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Ongoing projects at SCK-CEN of interest to the development of a Pb/Bi loop target for EURISOL

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Pb/Bi loop target for EURISOL kick-off meeting,
CERN, 10 May 2012

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Outline

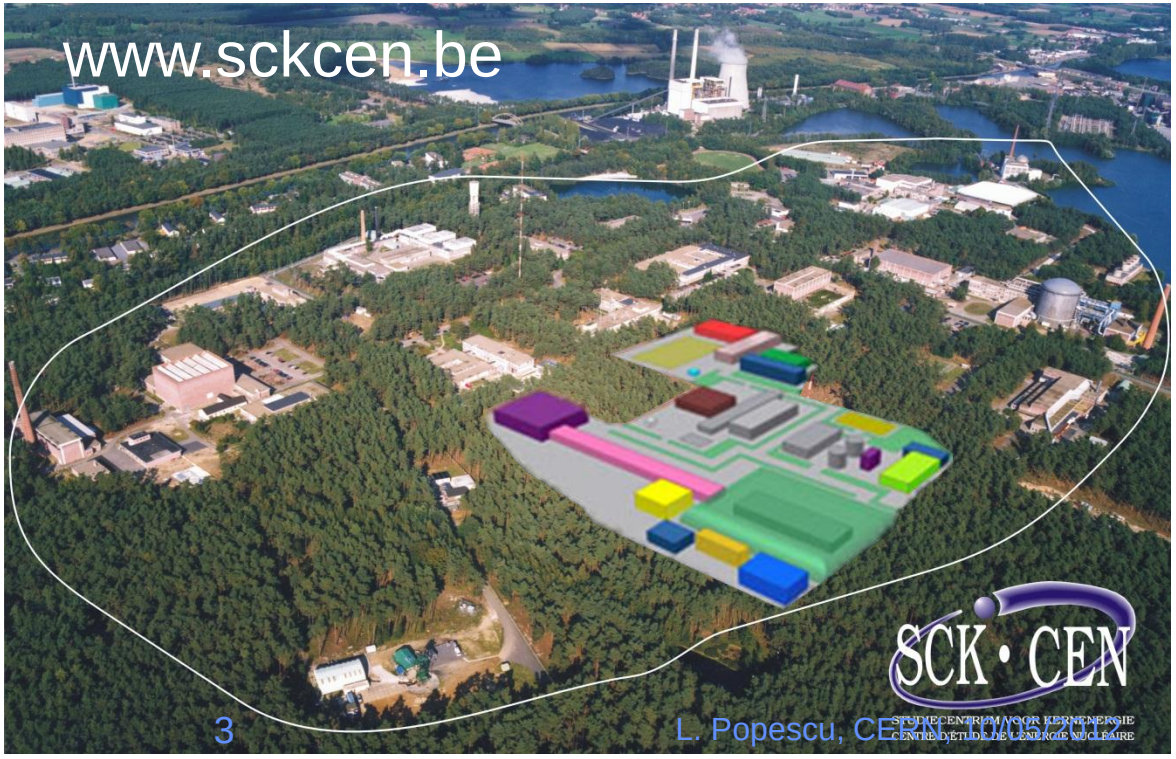
- SCK•CEN - Introduction
- MYRRHA
- GUINEVERE
- ISOL@MYRRHA
- Links to the present project

SCK•CEN Belgian Nuclear Research Centre

- created in 1952
  - cradle of nuclear research and energy development in Belgium
  - major international player in the field of nuclear research
- tutorship: federal Minister of Energy
- now: ~700 staff,

>50% with academic degree

- annual turnover: 115 M€
  - 40% government support
  - 60% contract work

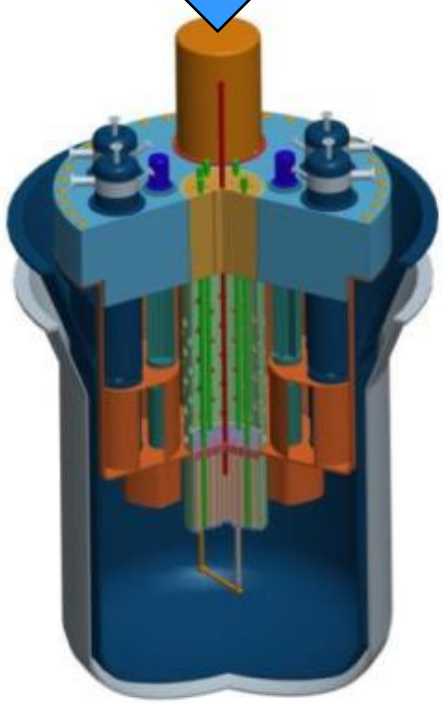


MYRRHA - Concept

Proton driver linac

- High power proton accelerator as driver
- Spallation target: LBE

- Subcritical reactor
  - High power density 30-32% MOX core
  - Liquid metal cooled (LBE)
  - High flexibility



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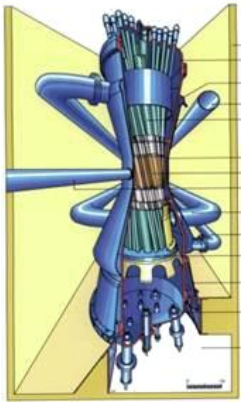
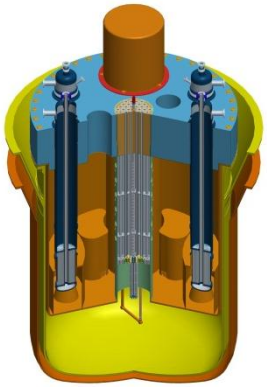
MYRRHA Replaces BR2



1962

BR2

- Material Testing Reactor (fission)
- Fuel testing for LWR & GEN II/GEN III
- Irradiation Services:
  - Medical RI
  - Silicium Doping
  - Others



2023

MYRRHA

- Fast Neutron Material Testing Reactor (fission + fusion)
- ADS-Demo + P&T Testing
- Irradiation Services:
  - Medical RI
  - Silicium Doping
  - Others
- Fuel testing for LFT GEN IV
- LFR European Technology Pilot Plant (ETPP)

