Platform for Research and Applications with Electrons

PRAE

Projet Emblématique

Programme SESAME

PRAE: Platform for Research and Applications with Electrons

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On behalf of the PRAE team
15/11/2018

With the support of

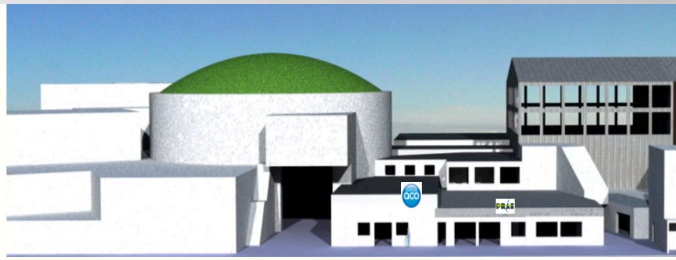
Outline

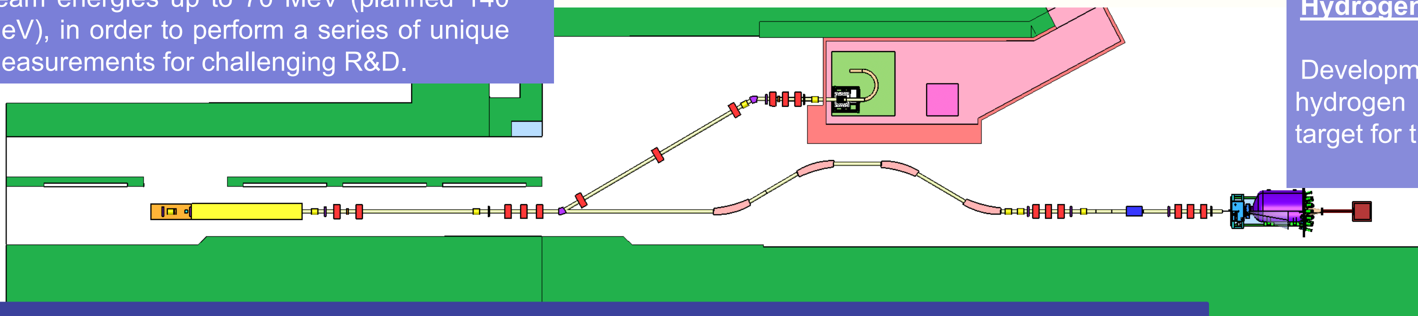
- *The PRAE project : Applications – objectives – progress status* 13’
  - *The Nuclear experiment*
  - *The Instrumentation R&D*
  - *The Radiobiology experiment*
  - *The Accelerator*
- *Project Management : Organisation, Budget, Planning, Status* 3’
- *Workshop* 2’
- *Perspectives & collaborations* 2’

What are we talking about ? PRAE project in ONE slide

Project

The **PRAE** project aims at creating a multidisciplinary Research and Development (R&D) platform at the Orsay campus, gathering various scientific communities involved in radiobiology, subatomic physics, instrumentation, particle accelerators, medical physics and clinical research around a high-performance electron accelerator with beam energies up to 70 MeV (planned 140 MeV), in order to perform a series of unique measurements for challenging R&D.





ProRad : proton electric form factor measurement

Beam Energy Compression System

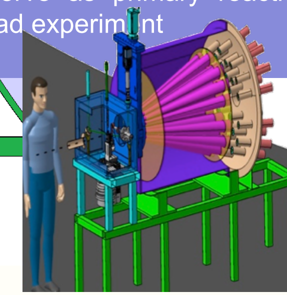
System allowing to reduce the beam momentum dispersion down to 5×10-4

Beam Energy Measurement Device

Development device allowing to measure the beam energy with a 5×10-4 accuracy

Hydrogen Jet Target

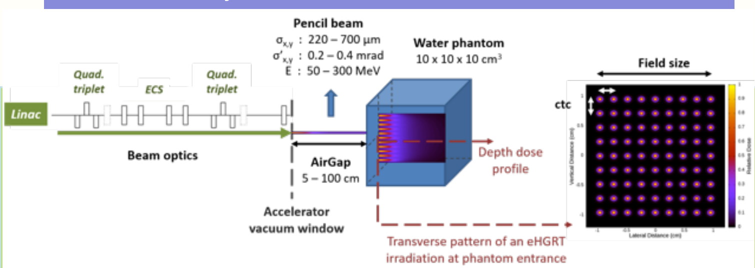
Development of a 15 µm diameter cryogenic hydrogen jet to serve as primary reaction target for the ProRad experiment



VHEE therapy

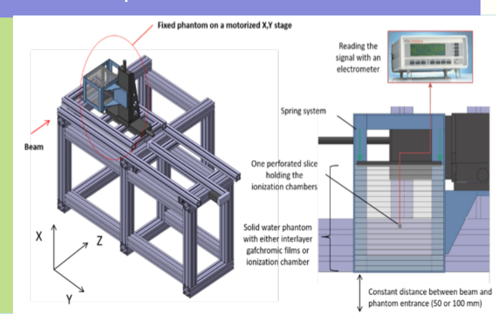
Grid or mini-beam therapy

One possible strategy to further improve the healthy tissue tolerance by using the concept of Spatially Fractionated Radiation (SFR) dose is the Grid or Mini-Beam Therapy (MBRT). In contrast to conventional RT the lateral dose-profile resulting of such grid-irradiation consist in a pattern of high doses in "peaks " and low doses in "valleys"



Flash therapy

The FLASH methodology consists of millisecond pulses of radiation (beam-on time ≤ 100-500 ms) delivered at a high dose-rate (≥ 40-100 Gy/s), hence over 2000 times faster than in conventional RT. Recently it has been shown that FLASH spares normal brain in mice from the loss of both memory and neural stem cells as endpoints



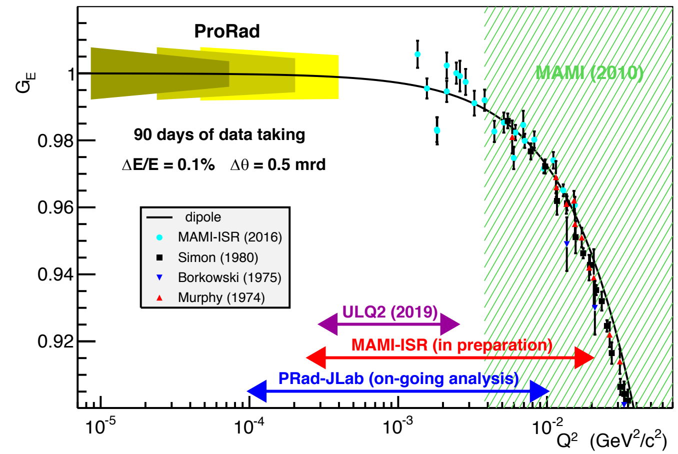
Instrumentation

Fully-equipped versatile platform for precision instrumentation R&D based on high-performance electron beam

Excellent technical performance: Timing reference, < 10 ps bunch length, Charge accuracy, RMS < 2×10-3 and Low straggling (energy >> 1 MeV)

High-performance, remotely controlled tools: Beam position, profile and monitoring, 60 digitization channels for users on NARVAL-based data acquisition and Motorized moving table for scans, accuracy < 500 µm

No need to place the detectors in vacuum

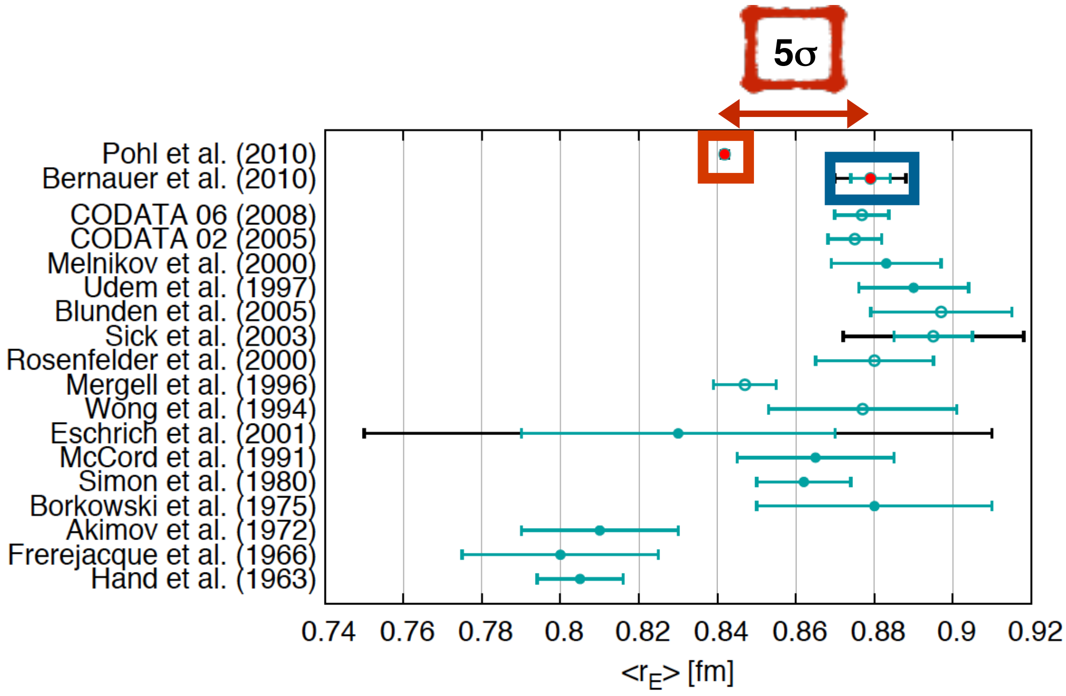


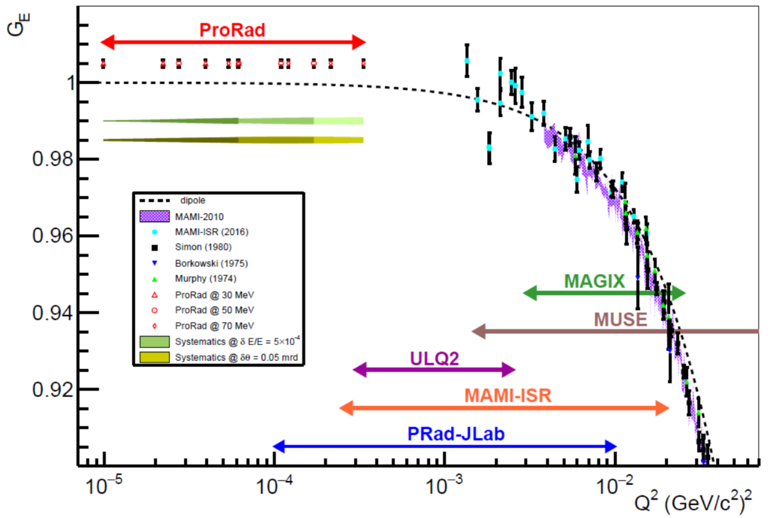
Why PRAE ?

