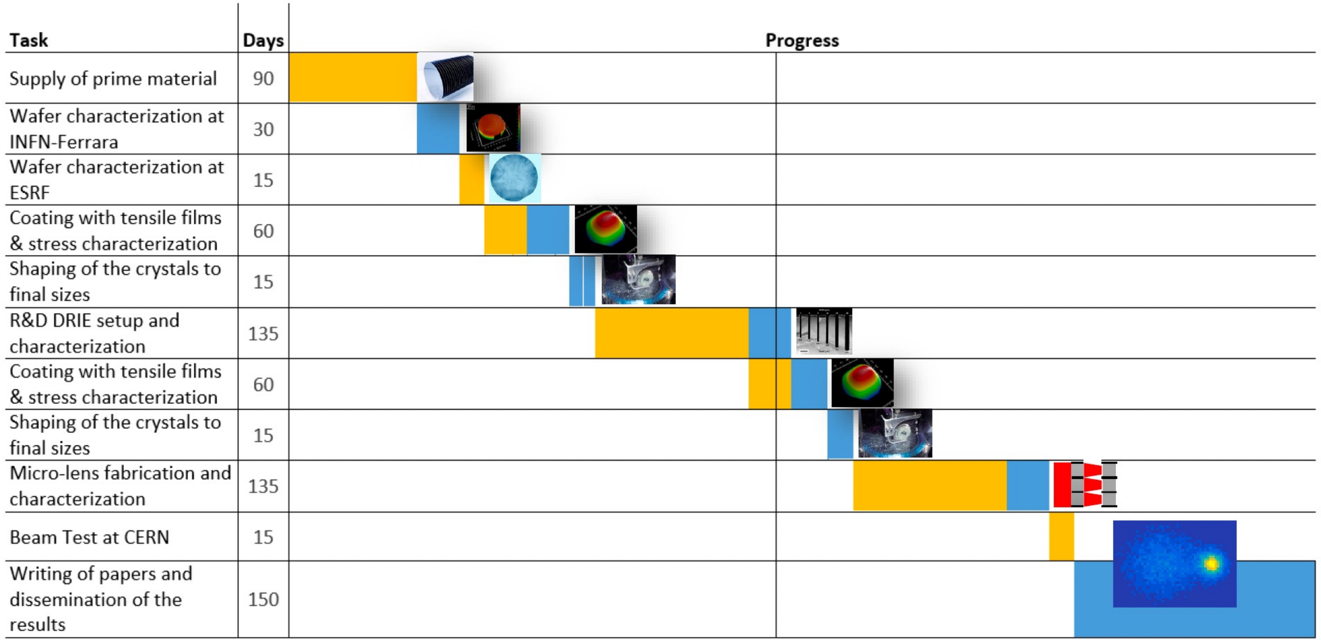
- High spatial precision
- Vertical walls with high aspect ratio
- No damage / stress on crystal

Silicon Nitride (Si_3N_4) film

- High adhesion to silicon
- Nanometric precision of film thickness
- Highly patternable with sub-micrometric precision



Timeline



Task	Days	Progress
Supply of prime material	90	
Wafer characterization at INFN-Ferrara	30	
Wafer characterization at ESRF	15	
Coating with tensile films & stress characterization	60	
Shaping of the crystals to final sizes	15	
R&D DRIE setup and characterization	135	
Coating with tensile films & stress characterization	60	
Shaping of the crystals to final sizes	15	
Micro-lens fabrication and characterization	135	
Beam Test at CERN	15	
Writing of papers and dissemination of the results	150	

🟨 External facilities

🟦 INFN Laboratories

Courtesy of M. Romagnoni

Guide Lines

let’s build them together:

- **Task:**

  CSN5 is a crucible of:

  - future know how/technology/infrastructures
  - know how enhancement/upgrade & technical spin off
  - new physics exploration, new fields promotion

- **Constraints:**

  - human and financial resources are finite

  ☞ CSN5 is selective based on

- Impact
- Methodology
- Feasibility

- **Tools:**

the proposals:

three sizes available

Grant **St.Exp** **Call**

constructed with

high → maximum → tbyc

ease of reading

for evaluation, review, follow-up

The three existing templates are a synthesis of these concepts

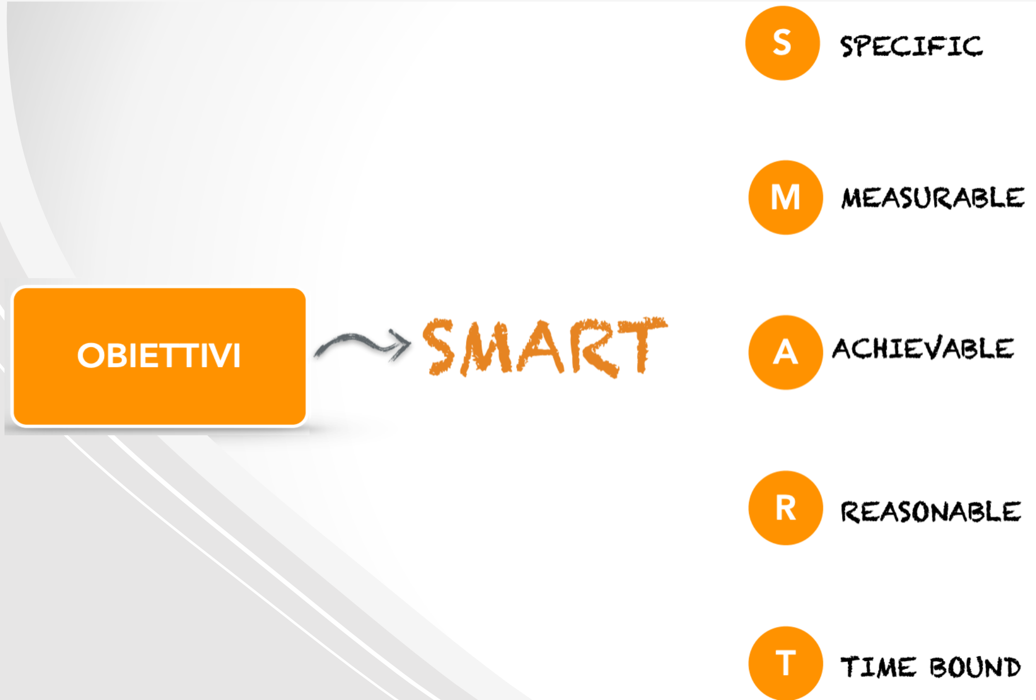
Available on the CSN5 web page (our living room)

Ultimate refinement:
the PM environment properly object oriented/shaped to provide a common platform-language for the scope

Work in progress

- After the Feb 2023 CSN5 with A. Falone intervention on behalf of the INFN-PM Committee a WG has been identified:G. Bisoffi, A. Falone, M. Laubenstein, G. Simi, C. Vaccarezza

- **Task**:by March 15th 2023 propose for discussion a template upgrade for Call proposals:
- clarifying revision of the terminology of the template based on the concepts established by the good practice of the PM
- Link to the PM Guide Lines for reference
- Clarifying examples and eventual short PM glossary
- **Goal**:ease the proposal preparation/review with the help of the PM expertise.



Thanks for your attention