MYRRHA - Concept

Proton driver linac

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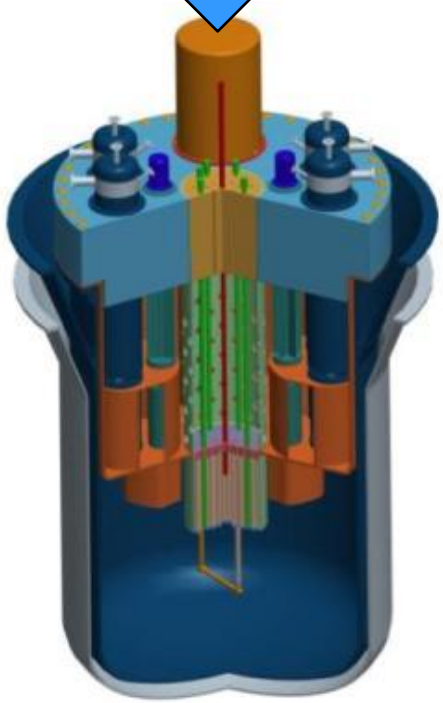
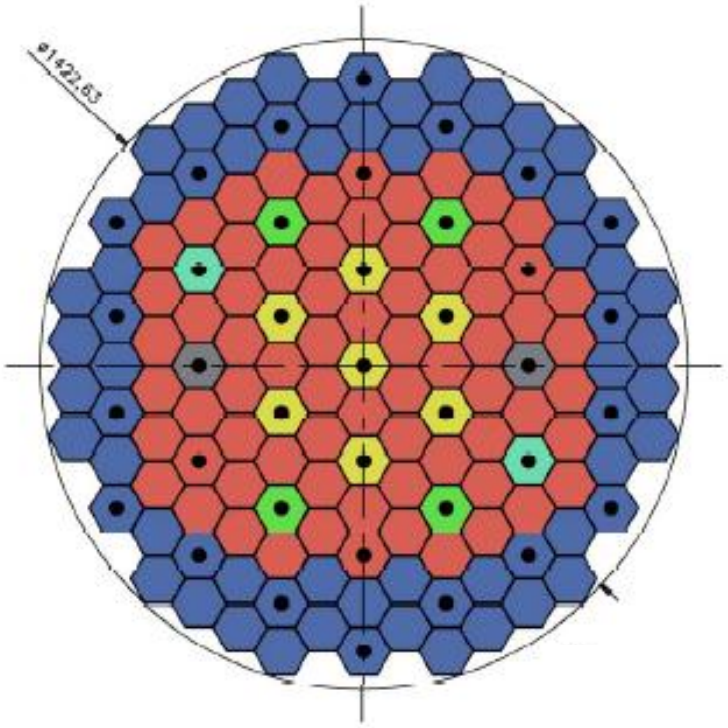


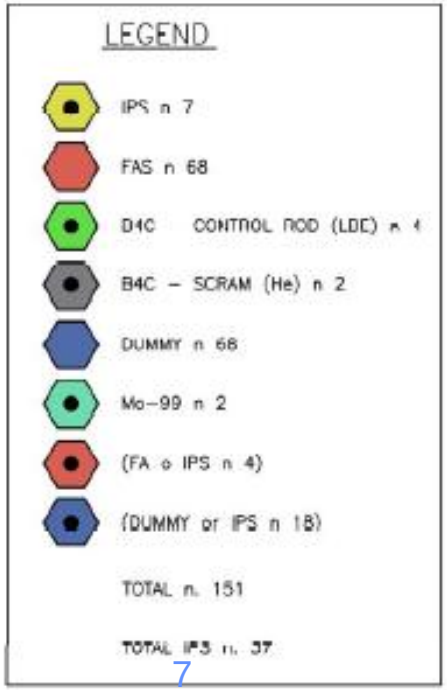
Reactor Layout - Core

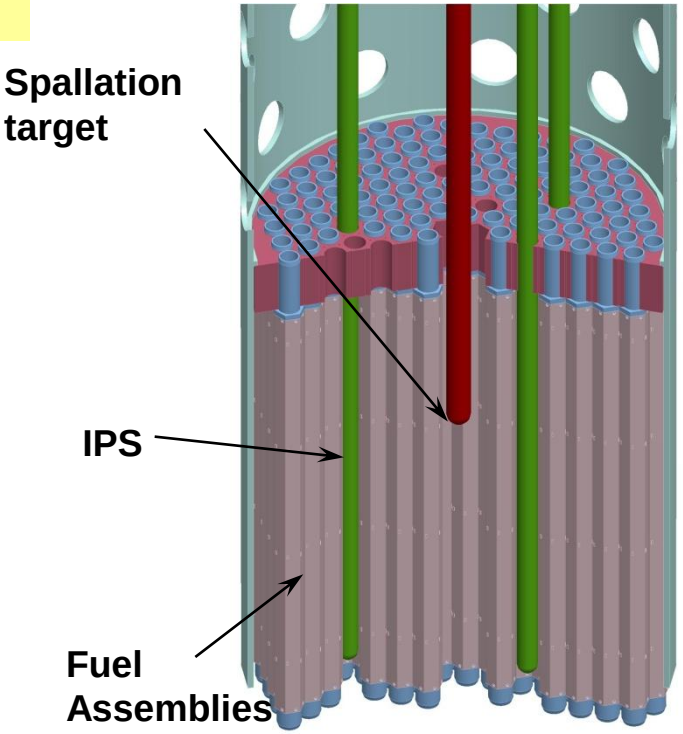
- 151 positions
- Diameter: 1450 mm
- k_{eff}≈0.95 (ADS mode)
- 30-35 % MOX fuel
- 37 multifunctional plugs

Total flux (hottest pin)	4.7E+15	n/cm^2/s
Fast flux above 0.75 MeV (hottest pin)	1.01E+15	n/cm^2/s
Dpa(/350 EFPD's) (hottest pin)	45	
Ppm He/dpa (hottest pin/target zone)	3.8/6.4	
Irradiation volume (8 In-Pile Sections)	3700*8	cm^3

Inlet temperature	270	°C
Coolant delta T	130	°C
Velocity (fuel rod)	1.9	m/sec
Temperature at cladding surface	500	°C
Maximum linear power	370	W/cm



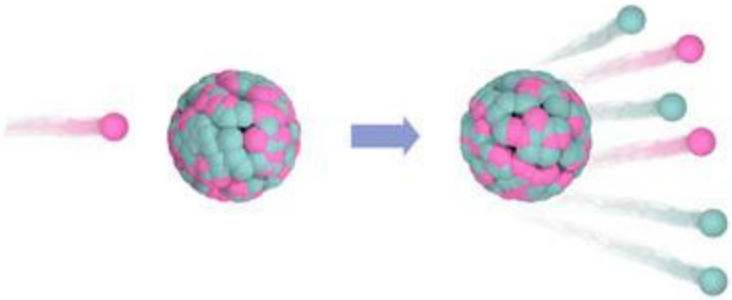




Spallation Target

Design requirements

- enough neutrons to feed the sub-critical core at its k_{eff} value of 0.95
- capable to evacuate the heat deposited by the beam (~ 65 % of the total beam power, i.e. ≈ 2.1 MW)
- spatial constrains: fit in the central hole of the sub-critical core assembly and be as compact as possible to generate the highest possible neutron fluxes in the immediate surroundings of the target
- must reach an appropriate lifetime and it must comply with the fundamental role of MYRRHA as a flexible high intensity experimental irradiation device



A liquid metal, for which lead-bismuth eutectic (LBE) has been chosen, is selected as target material to obtain a high neutron gain and to allow forced convective heat removal.