Axis 1 : The nuclear physics / nucleon structure

- ❑ *Principle experiment:* ***proton charge radius measurement, 30-70 MeV***

ProRad: the proton radius puzzle





Muonic hydrogen spectroscopy

r_p = 0.84184±0.00067 fm

Direct measurement

(10 times more precise)

$$r_p = \sqrt{<r^2>} = \sqrt{-6\frac{\partial G_E^2(Q^2)}{\partial Q^2}\Big|_{Q^2=0}}$$

Electron scattering experiments

r_p = 0.87900±0.00800 fm

Indirect measurement

(extrapolation of Form Factor data to Q^2 =0)

→ **Problem**: the proton is smaller as « seen » by muons than by electrons

ProRad goal: A high precision measurement of the proton electric form factor at very low Q^2 in linear region

ProRad: experiment requirements

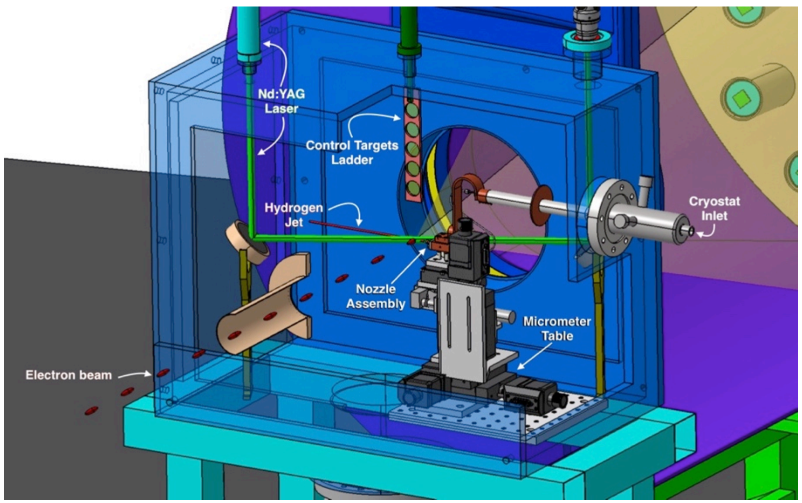
ProRad target experiment requirements:

- A windowless hydrogen target
- Optimized measurement of the scattered electron energy and position ($\Delta E/E = 5 \times 10^{-4}$, $\sigma_{x,y} < 0.5$ mm, $\Delta\theta < 0.05$ mrad)

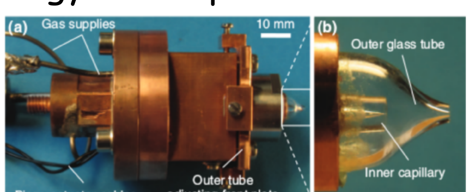
French-German collaboration

Hydrogen target

A very stable **windowless** and **self-replenishing** target of **15 µm diameter**



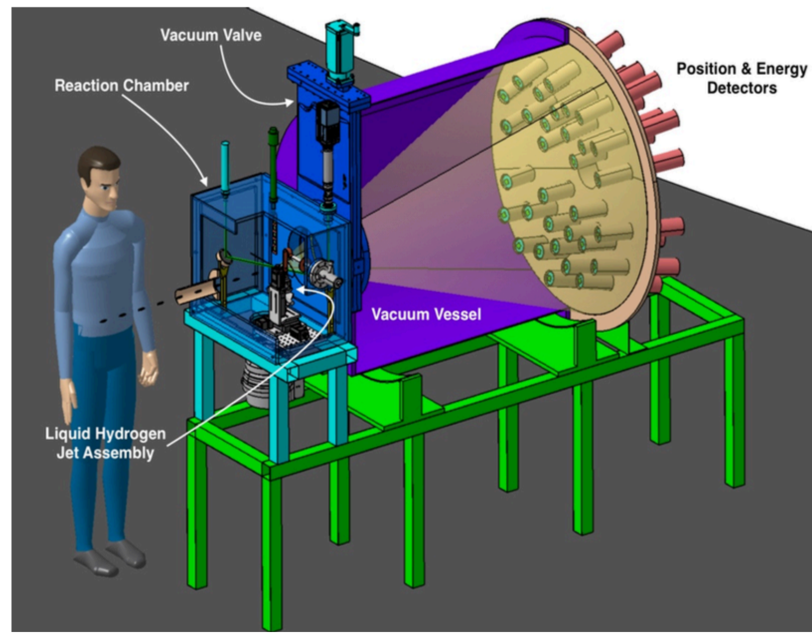
Ultra cold liquid technology developed at Frankfurt University



Reaction chamber with target assembly

28 **elementary detectors** placed at **4** different **scattering angles** at a distance of **2 m** from the target

Endcap



R.A. Costa Fraga et al. Rev. Sci, Inst. 83 (2012) 025102

Status

- Beam energy measurement with OTR has been studied and demonstrated that it not fulfilled precision requirements for ProRad
- Thesis on beam energy measurement started in September (Lucien Causse -ENS Cachan) : beam energy measurement with magnetic approach based on previous developments at JLAb.
- Design, production and delivery of electromagnetic calorimeter (BGO crystals) ; SAT on going; tests with beams (ALTO ou BTF) in discussion. Work done by Mostafa Hoballah, post-doc P2IO
- Reinforcement of JGWU/GSI collaboration for the Hydrogen jet target in discussion
- A prototype of position detector (scintillator + optical fiber + SiPMs) is on going. End of post-doc contract. Need to find manpower to go ahead this development.

Why PRAE ?
Axis 2 : Instrumentation R&D Platform

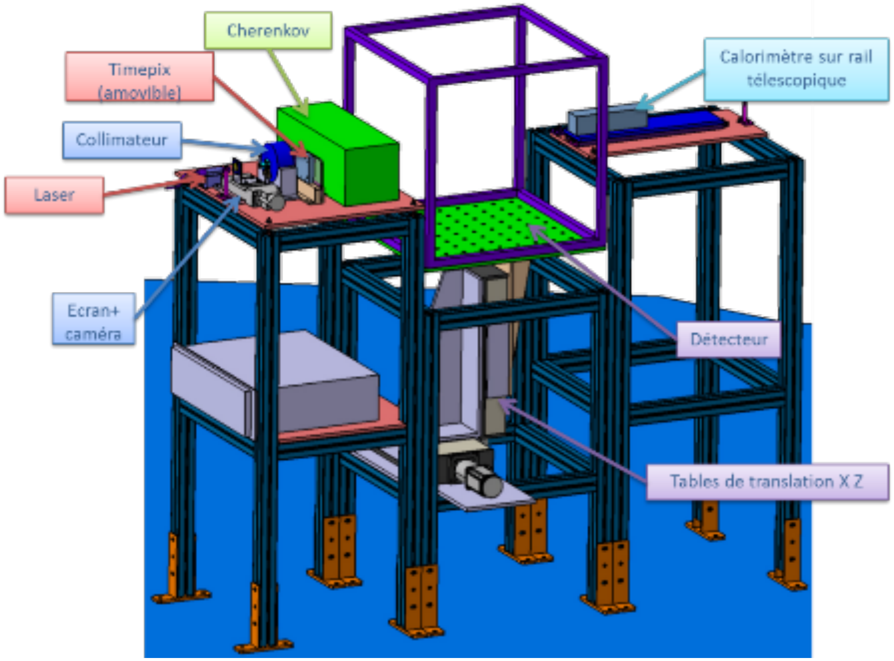
❑ *Principle goal is to construct versatile platform for detector R&D and tests:* ***deliver calibrated beam with adjusted and known kinematics and number of electrons per sample***

Instrumentation R&D at PRAE

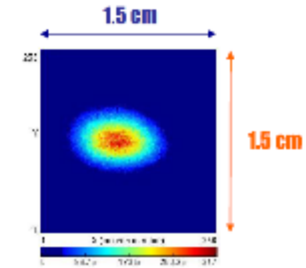
- **Fully-equipped versatile tool for precision instrumentation R&D based on high-performance electron beam**
- Excellent technical performance
  - **Timing** reference, < 10 ps bunch length
  - **Charge accuracy**, RMS < 2×10^{-3}
  - Low straggling (energy >> 1 MeV)
- High-performance, remotely controlled tools
  - **Beam position, profile and monitoring**
  - 60 digitization channels for users on NARVAL-based **data acquisition**
  - Motorized **moving table for scans**, accuracy < 500 μm
- No need to place the detectors in vacuum

Measure the time, charge and imaging performance of particle detectors
→ *Calibration for charge, trigger, tracking detectors*

Deliverables

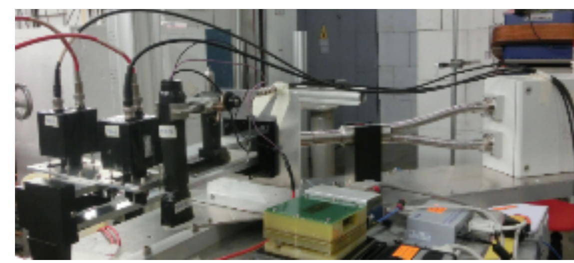


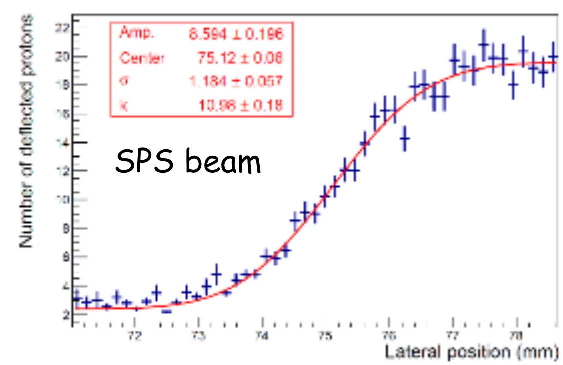
Timepix detector for precision spot measurement



Cherenkov quartz counter for intensity monitoring

2 channel Cherenkov counters (LAL) tested at BTF (Frascati); installed in the SPS (CERN) beam pipe



