BIOLEIR

Maurizio Vretenar on behalf of Manjit Dosanih,
using slides by Silvia Schuh
for the BioLEIR Study Group

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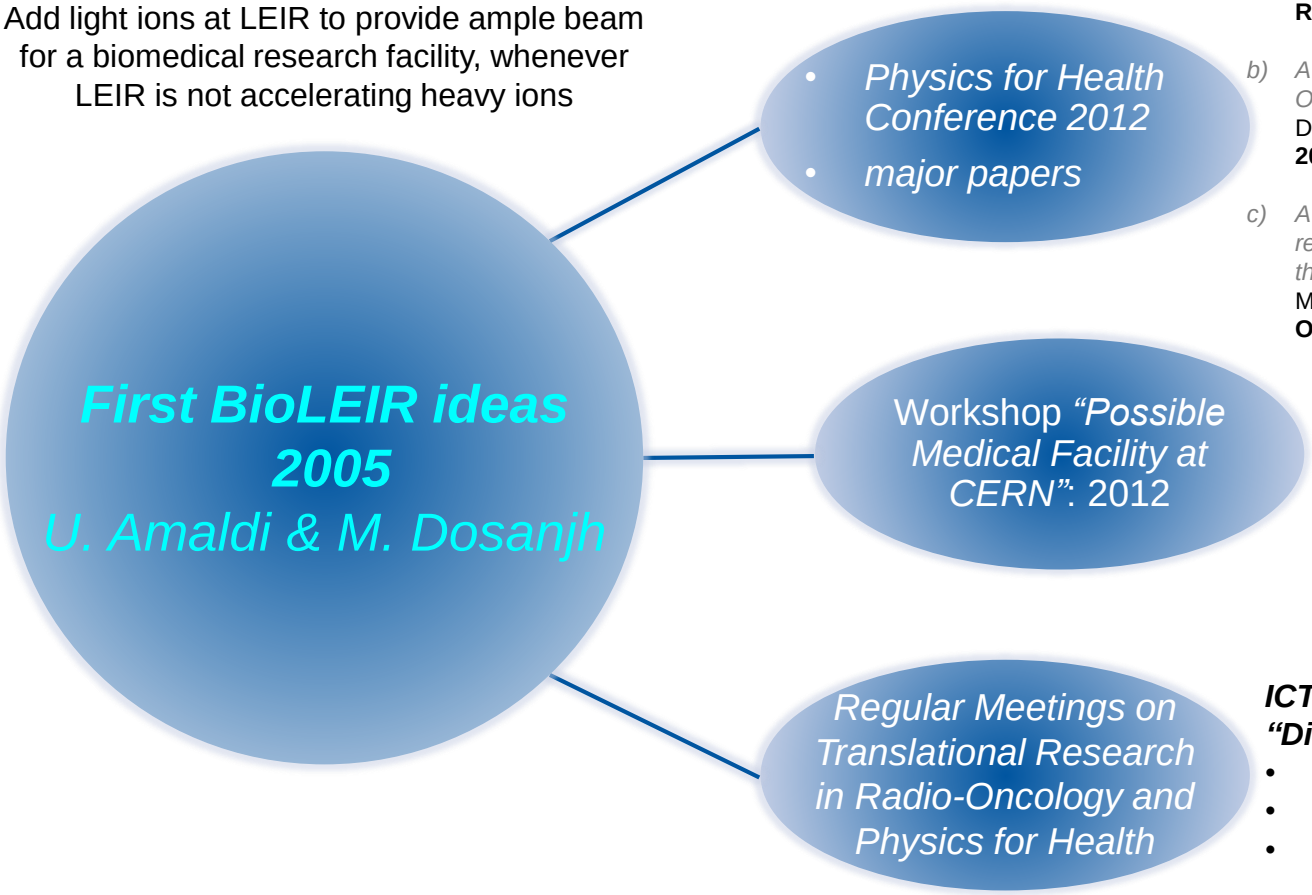
Historical Perspective

Add light ions at LEIR to provide ample beam for a biomedical research facility, whenever LEIR is not accelerating heavy ions



a) *Feasibility study for a biomedical experimental facility based on LEIR at CERN,* Abler D, Garonna A, Carli C, Dosanjh M, Peach K, **J Radiat Res. 2013 Jul; 54 Suppl 1**

b) *A possible biomedical facility at the European Organization for Nuclear Research (CERN),* Dosanjh M, Jones B, Myers S, **Br J Radiol. 2013 May; 86(1025)**

c) *A community call for a dedicated radiobiological research facility to support particle beam cancer therapy,* Holzscheiter MH, Bassler N, Dosanjh M, Sorensen BS, Overgaard J, **Radiother Oncol. 2012 Oct;105(1)**