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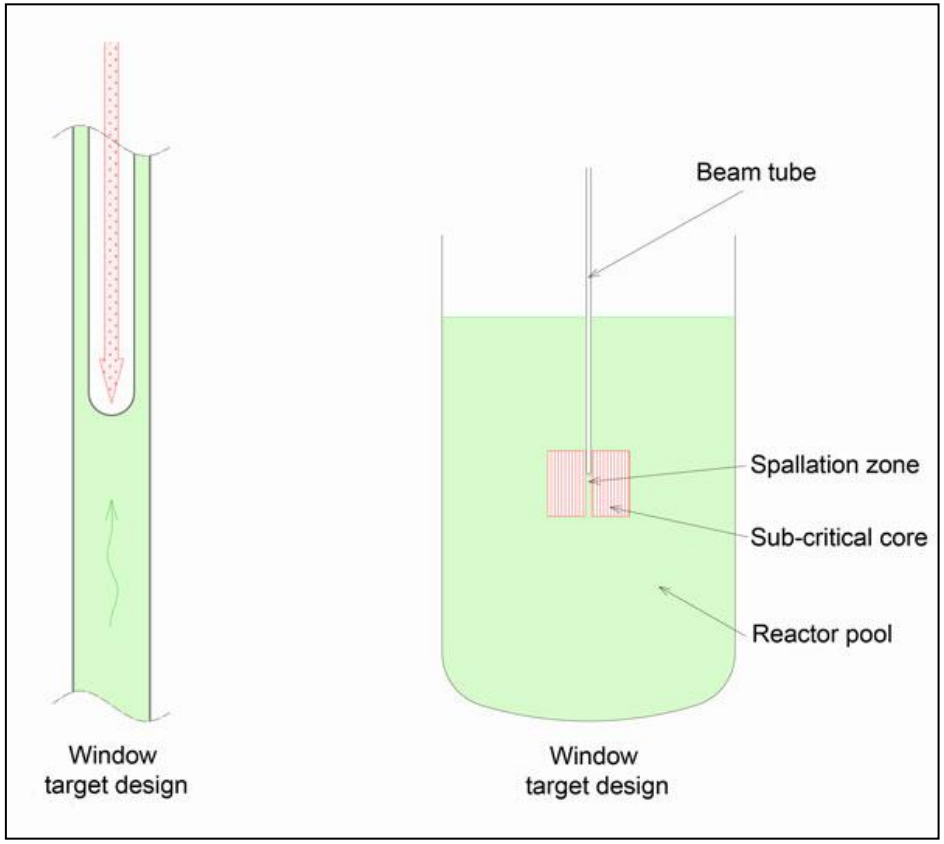
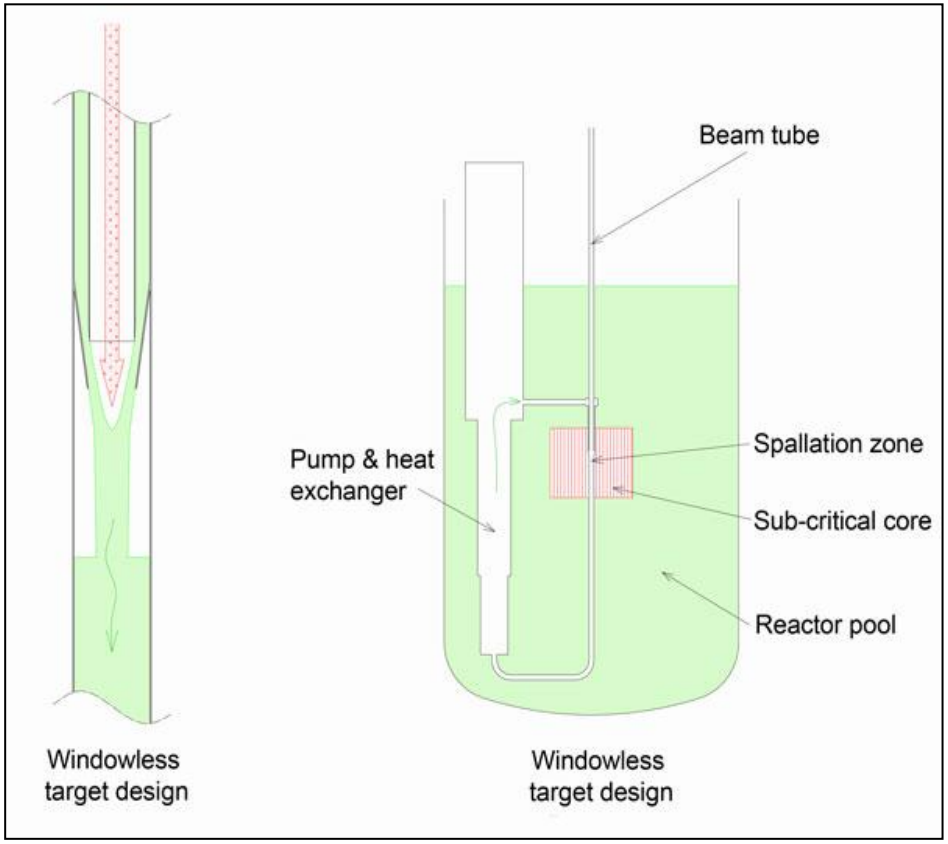
Spallation Target – Two Options

- **Window-target design**



- **Windowless-target design**



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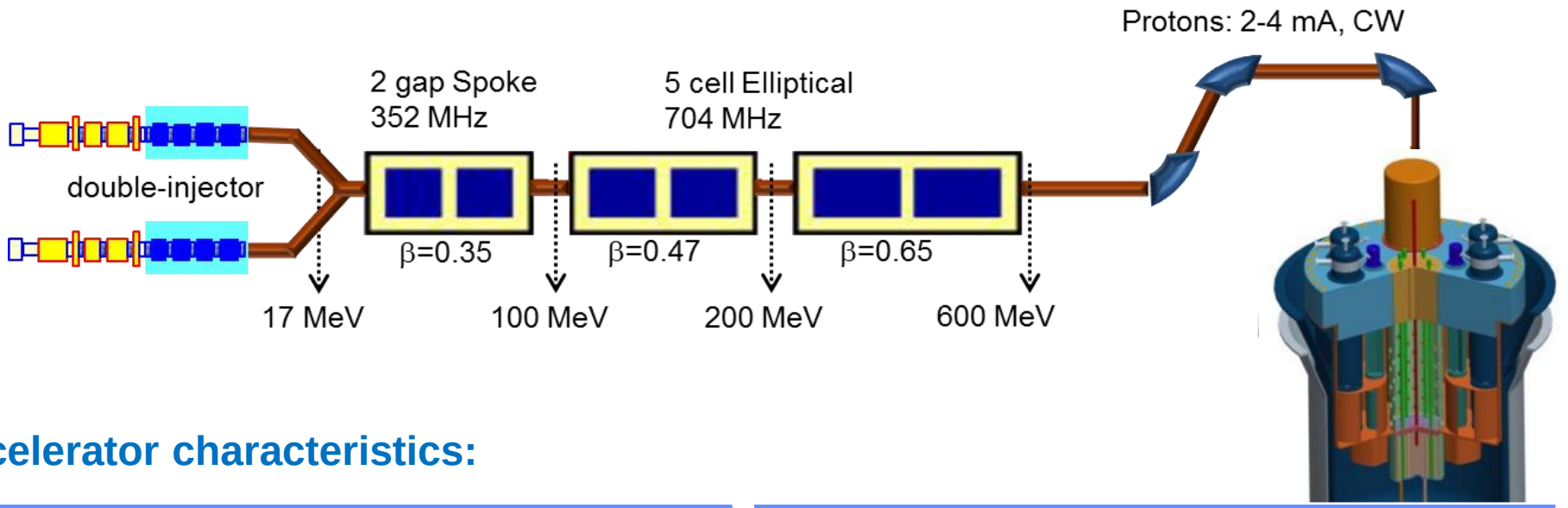
MYRRHA - Proton Driver



Accelerator characteristics:

Fundamental parameters (ADS)	
Particle	p
Beam energy	600 MeV
Beam current	4 mA
Mode	CW
MTBF	> 250 h