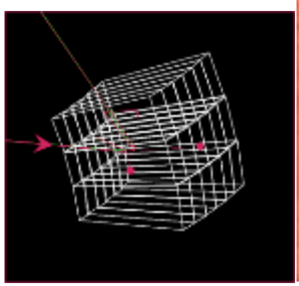


DAQ + slow control

- ❑ 60 user digitization signals (WaveCatcher)
- ❑ DCOD = NARVAL + ENX

Calorimeter for energy monitoring

BGO scintillator crystals in compact matrix geometry



Example of a calorimeter realized at IPN

Status

- Delivery of Collimator
- Delivery of the translation table
- Delivery of BGO + PMT
- Workshop PRAE => Possible collaboration in discussion with D. Dauvergne – LPSC : Electron channeling at PRAE for the investigation of Zitterbewegung and/or internal clock

Why PRAE ?
Axis 3 : Radiobiology experiments

- *New approaches in radiotherapy: VHEE*
- *Delivery doses:*
    - *Grid mini-beam*
    - *FLASH*

New approaches in radiotherapy

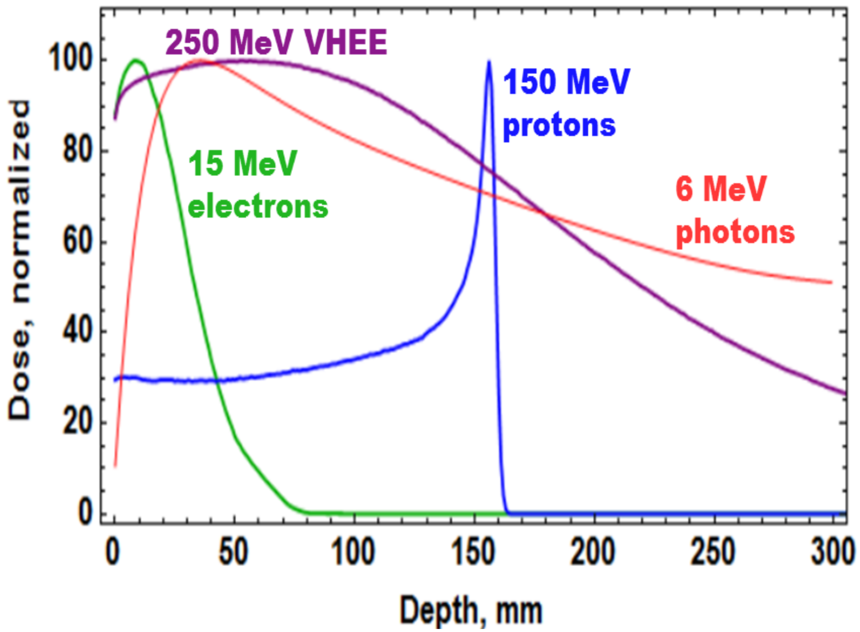
- Radiotherapy (RT): treatment of some **radio resistant tumors, pediatric cancers** and tumors close to a delicate structure (i.e. spinal cord) is currently **limited**
- Standard RT restricted to the few temporal and spatial schemes, dose rates, broad field sizes: mainly photons, 2 Gy/session, 1 session/day, 5 days/week, dose rates ~ 2 Gy/min, field sizes > cm2, homogeneous dose distributions
- One main challenge is to find novel approaches to **increase normal tissue resistance**

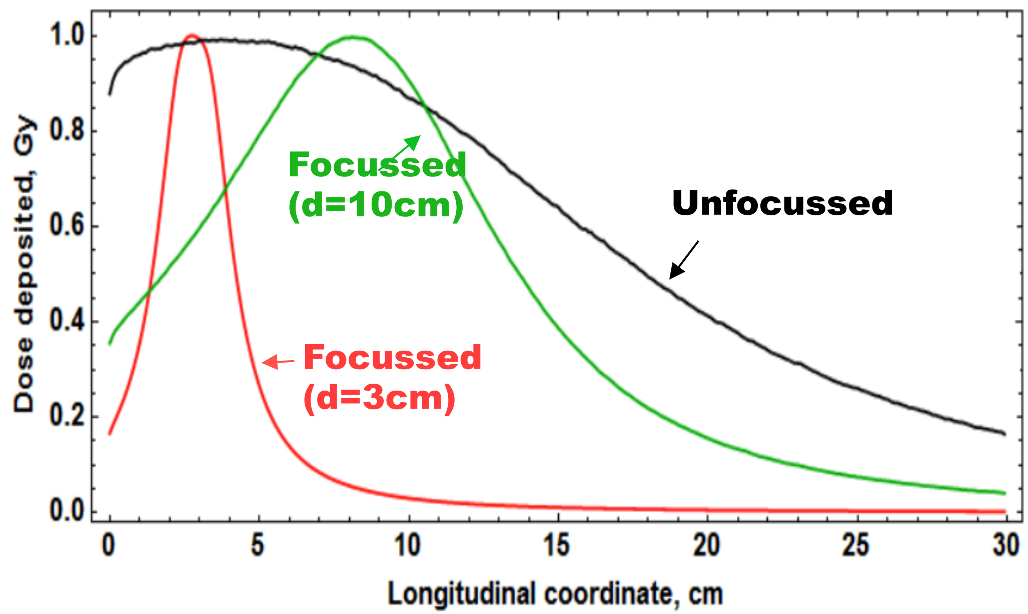
Possible strategies to spare normal tissue

- Different particle types: **Very High Energy Electrons (VHEE)**
- Different dose delivery methods: **Grid Mini-beam or FLASH**

VHEE State of the art:

- Their ballistic and dosimetry properties can surpass those of photons, which are currently the most commonly used in RT.
- Their position compared to protons need to be evaluated, but they can be produced at a reduced cost.





Depth Dose curve for various particle beams in water (beam widths r=0.5 cm)

+ **Conformity?**
+ **Decrease of integral dose?**
+ **High dose rate**
+ **Scanned beams**
+ “Compact”, cheap
+ ….

- Skin dose ?
- Bone dose ?
- Penumbra?
- Effect of inhomogeneities?
- Neutrons ?
- …..

VHEE beams: advantages vs MV photons

✓ ***Very good dosimetric properties*** **:** low-lateral penumbra, flat longitudinal profile, no perturbation at heterogeneity interfaces

✓ ***Magnetic collimation***: pencil beam scanning, precise intensity modulated irradiations *(DesRosiers et al., Indiana)*

Clinical cases comparison ***:***

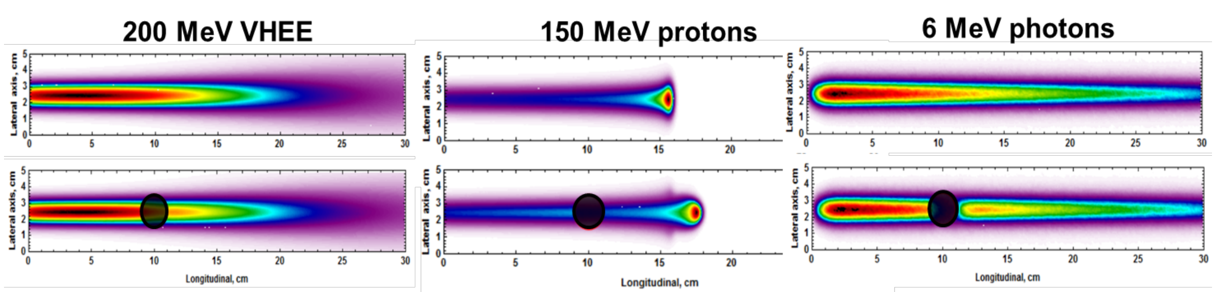
Better organ-at-risk protection with VHEE compared to VMAT *(Bazalova-Carter et al., Stanford)*

→ No biological experiments *in vitro* or *in vivo*

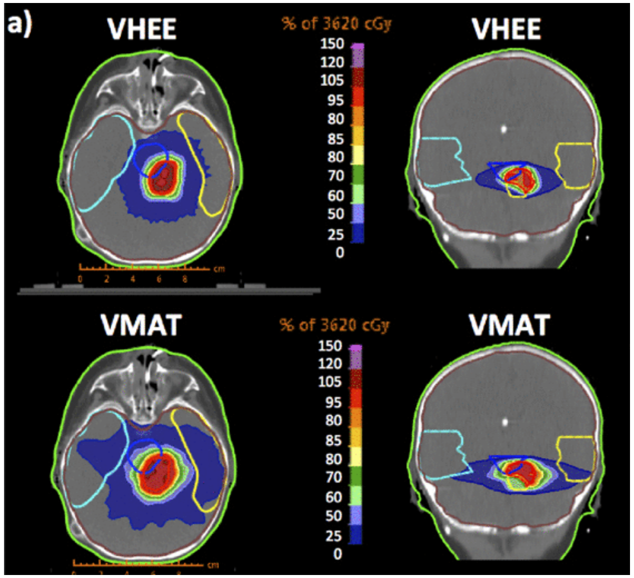
VHEE beams: advantages vs protons

✓ ***Cost :*** more compact accelerators

✓ *Easier beam manipulation*

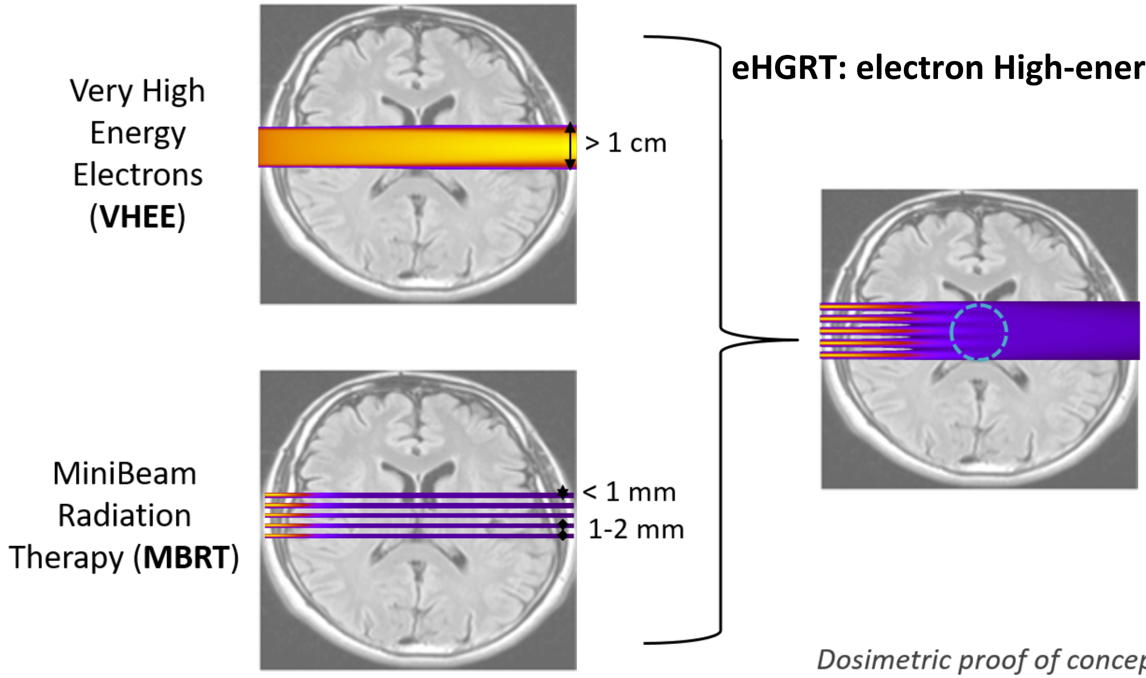


Behavior of VHEE, photon and proton beams traversing a air cavity *(Agnese Lagzda, manchester)*