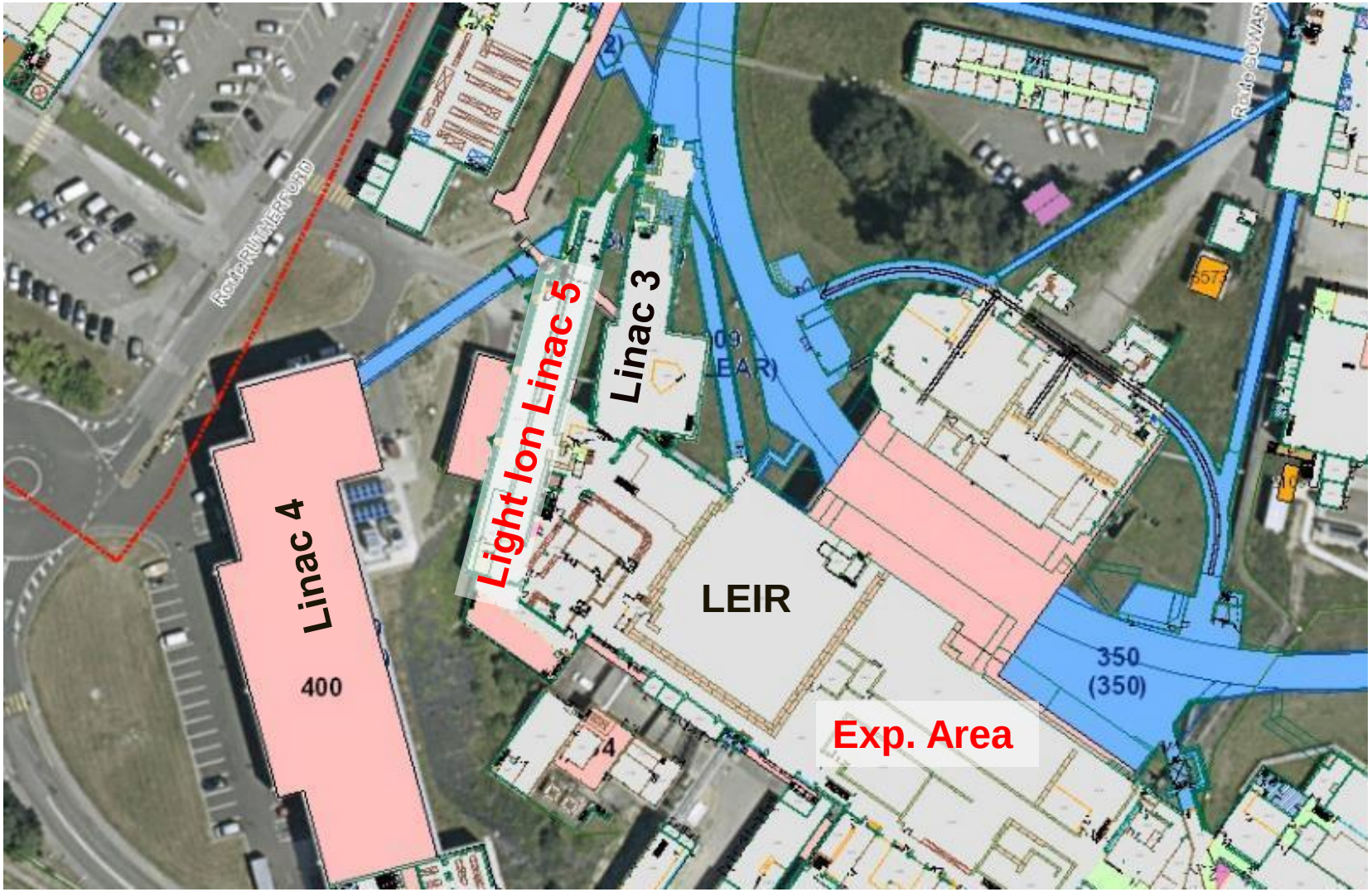
ICTR-PHE Conferences & "Divonne Meetings":

- *2012*
- *2014*
- *2016*

All yield a consistent message :

BioLEIR is an essential initiative for the biomedical community!