Failure= beam trip > 3s

implementation	
Superconducting linac	
frequency	176/352/704 MHz
Reliability = redundancy	Double injector
	"fault tolerant" scheme

MYRRHA Proton Driver

(Courtesy Dirk Vandeplassche, SCK•CEN)

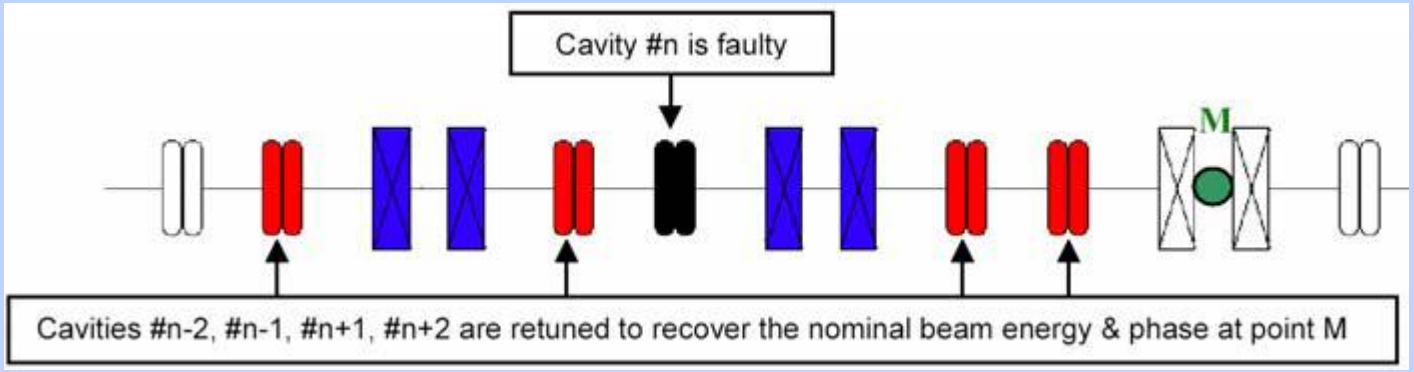
- implementation of reliability : 3 principles
  1. overrating
  2. reliability (availability) → ***redundancy*** → parallel scheme (double-injector) / serial scheme (modular high en. sections)
  3. repairability
- principles to be applied to the basic linac layout, but also to much of the ancillary equipment

MYRRHA Proton Driver

(Courtesy Dirk Vandeplassche, SCK•CEN)

- implementation of reliability : 3 principles
  1. overrating
  2. reliability (availability) ⇒ ***redundancy*** → parallel scheme (double-injector) / serial scheme (modular high en. sections)
  3. repairability

Principle of fault tolerance in the superconducting spoke linac



within < 3 sec

- Detection of an RF fault
- Change RF phase in neighboring cavities
- Increase RF field in neighboring cavities

Increase of 25% field level
-> 50% power margin required

MYRRHA Proton Driver - Methodology and Time Frame

(Courtesy Dirk Vandeplassche, SCK•CEN)

- SCK•CEN situation: building in-house accelerator expertise
- collaborations
  - originally industrial approach
  - historically in FP context (Euratom / Fission)
  - today in phase of financed R&D of MYRRHA project, with a deadline (int. review) = e.o. 2014
    - FP7 project MAX, naturally based on historical FP partners
    - SCK•CEN activity
formal bilateral collaborations with "principal architects"
- schedule
  - engineering design 2010 – 2014
  - prototyping : 2015 – 2018
  - production & installation : 2018 – 2021
  - commissioning : 2022 – 2024

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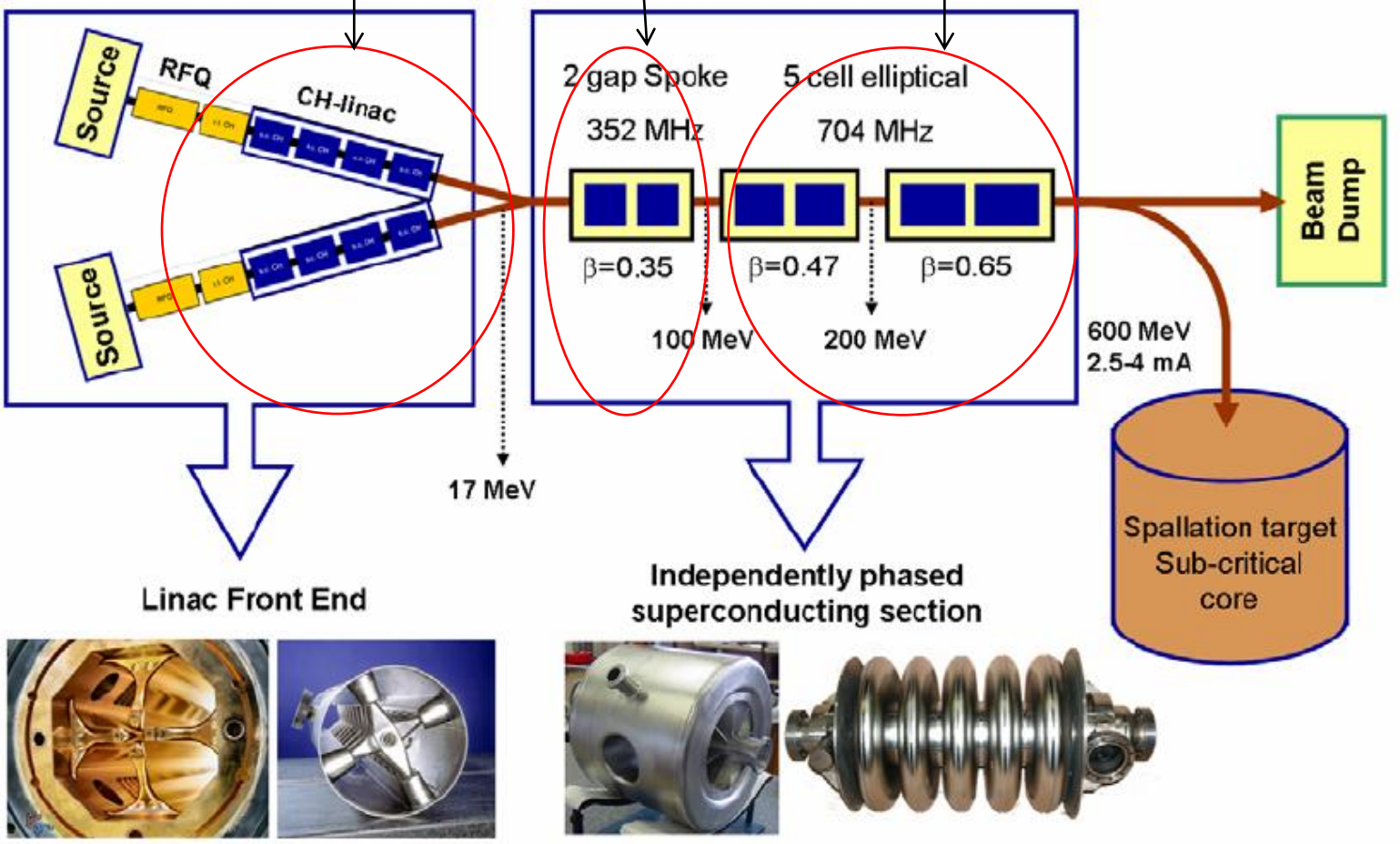
MYRRHA Proton Driver