Brain tumour dose maps for 100 MeV VHEE and 6 MV volumetric modulated arc photon therapy (VMAT)
Bazalova-Carter, 2015

Objectives of IMNC@PRAE: combine advantage of VHEE beams with spatial fractionation



Dosimetric proof of concept Martinez et al., Med. Phys. 2015

- ❑ **«Protective» effect of healthy tissues** reproduced with **proton mini-beams** + tumor control increased ***Prezado et al., 2017***

Radiobiological effect of spatial fractionation :

- ❑ **Cell repair and repopulation** in valley regions
- ❑ Differential tissue effect between vascularization «immature» and «mature» ***Bouchet et al.***

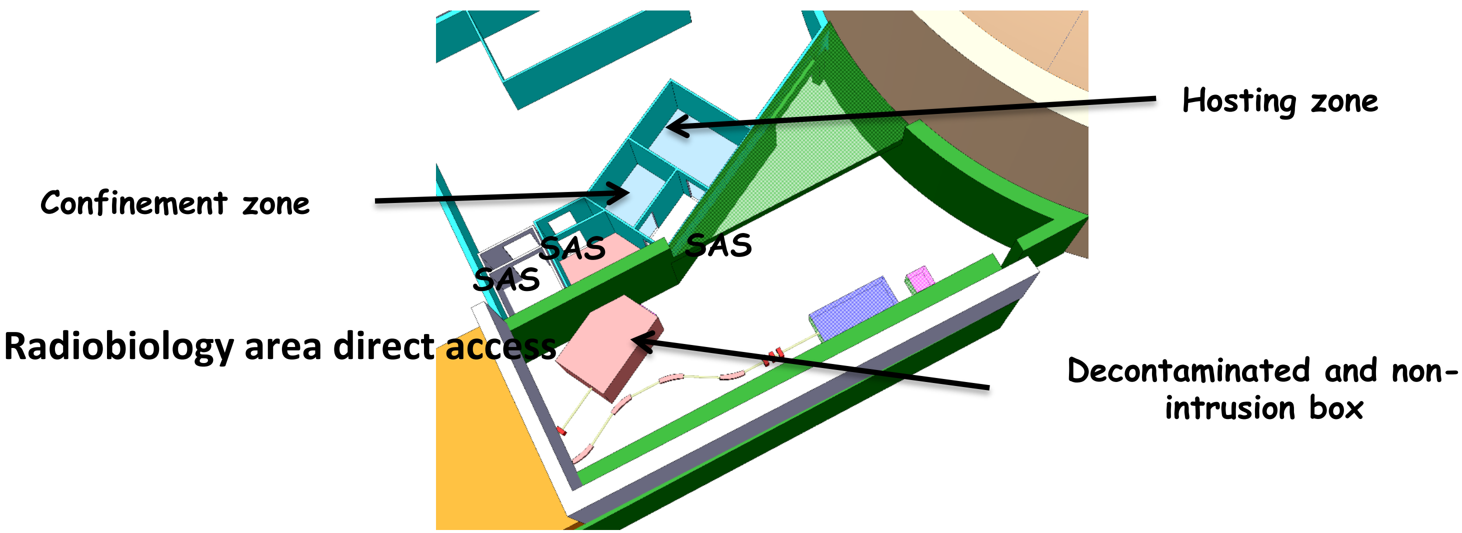
→ **At PRAE: objective to perform all the numerical and experimental dosimetric validation until the *in vivo* proof of concept**

Progress summary

- **Monte Carlo studies:**
  - Beam optics optimization: dosimetry in water (Golfe AF and al. IPAC 2018:516-519 doi:10.18429/ JACoW-IPAC2018 MOPML051)
  - Preclinical calculations in progress
- **Experiments** ***(year 2020 - 20…)*****:**
  - **Experimental dosimetry: challenge of VHEE and very small beam sizes**
  - **In vivo proof of concept: efficiency of eHGRT for high-dose healthy-tissue tolerance**
- **New collaboration with the CEA in discussion for dosimetry (Meeting 5 December 2018)**
- **Reinforcement of the collaboration with Curie Institute (use of pet facility, expertise...)**

—> ***In vivo*** **experiment would be a specificity of PRAE / other VHEE installations**

- **Design of Infrastructure dedicated to Radiobiology**



- **Interest of the PRAE beam for other radiobiological experiments: « Flash-effect »**

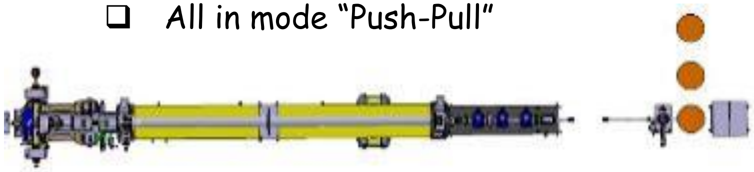
How are we doing ?
The accelerator construction and related R&D

- *Parameters and Phases*
- *Optics design and simulations*
- *RF gun and High-Gradient Linac*
- *Beam diagnostics*

Evolution of different designs

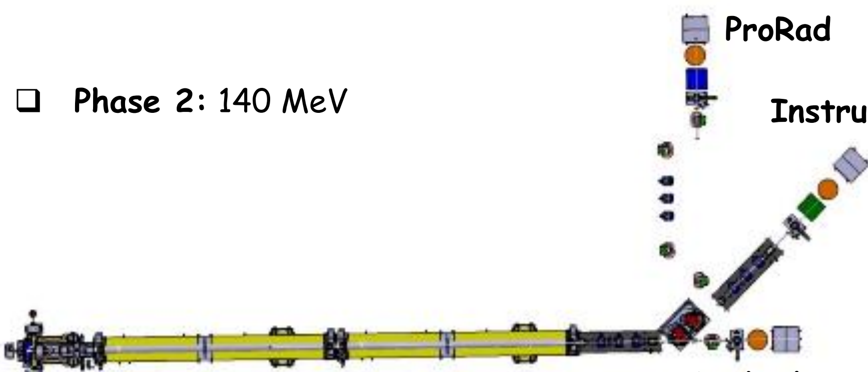
Initial version, presented to P2IO/SESAME

- **Phase 0:** RF gun at 50 Hz; 50-70 MeV
  - All in mode "Push-Pull"



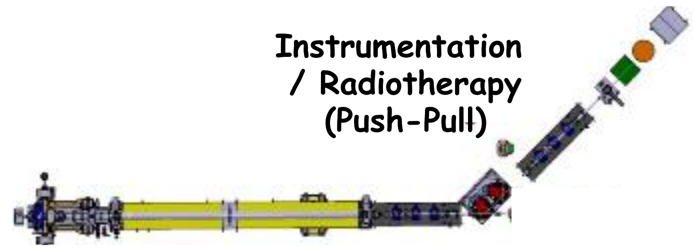
- **Phase 1:** two deviated lines
  - Scanning dipole for Radiotherapy
  - Spectrometer for Instrumentation
  - Magnetic chicane for ProRad

- **Phase 2:** 140 MeV



Optimized version, given constraints

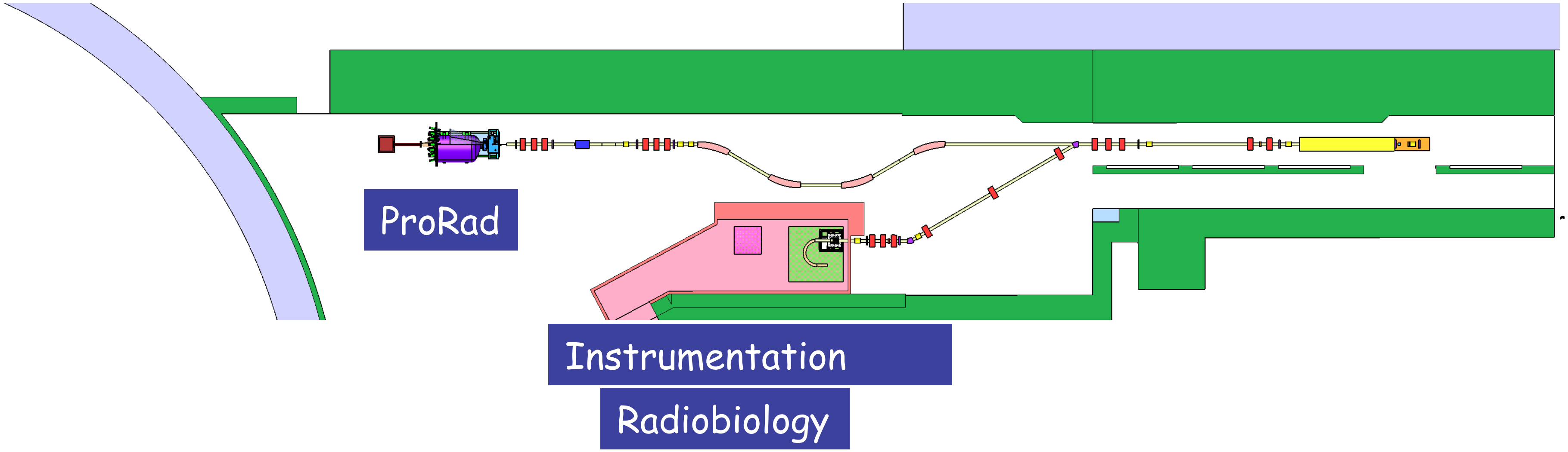
- **Phase A0:** RF gun at 50 Hz; 50-70 MeV, one line :
  - Deviated: instrumentation and radiobiology in mode "Push-Pull"