BioLEIR facility outline



Biomedical Motivation

Potential **impact of BioLEIR** in the biomedical field & on clinical protocols

- Systematic understanding of **RBE** (Relative Biological Effect)
  - ☞ reduce uncertainties in dose calculations & dose delivery ☞ avoid under-/over-dosage
- Systematic study: which **type(s) of ions** most effective for which cancer(s)
  - Explore the full range of light ions, up to O (same beam parameters , reduced systematics)
  - Clinical settings ☞ clinical operations prime over non-clinical research access ☞ limited beamtime available ☞ little freedom to "play" with beam settings (certification)
- Ion type for **next generation** of hadrontherapy centres (f.e. based on a PIMMS2)
- Particle range – Ballistics – Fragmentation
- Detectors suitable for beam monitoring and dosimetry
- Imaging tools
- Treatment planning tools (MC, RBE, LET, tumour painting)
- Real-time tumor tracking and dose delivery, motion mitigation
- Big data

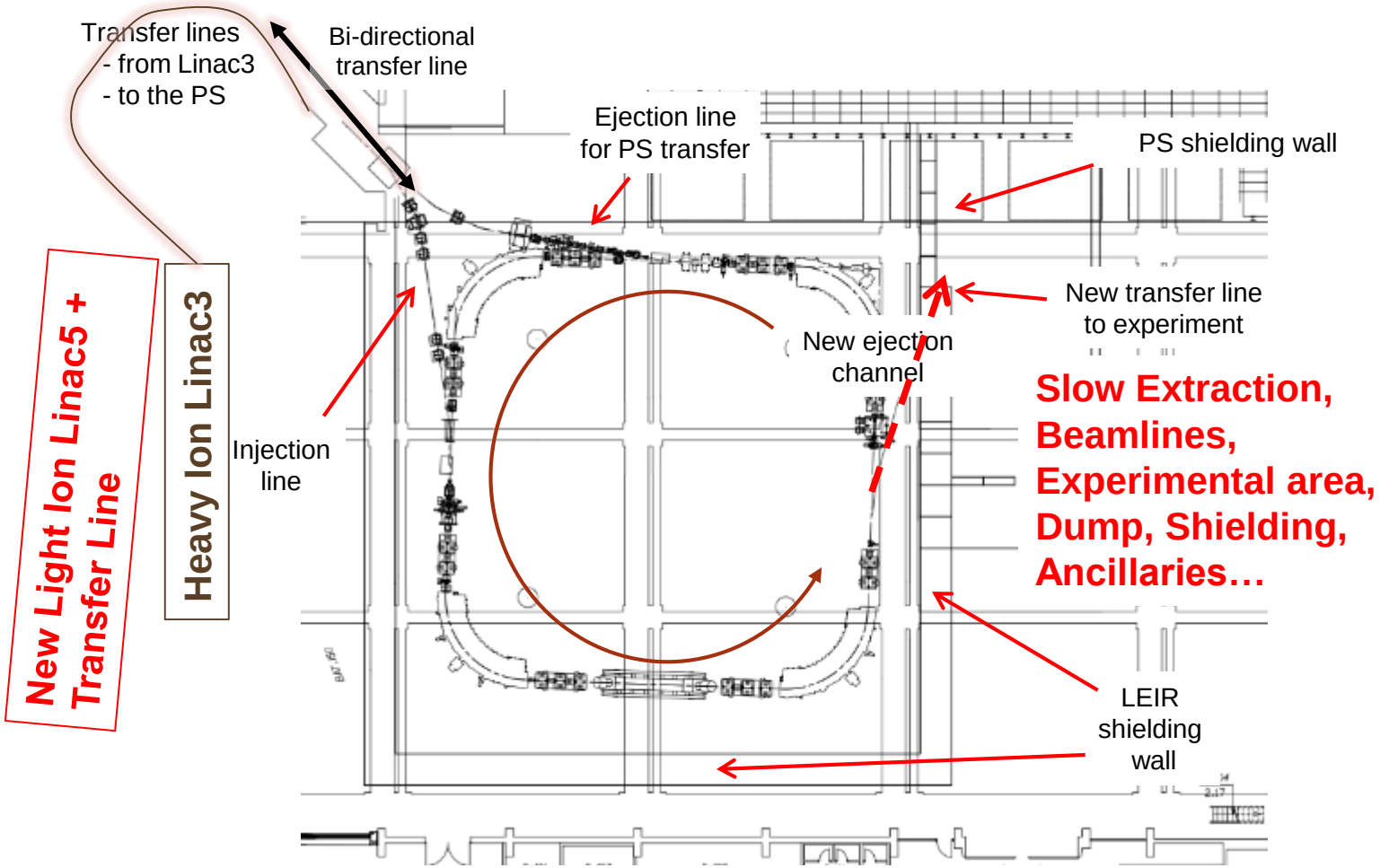
Facility Requirements / **Parameters**

- **H, He, Li, Be, B, C, N, O** (with new light ion Linac)
- Heavier ions from Linac 3, down to Oxygen
- Single source if rapid ion change
- Two sources would allow mixed irradiation

- Energies down to 50 MeV/u
- Energies up to 440 MeV/u (after power converter upgrade)