Within MAX (FP7)

Collab. with Frankfurt University

Collab. with IPN Orsay

Collab. with INFN Milano



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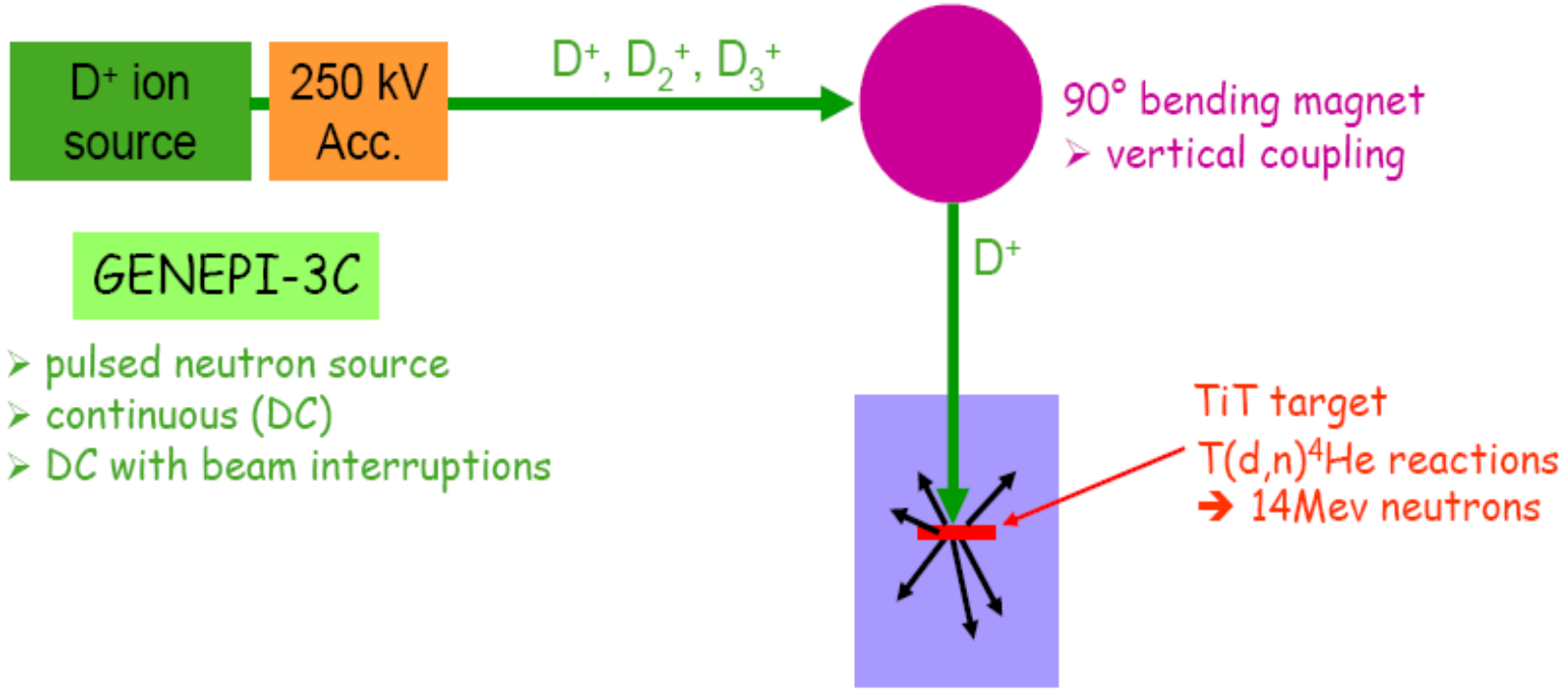
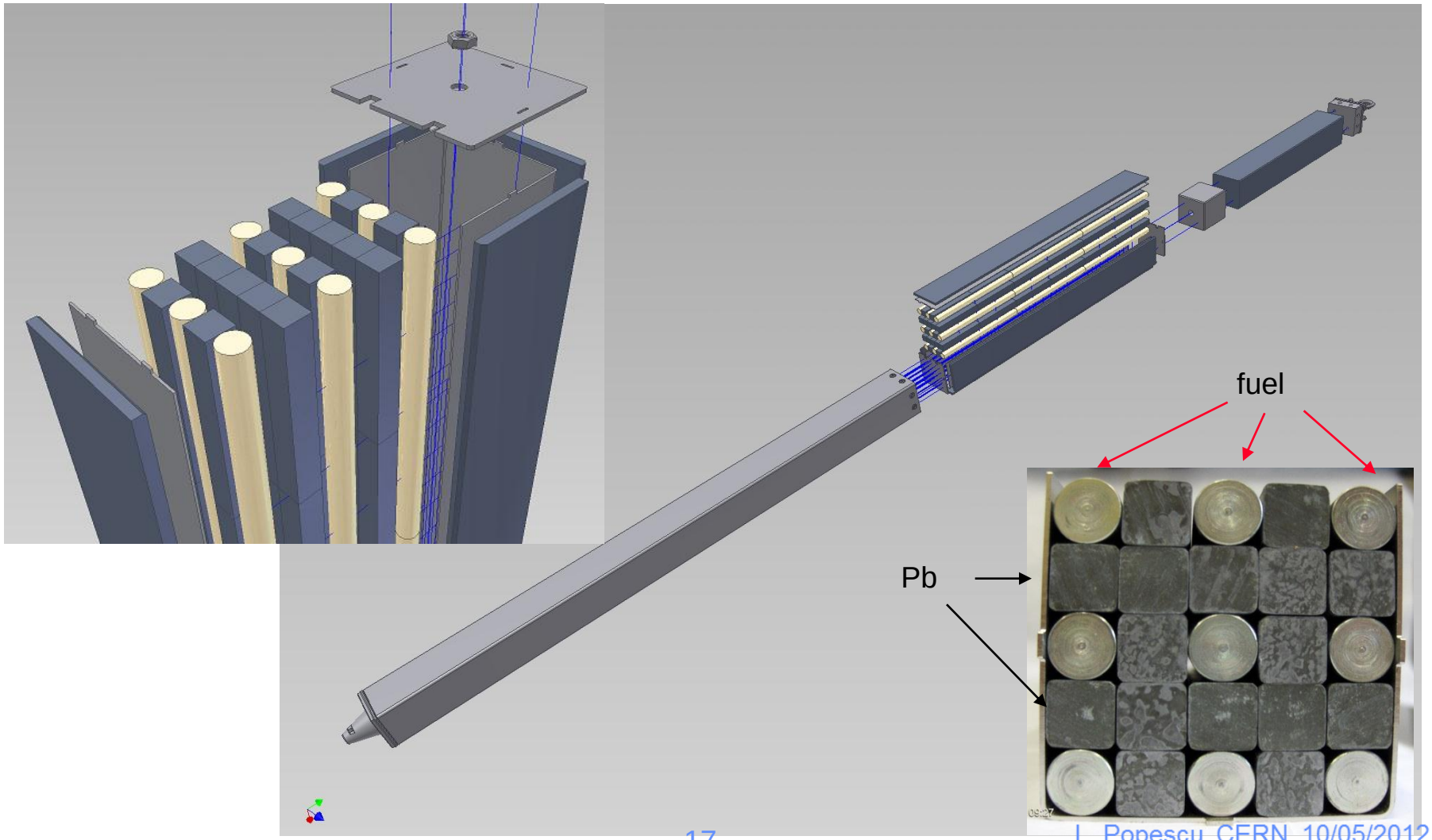
GUINEVERE – a Step Towards MYRRHA