- **Phase A1: Phase A0** + direct beam line : ProRad with magnetic chicane

- **Phase B:**
  - Scanning dipole for Radiotherapy
  - Complete set of channels
  - 140 MeV

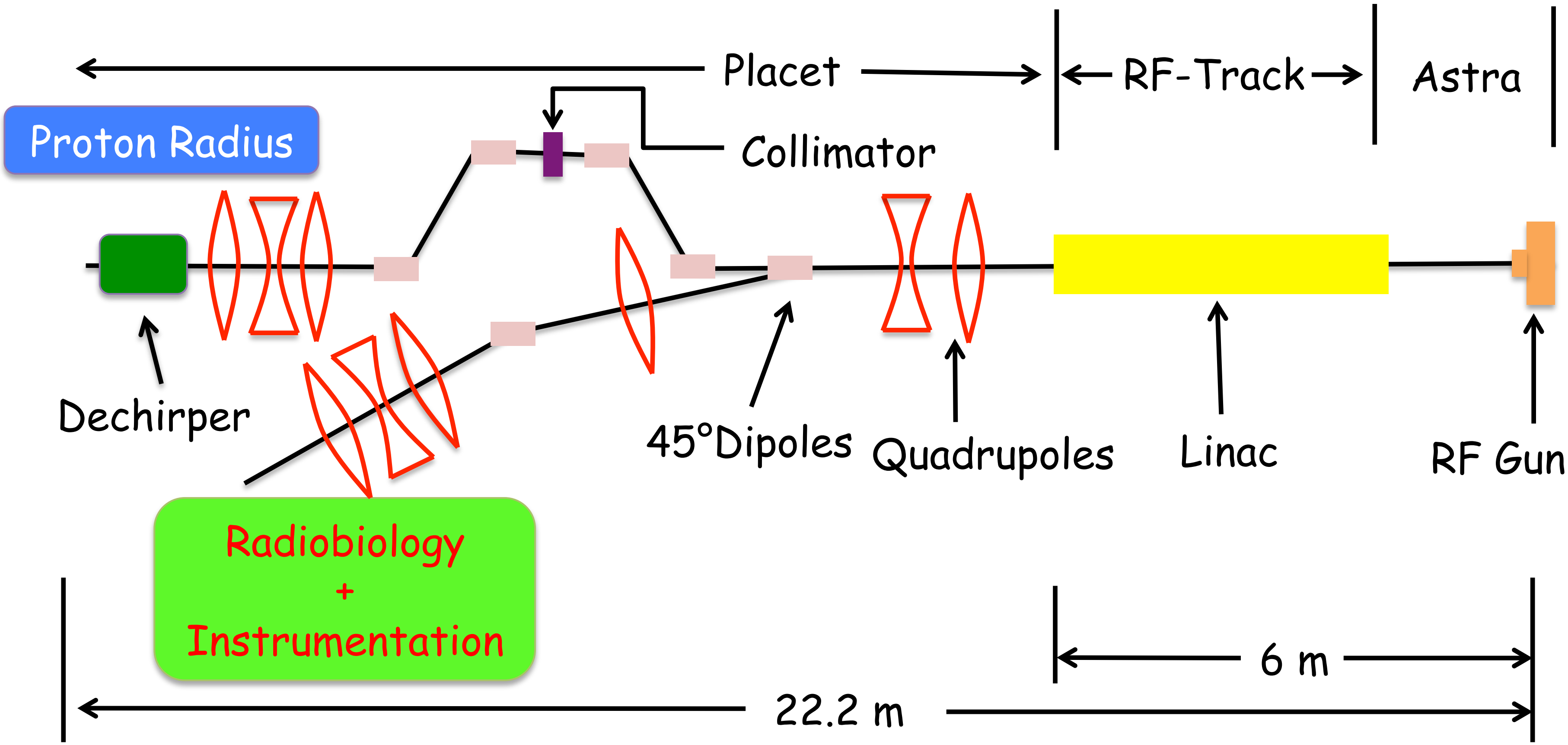
PRAE Parameters and Phases



Beam parameters	Phase A - B
Energy, MeV	50-70 (100-140)
Charge (variable), nC	0.00005 – 2
Normalized emittance, mm.mrad	**3-10**
RF frequency, GHz	3.0
Repetition rate, Hz	**50**
Transverse size, mm	**0.5**
Bunch length, ps	**< 10**
Energy spread, %	**< 0.2**
Bunches per pulse	1

Layout of PRAE

The beamline is simulated with:

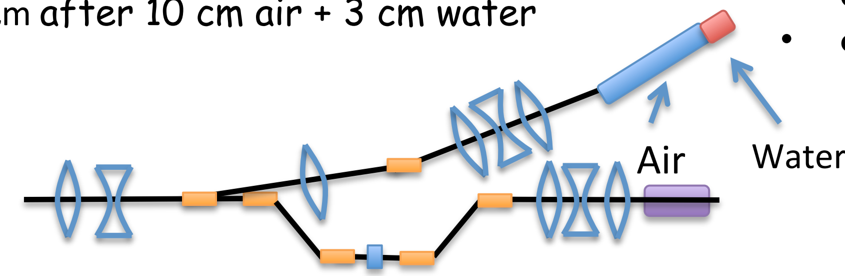


One doublet and one triplet, **flexible final conditions**, with a Energy compression System (ECS) in the direct line and a dedicated Beam Energy Measurement in the deviated line.

Beam simulations for radiobiology

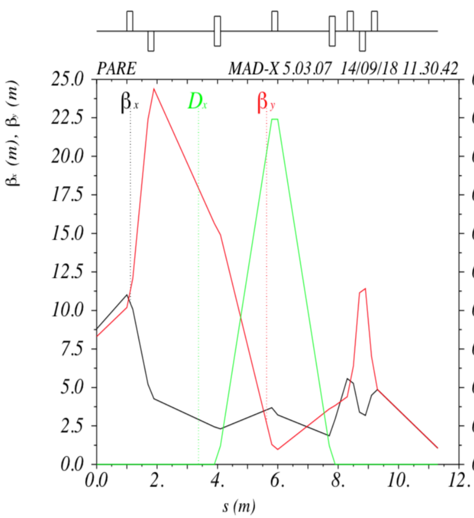
Two scenarios:

- Mini Beam
  - $\sigma_{x,y}$ = 400 – 700 μm after 10 cm air + 3 cm water
  - Low divergence
- FLASH beam
  - $\sigma_{x,y}$ = 10 mm × 10 mm , Δt = 100 ms
  - $\sigma_{x,y}$ = 26 mm × 18 mm , Δt = 500 ms



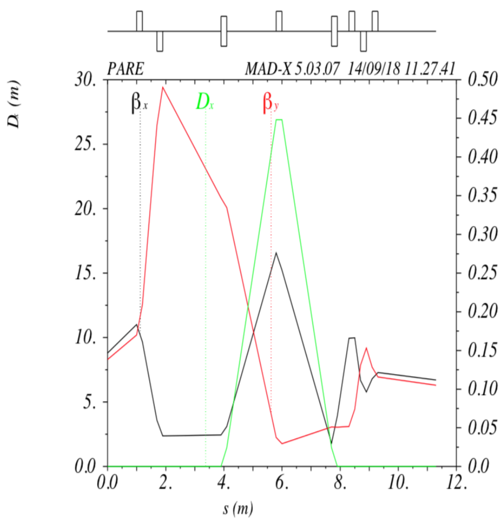
Two beams simulated :

- $\sigma_x = \sigma_y$ = 151 μm
- $\sigma_{x'} = \sigma_{y'}$ = 132 μrad
- σ_E/ E = 2.83 × 10^{-3}



- σ_x = 957 μm
- σ_y = 917 μm
- $\sigma_{x'} = \sigma_{y'}$ = 30 mrad

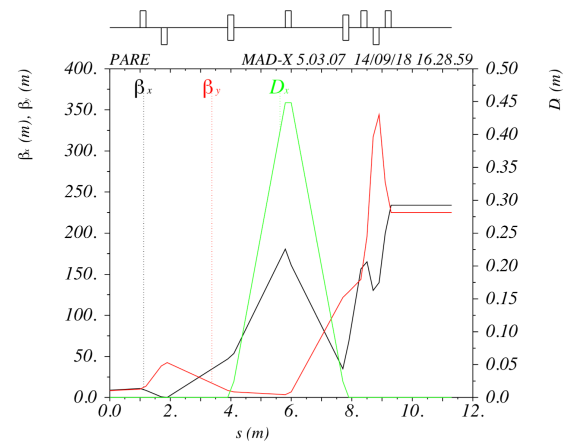
- $\sigma_x = \sigma_y$ = 500 μm
- $\sigma_{x'} = \sigma_{y'}$ = 80 μrad
- σ_E/ E = 2.83 × 10^{-3}



- σ_x = 1053 μm
- σ_y = 1057 μm
- $\sigma_{x'} = \sigma_{y'}$ = 31 mrad

One beam simulated :

- $\sigma_x = \sigma_y$ = 3000 μm
- $\sigma_{x'}$ = 26 μrad
- $\sigma_{y'}$ = 18 μrad
- σ_E/ E = 2.83 × 10^{-3}



After drifting in the air about 1.35 m, the beam can reach the 10 * 10 mm beam size. The beam size does not increase much in the 3 cm water To get the large 26*18 mm beam, we will need about 2 meter air drift.So we study the possibility to add a defocusing doublet in the air.

The Mini beam optic design, with the 70 MeV beam, has to be improved to fulfill the requirement of the radiobiology. Work is in progress to fit the required parameters for the beam delivery doses modalities.

Summary results simulations for ProRad

On crest

Angle	R_colli (mm)	Ref_E (GeV)	$\delta E/E$ (10^{-4})	Survived (%)	$\delta E/E$ with dechirper
10	0.5	70.298	10.7	28.38	
30	2	70.298	4.1	51.64	
45	2	70.298	1.8	28.11	
55	6	70.298	2.1	39.64	

High energy tail

10	**5**	**69.158**	**51.4**	**52.4**	**5.3**
30	10	69.158	28.4	31.38	0.15
45	25	69.158	34.9	39.6	0.16
55	10	69.158	8.4	9.46	0.09(23.6)

High energy head

10	**5**	**69.132**	**49.4**	**50.5**	**1.18**
30	10	69.132	28.1	30.8	0.07
45	25	69.132	34.4	38.7	0.09
55	10	69.132	8.3	8.27	0.08 (23.6%)

- Larger angle means larger CSR effect
- The crest beam is sensitive to the magnetic imperfection and misalignment.
- Using the off crest beam with passive dechirper structure will be easier.
- The current requirement for the Prorad is small, we can allow larger paticle loss.

Future work

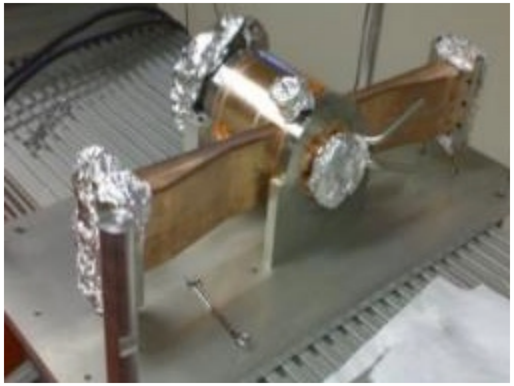
- Reoptimize the RF injector
  - Use of the the doublet quadrupoles for investigation of the emittance compensation and easiest the operation.
  - Optimize the distance between the RF Gun and the Linac
  - Optimize the solenoid configuration
- Work is on going for the start-to-end simulation
- Evaluate and simulate the CSR effect in the dipole magnets, the misalignment and the imperfection of all components
- Optimize the configuration of the magnetic chicane
- Investigate the passive dechirper structure
- Studies are on going to improve the beam delivery modalities for radiobiology

=> 1 post-doc P2IO (Yanliang Han) and 1 thesis Univ Paris-Saclay – Chinese Academy of Sciences IHEP (Bowen Bai)

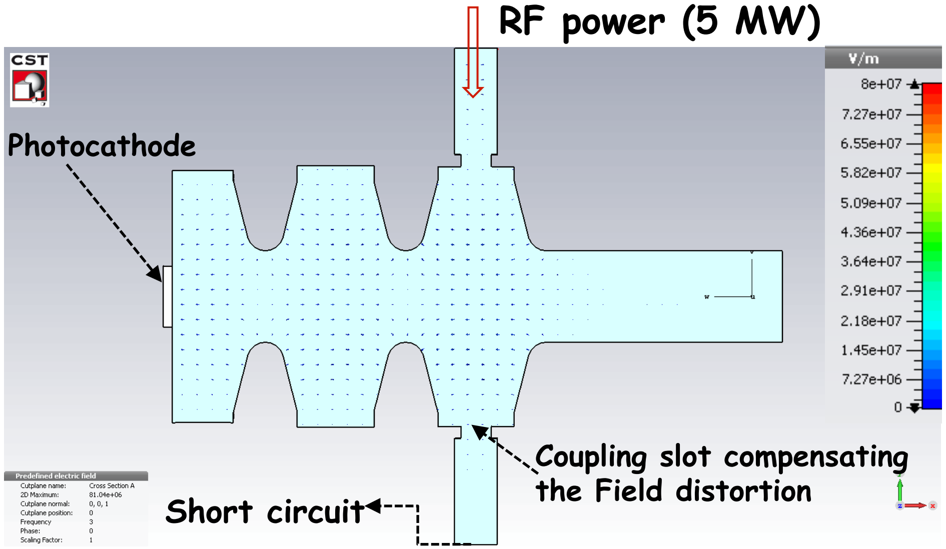
The RF gun based on PHIN RF gun

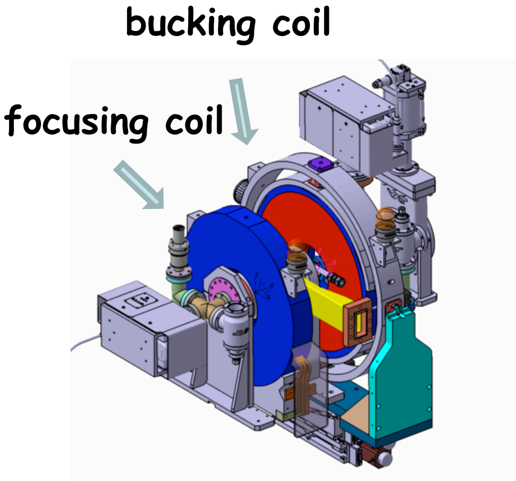
Photo-injector specification	Value
Operation frequency	2998,55 MHz (30°C, in vacuum)
Charge	1 nC
Laser wavelength, pulse energy	266 nm, 100 µJ
RF Gun Q and Rs	14400, 49 MΩ/m
RF Gun accelerating gradient	80 MV/m @ 5 MW
Normalized emittance (rms)	4.4 π mm mrad
Energy spread	0.4 %
Bunch length (rms)	5 ps

Example : 2.5 cells RF gun designed and produced at LAL for ThomX



Accelerating gradient (TM_{010} _ π mode):
80 MV/m at P_{in}=5 MW





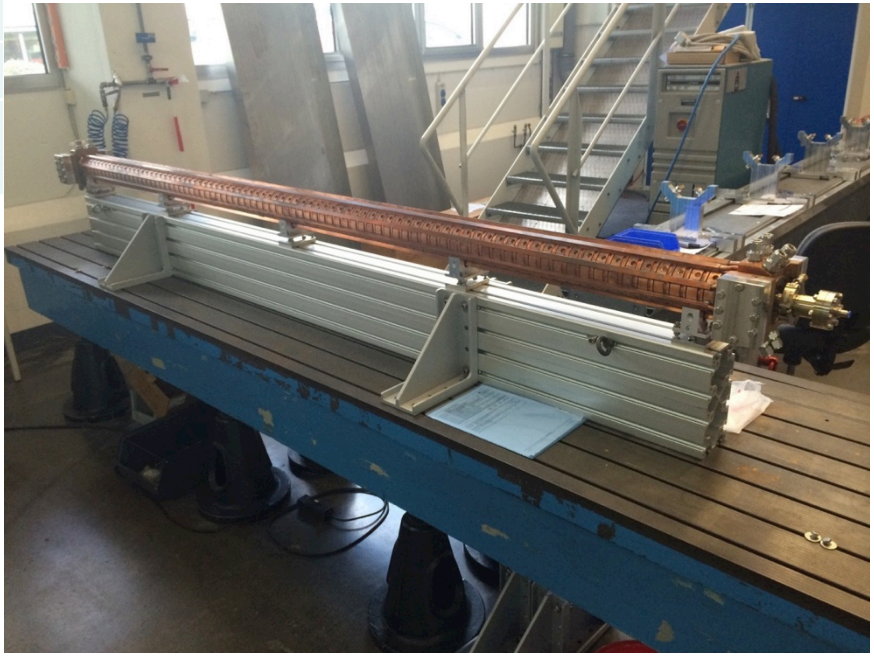
STATUS :

- RF and magnetic simulations are done
- *Astra simulations on going*
- Order of Copper done
- Start of fabrication : Jan. 2019

The High-Gradient linac

Accelerating section specifications	Value
Length	3.5 m
Number of Couplers + Cells	1 + 96 +1
Type	Constant gradient
Phase advance	2π/3
Frequency	2998.55 @ 30°C
Pulse width	3 μs
Repetition rate	50 Hz
Max. input Power	40 MW
Max average power	5 kW

- The Structures **are SLAC-type structures**
- Constant gradient
- Race track coupler for quadrupole compensation
- BIG Splitter for dipole compensation
- 2 RF loads



Status

- Choice of TW S-Band structures
- Call for tender done
- Order to RI
- Kick-off meeting 2nd October 2018
- Expected delivery in October 2019

research instruments

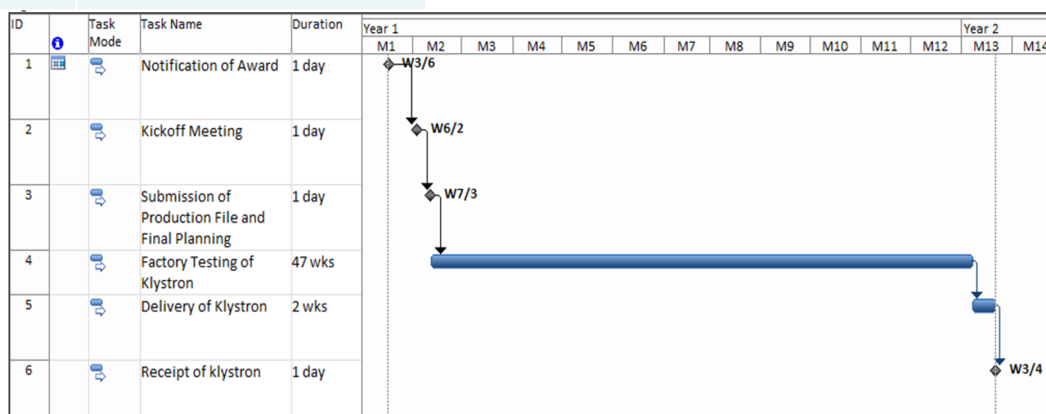
The Klystron

Klystron specifications	Value
Frequency Functioning mode	Pulsed
Repetition Rate	50 Hz
Beam Pulse Width (mid-height)	≥ 6,5 µS
RF Pulse Width (flat top)	≥ 4,5 µS
Peak RF output power	≥ 45 MW
Nominal beam voltage	≥ 10 kW
Nominal beam current	340 A
Micro-perveance	2
Efficiency (@ saturated RF output power)	≥ 43%
Gain (@ saturated RF output power)	≥ 47
Bandwidth -1dB (@ saturated RF output power)	≥ 8 MHz
RF input power	≤ 500 W
Nominal load VSWR	≤ 1.1:1
Sustainable load VSWR	≥ 1.35:1