- A zero-power fast n-spectrum facility @ SCK•CEN (sub-critical & critical mode)
- A collaborative work within EUROTRANS



GUINEVERE - Fuel Assembly



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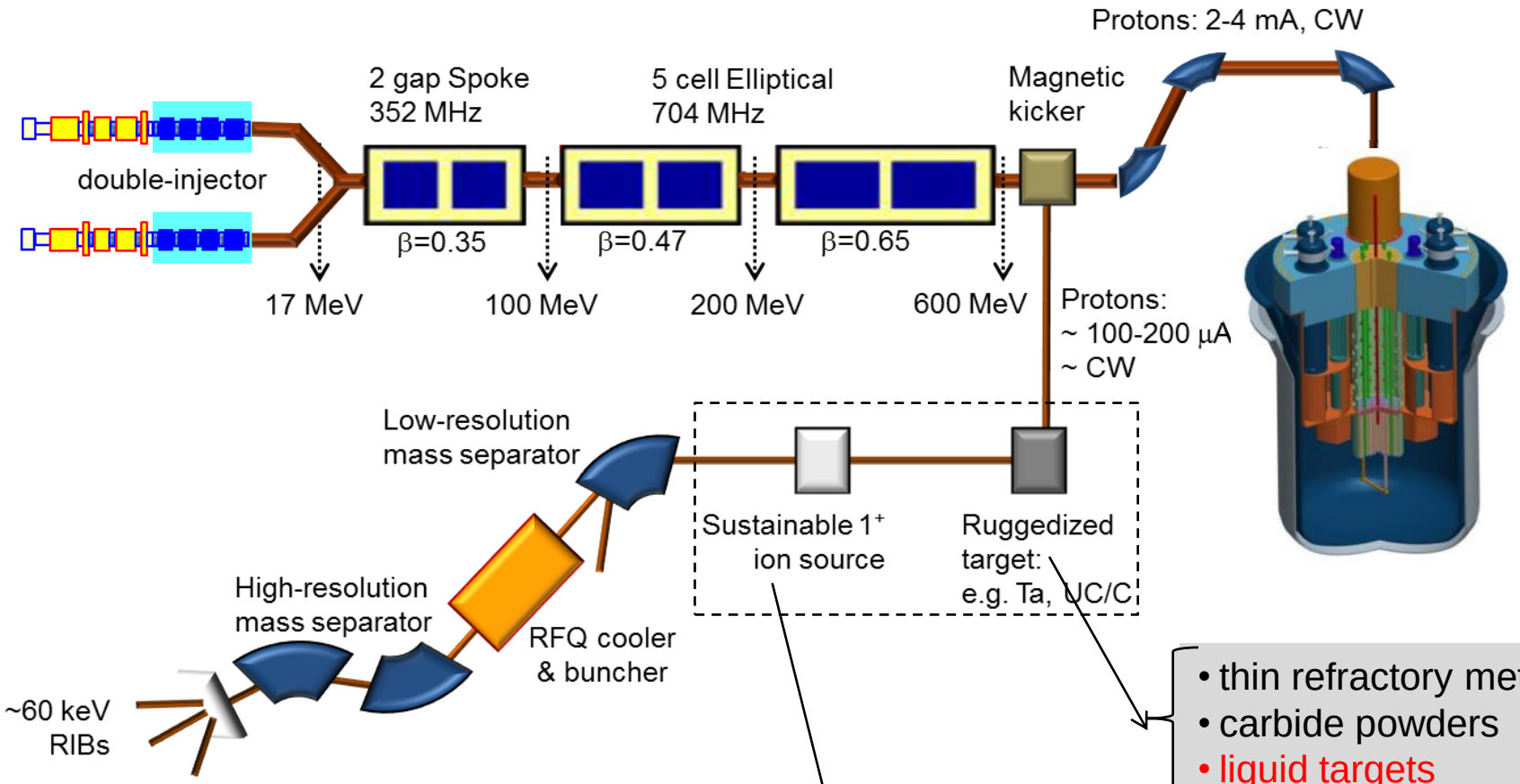
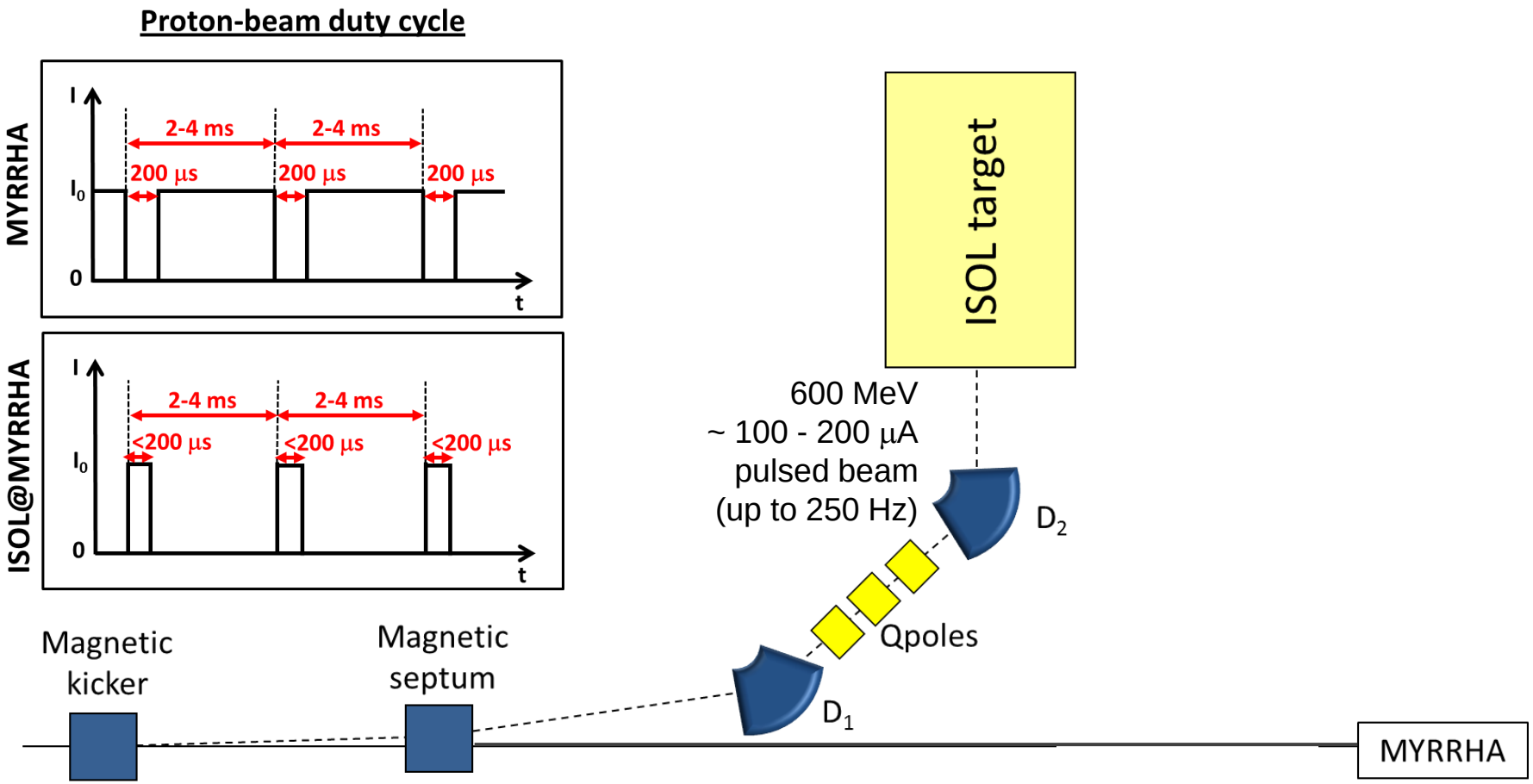
ISOL@MYRRHA - Concept



Beam-Splitting System (Concept)



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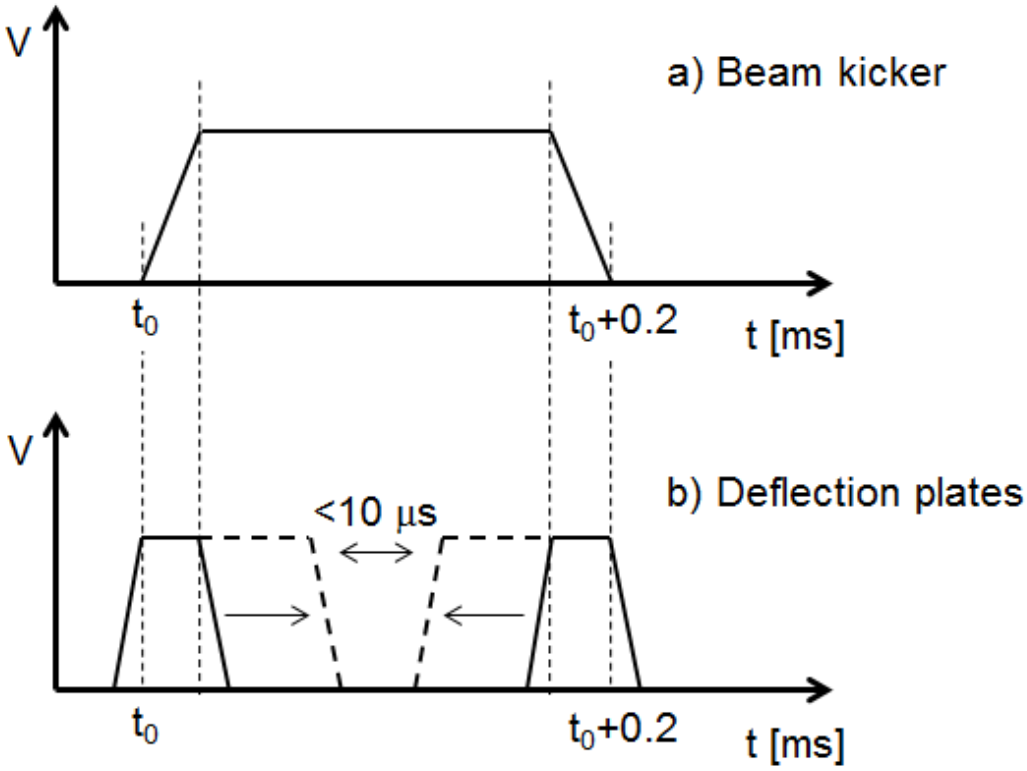
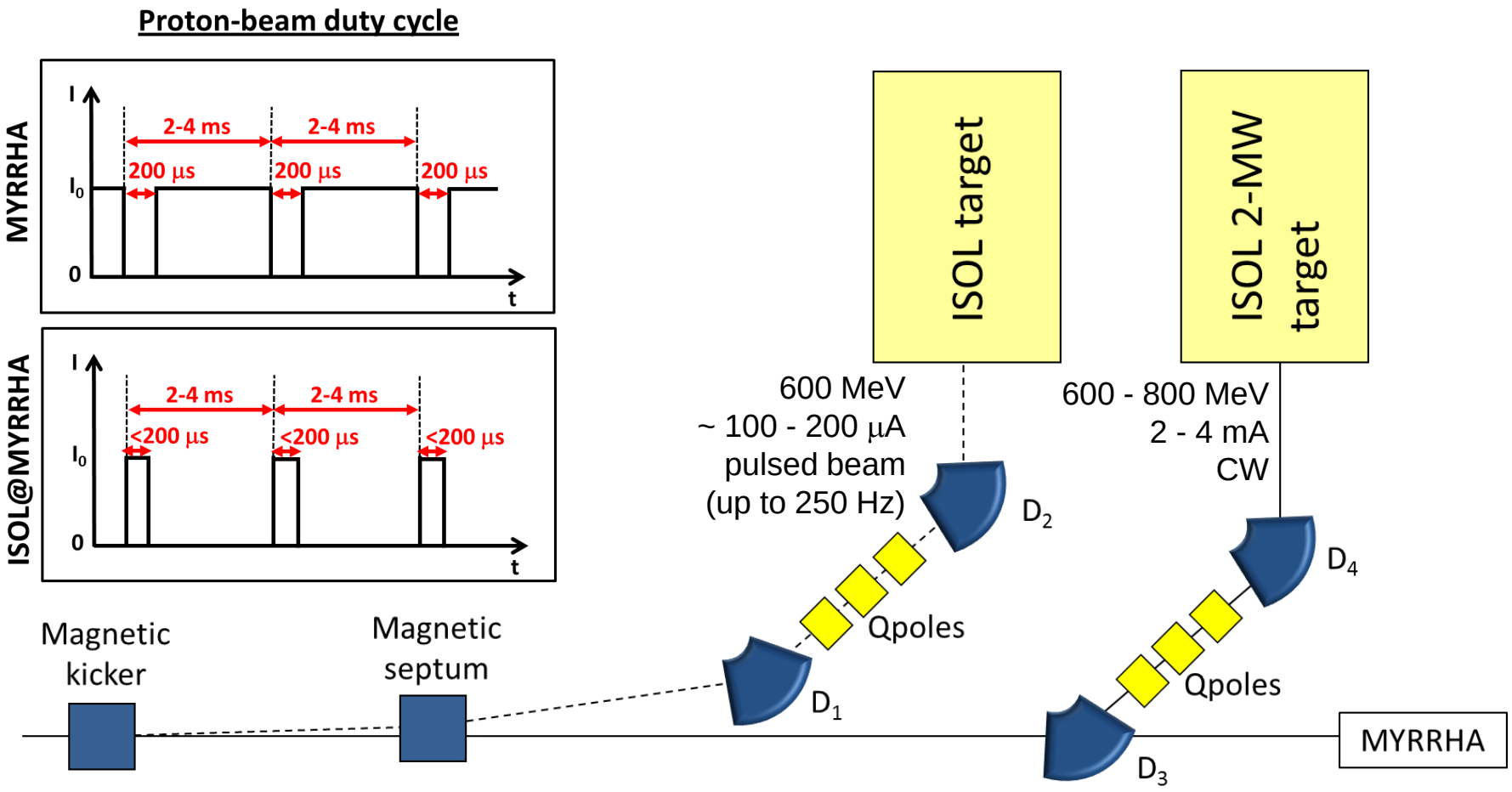