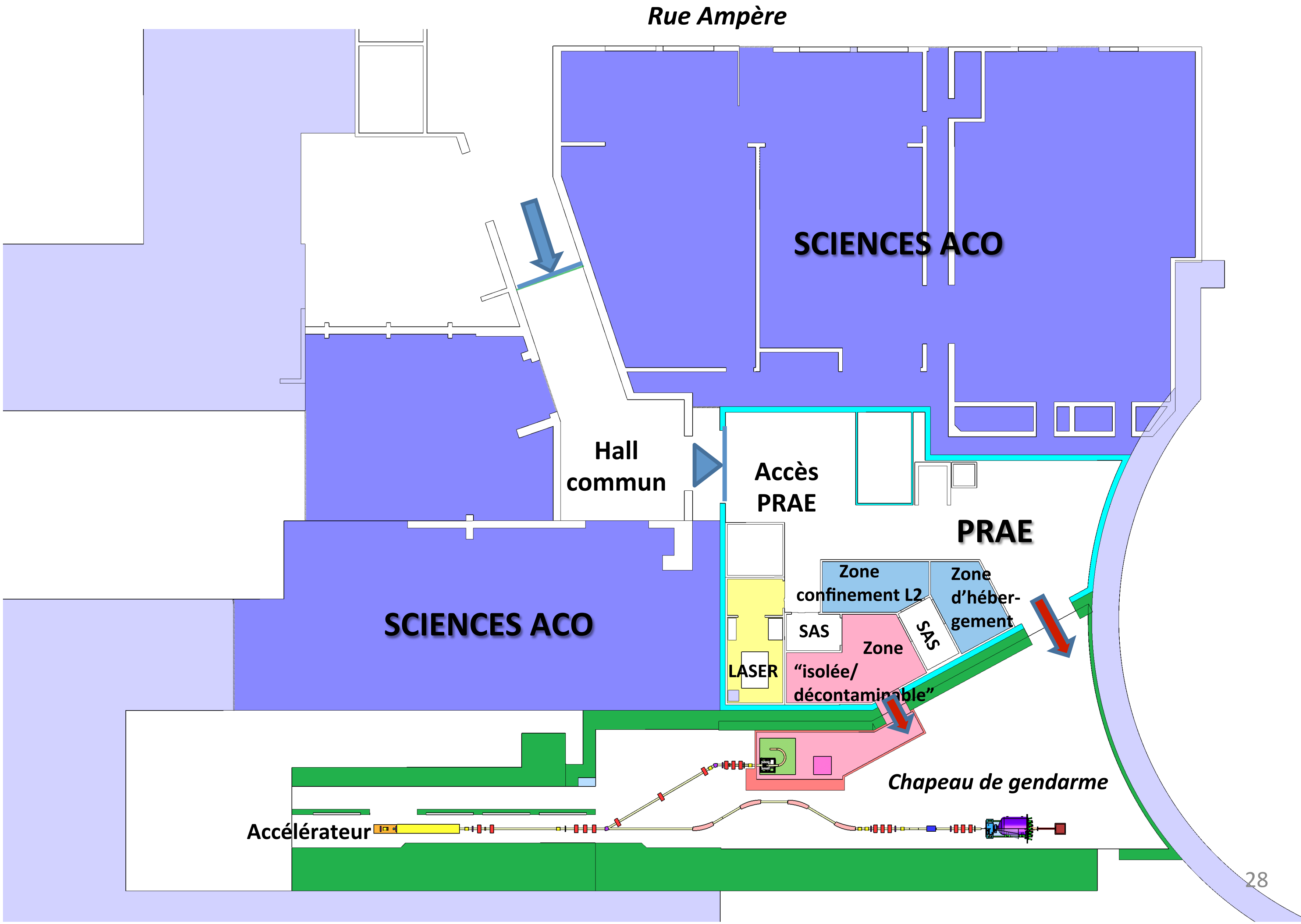
CPI
Communications & Power Industries
microwave power products division

STATUS :

- Call for tender done
- Choice of CPI supplier
- Kick – off meeting 10th Sept. 2018
- Expected delivery in Oct 2019



Where are we located ?
Between Sciences Aco museum and SuperAco



MOE Status

PHASE 1
Digging activities

PHASE 2
Site rehabilitation
Facility extension

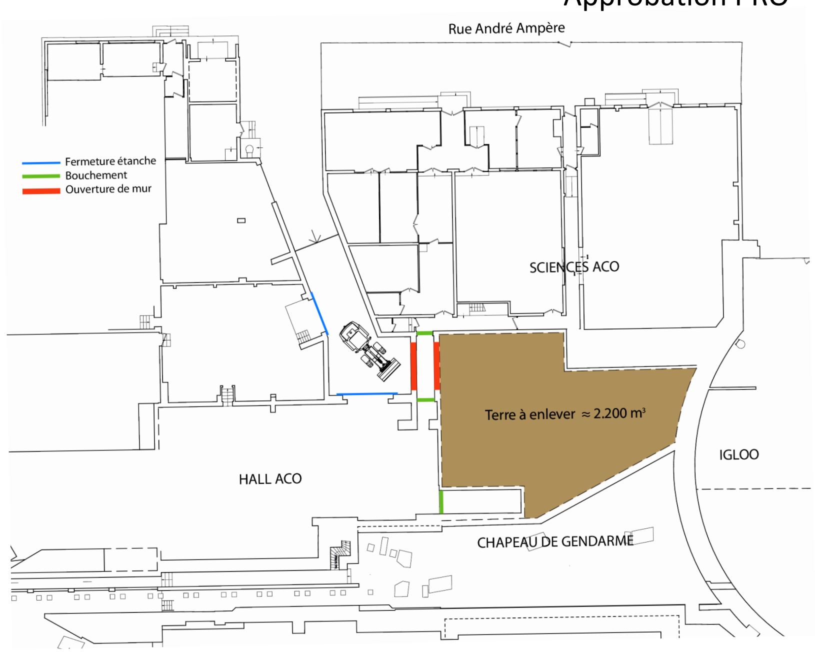
2018	2019				2020	
T4	T1	T2	T3	T4	T1	T2

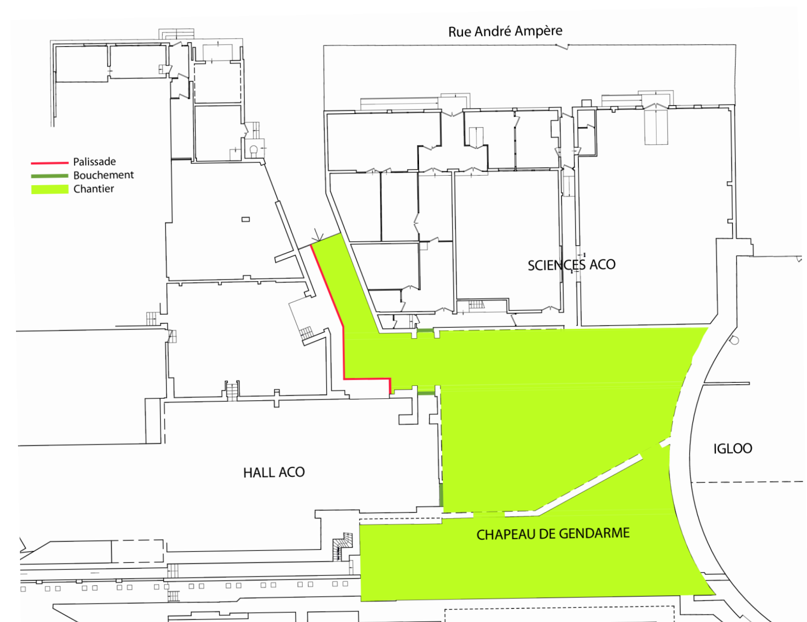
PHASE 1

PHASE 2

Approbation PRO

Début de chantier





Plans - J.M. Daubourg

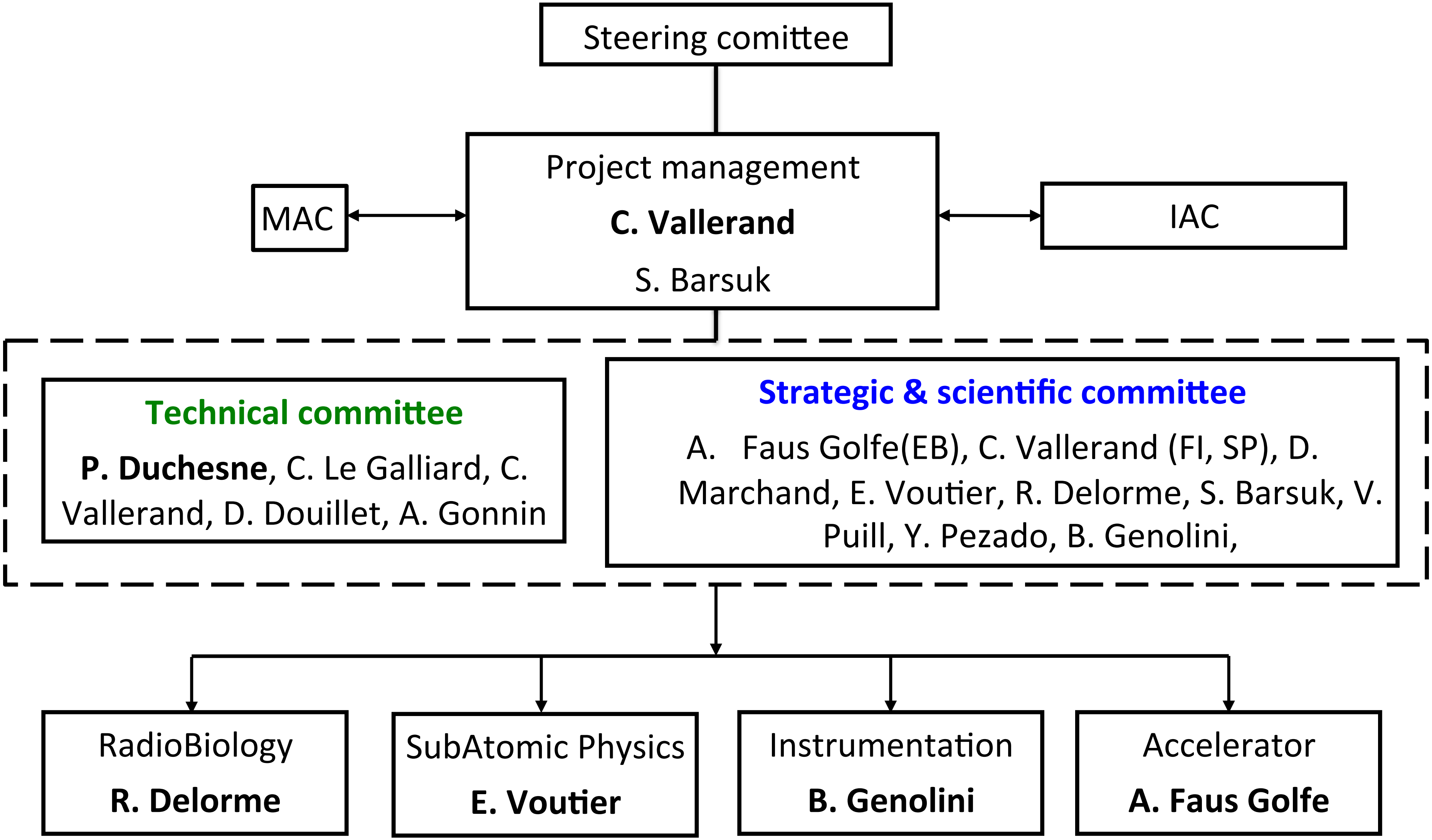
Status :

- Architect chosen
- Kick-off meeting done
- Building delivery in June 2020

Project Management

- *Organisation*
- *Budget*
- *Planning*
- *Status*

Organization chart



EB : Editorial Board
FI : Finances

SP : Search for Partners
IAC : International advisory Committee
MAC : Machine Advisory Committee

Budget

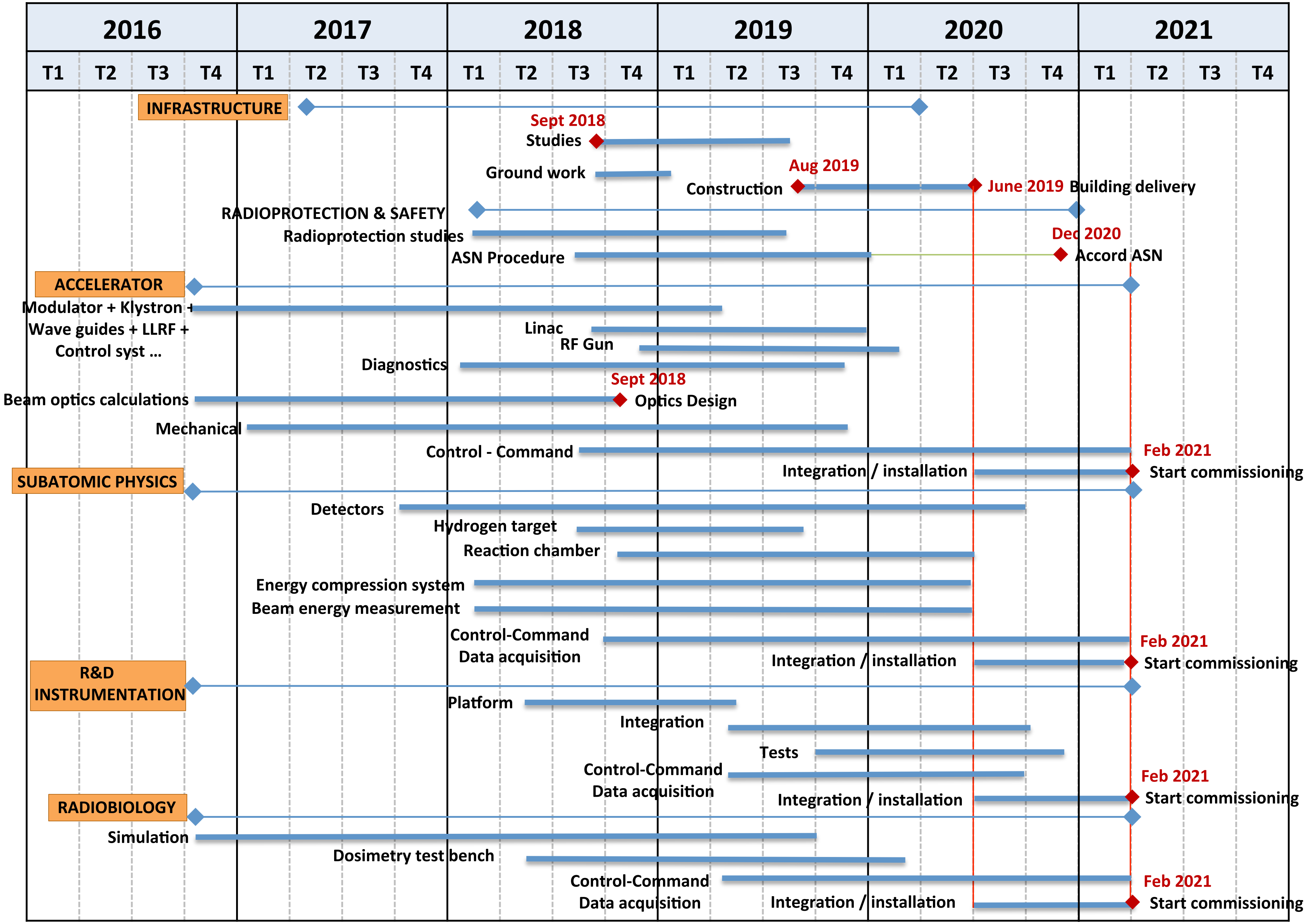
- **Synthesis of main expenditures :**

Photomultiplicators/BGO	12 062,00 €	2017	P2IO
LINAC	235 000,00 €	2018	SESAME
Klystron	155 000,00 €	2018	P2IO
Translation table	21 680,00 €	2017	P2IO
Diagnostics	7 540,19 €	2018	P2IO
Crystals	106 604,74 €	2018	SESAME

- **Allocated Financement : 1 684 000,00 €**
  - SESAME 1 070 000,00 € (fin 2029)
  - P2IO 514 000,00 € (fin 2019)
  - LAL/IPNO 100 000,00 €

- Rest at 3rd October 2018 : 1 096 400,67 € in which 305 832,77 € for P2IO

When ?



2016
2017
2018
2019
2020
2021
T1 T2 T3 T4
INFRASTRUCTURE
Sept 2018
Studies
Ground work
Aug 2019
Construction
June 2019 Building delivery
RADIOPROTECTION & SAFETY
Radioprotection studies
Dec 2020
ASN Procedure
Accord ASN
ACCELERATOR
Modulator + Klystron + Wave guides + LLRF + Control syst …
Linac
RF Gun
Diagnostics
Sept 2018
Beam optics calculations
Optics Design
Mechanical
Control - Command
Feb 2021
Integration / installation
Start commissioning
SUBATOMIC PHYSICS
Detectors
Hydrogen target
Reaction chamber
Energy compression system
Beam energy measurement
Control-Command
Data acquisition
Feb 2021
Integration / installation
Start commissioning
R&D INSTRUMENTATION
Platform
Integration
Tests
Control-Command
Data acquisition
Feb 2021
Integration / installation
Start commissioning
RADIOBIOLOGY
Simulation
Dosimetry test bench
Control-Command
Data acquisition
Feb 2021
Integration / installation
Start commissioning

Status : Project management

- **Development of a busines model and a market survey with the valorisation responsible for the Orsay Valley (S. Kamara)**

- **Implication of IRSD into PRAE** => Request on going

- Implementation of a **WBS** for the fourth WP

- **Implementation of a new organization**

- Development of **MoU on going**

- **Fundings :**
  - **Rejection of ANR/DFG**
  - **Optimisation of Accelerator :**
    - **use of translation table for instrumentation and radiobiology,**
    - **same dipoles**
    - **Recuperation of materials (modulators and quadrupoles from SLAC. Quadrupoles and steerers from CERN)**
  - **2 ATTRACTS call proposal submitted :**
    - **Precision tools for the electron beam handling : PTEBH**
    - **Development of Instrumed Phantom for Medical Applications : DIMPA**

- **New collaborations in discussion with KINR (Instrumented Phantom), the university of KieV (Profiler and its feedback with IA for the Scanning dipole tuning), the CEA (dosimetry), the company ACS and SB TEchnologies (Use of IA dans les accélérateurs) and University of Frankfurt for the hydrogen target loan.**

Workshop – P2IO

=> Reinforcement and development of new collaborations

=> Many participants interested by PRAE beam

GREAT SUCCESS

http://workshop-prae2018.lal.in2p3.fr/

Few Publications

2018

1. M. Hoballah *Constraints on low Q2 data for the extraction of the proton charge radius*, Germany, 23-27 April 2018
2. A. Vnuchenko and al. *Start-to-End Beam Dynamics Simulations for PRAE,* IPAC2018
3. Talk : Rabiology preclinic dose optimisation, ESTRO2018, EP-2198, Radiother Oncol. 2018;127:S1214-S1215, R. Delorme and al.
4. Talk : The ProRad experiment, 23-27/07/18, Proton Radius Puzzle 2018 workshop, MITP Mainz, D. Marchand
5. Talk : WE-HERAEUS Seminar on baryon form factors : where do we stand ?, Bad Honnef, Germany, 23-27 April 2018
6. Talk : The ProRad experiment, French-Ukrainian Workshop on the Instrumentation developments for high energy physics, 26-28 Oct. 2018
7. Talk : PRAE project, French-Ukrainian Workshop on the Instrumentation developments for high energy physics, 26-28 Oct. 2018
8. Article on going for Nature Review Physics (invitation), article submitted to EPJA about ProRad and article on going for Nuclear Physics News (ENPS)

2017

1. Marchand D. et al. *A new platform for research and applications with electrons: the PRAE project*. EPJ Web Conf. 2017;138:1012. doi:10.1051/epjconf/201713801012.
2. Barsuk S et al. *First Optics Design And Beam Performance Simulation Of Prae: Platform For Research And Applications With Electrons At Orsay*. In: IPAC 2017, Copenhagen, Denmark.
3. Talk : *The proton radius puzzle and the ProRad experiment*, EINN, Paphos Chypre 29Oct. – 4 Nov.
4. Talk : *The ProRad experiment,* French-Ukrainian Workshop on the Instrumentation developments for high energy physics, 6-8 Nov. 2017
5. M. Hoballah, *The proton radius puzzle and the ProRad experiment,* SFP, 3-7 Juil.

Conclusion & Perspectives

MID-TERM :

- **Go ahead to contact industrials for the PRAE construction as well as the use of beam**
- **Explore Artificial Intelligence as a part of R&D Accelerator and as a « rebranding » in collaboration with SB Technologies et ACS companies**
- Develop a business model to foresee the PRAE become after ProRad+dosimetry experiments : continue to run as a Research platform AND/OR transform the accelerator as a professional platform for Radiobiology/Industrial OR STOP PRAE
- Complete Radiobiology and Nuclear Physics experiments to propose a greater offer and elarge the community
- Go ahead to look for sources of fundings or material recuperation

SHORT-TERM :

- CDR document
- Foresee a MAC (Avril – Mai 2019)
- Evaluate the PRAE operating cost

Thank you for your attention

Thank you to the PRAE team

Thank you to our partners