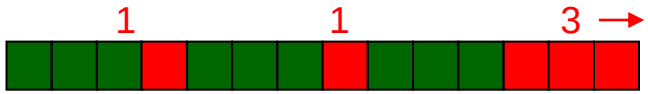
Time structure of (a) the beam-kicker voltage after the acceleration section (600 MeV)

Deflection-plate voltage in front of the RFQ entrance (30 keV)

Beam-Splitting System (Concept)



MYRRHA operation:



ISOL@MYRRHA Facility Characteristics

- based on proven technology (largely based on experience at ISOLDE and TRIUMF)
- keep open the possibilities for higher intensity beams
- can deliver:
  - pure RIB: selective ionization, chemistry, M/DM > 10.000
  - intense RIB (x100 compared to the present ISOLDE 'standard' RIB)
  - RIB of good ion optical quality
  - optimal experimental conditions/lay-out/support (green-field facility!)
  - **extended beam times with stable operation**

experiments
- need very high statistics;
- need many time-consuming systematic measurements;
- hunt for very rare events;
- have an inherent limited detection efficiency.

- complementary to ISOL and In-Flight facilities

ISOL@MYRRHA Project at SCK•CEN

- ISOL@MYRRHA - an integral part of the MYRRHA project
  - Delivery of the proton beam by MYRRHA

  but
  - To be developed within a separate consortium
- Physics experiments (from the focal plane of the separator)
  - To be set up and run by users
  - Support by ISOL@MYRRHA physics group at SCK•CEN
- Conceptual design phase (2012-2014) followed by a basic design in the FEED-phase (2015-2017)
- R&D on target-ion-source systems and parasitic operation with MYRRHA

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Next on ISOL@MYRRHA

Conceptual Design (2012-2014)

- Task1: Beam splitter
- Task2: Target Ion Source
- Task3: Beam preparation: RFQ Cooler & Buncher + Mass Separators
- Task4: Safety & Radioprotection
- Task5: Overall conceptual design

Technical Design Study for intense radioactive ion beams at ISOL@MYRRHA on the NuPECC long range plan 2010 (Dec. 2010)

Project Schedule

2012-2014	Conceptual Design
2015-2017	Front End Engineering Design
2018	Awarding construction contracts
2019-2021	Manufacturing of components & construction
2022	Assembly & Installation
2023-2024	Commissioning
2025 -	Exploitation

Potential contributions to the present project within EURISOL

- In-house expertise build-up within the design study of the PbBi MYRRHA spallation target - SCK•CEN can play an advisory role
- TIS developments at SCK•CEN
  - PhD on ISOL liquid-target design study
    - covers the CFD part of the present project within EURISOL
  - Post-doc on TIS for ISOL@MYRRHA, addressing also the design of the target station (short stage at CERN & TRIUMF considered)
- Planned R&D project on target development (ERC StG application)
  - Making use of the in-house expertise in material science, chemistry, PbBi technology
  - Building a team of in-house experts supplemented by new openings
  - More interactions with the present project within EURISOL become possible

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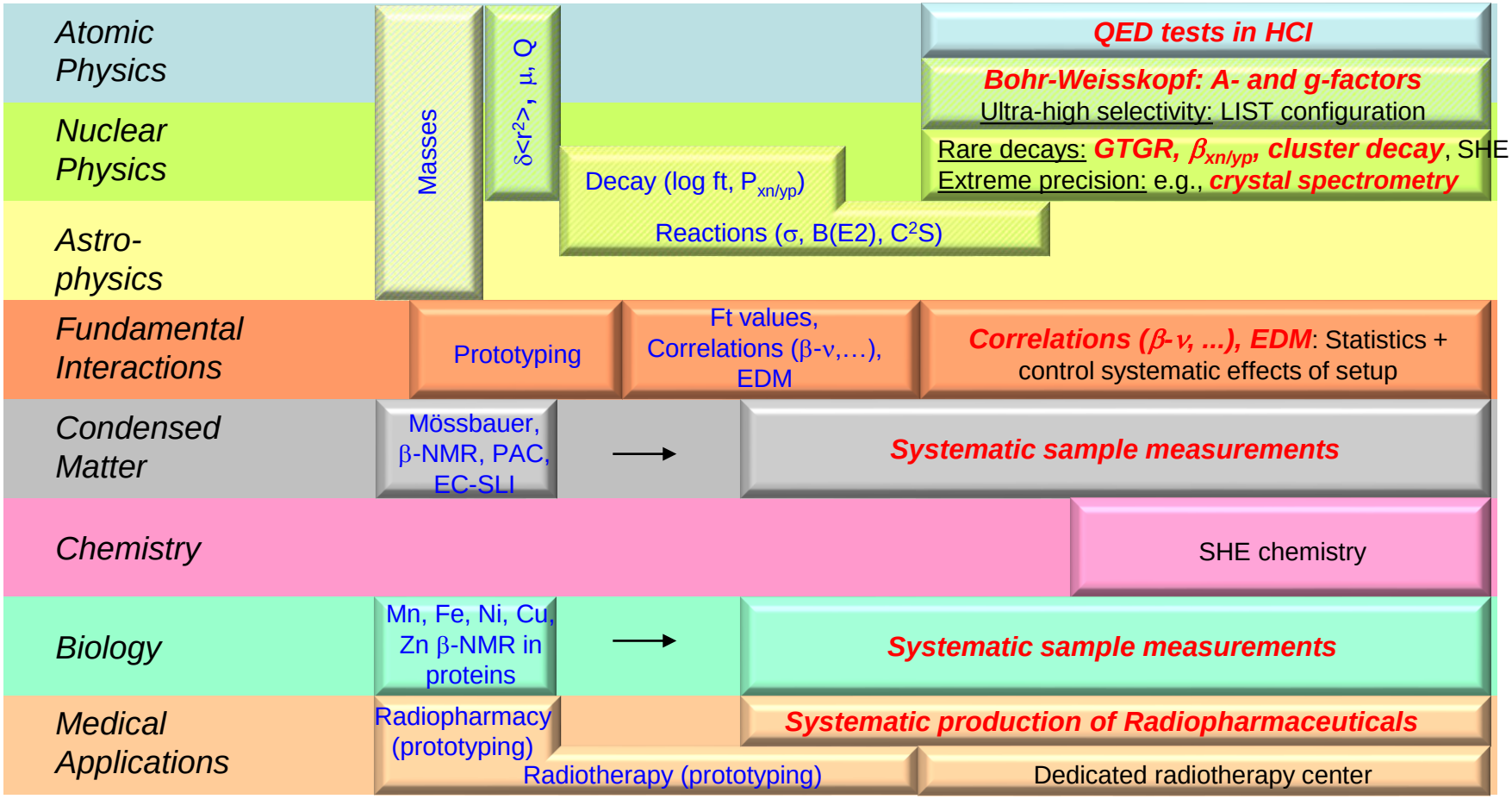
Applications (ISOL@MYRRHA Applications)



Typical Beam Time/Experiment

Day — Week — **Month** — Year