- Higher energies (?)

- Cycle time of 4.8 s (4 basic periods)
- Slow extraction : $\mathcal{O}(10^8 – 10^{10})$ ions per spill
- Energy change @ synchrotron (spill), and/or range shifter

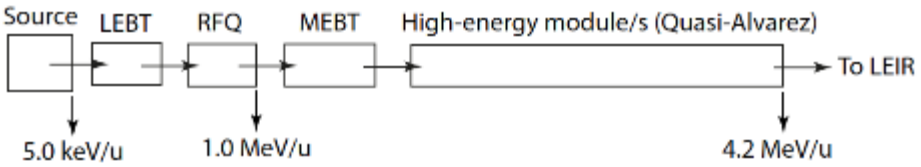
BioLEIR facility outline



Frontend and Linac

Design the frontend for **optimal matching** between source and Linac

- Design of source output shaping
- Design of new beamline elements (RFQ)



Design of a **new light ion LINAC5**

- Quasi-Alvarez DTL structure, optimized for q/m=1/3 and 1/4
- Shortened: Quad in every 3rd driftcell
- Use of PMQ

Opportunity to **reuse LINAC2** area

Interest from CNAO

Risk: Ageing Infrastructure

A. Lombardi, J. Garland, J-B. Lallement

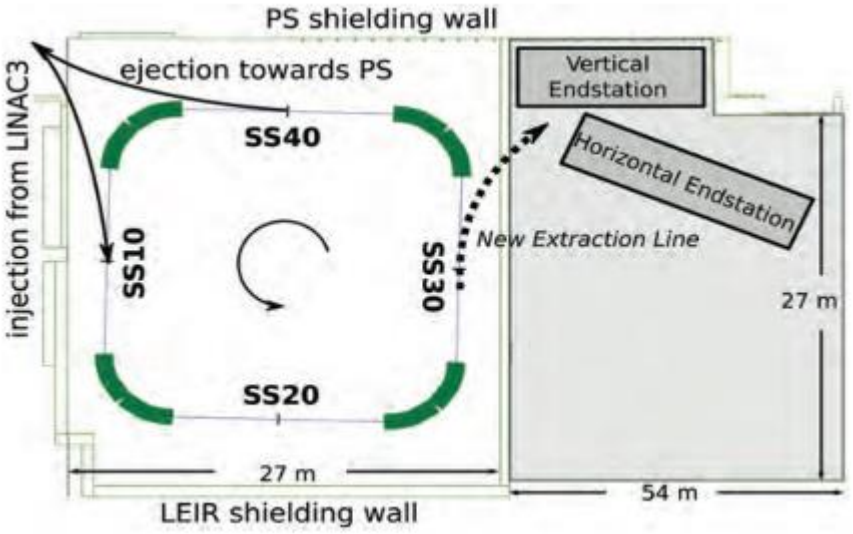
LEIR synchrotron

Several aspects concerning LEIR need further, detailed beam dynamics studies:

- Efficiency and stability of the injection system from LINAC3/5 to LEIR
- Intensity & stability for different ion species at energies up to 440 MeV/u & as low as 50 MeV/u
- Efficiency and stability of slow extraction system
- Effect of electron cooling and/or solenoid on different light ions operation
- Efficiency and stability of the ejection system towards the PS with BioLEIR elements present
- Impact of BioLEIR devices on LHC beams

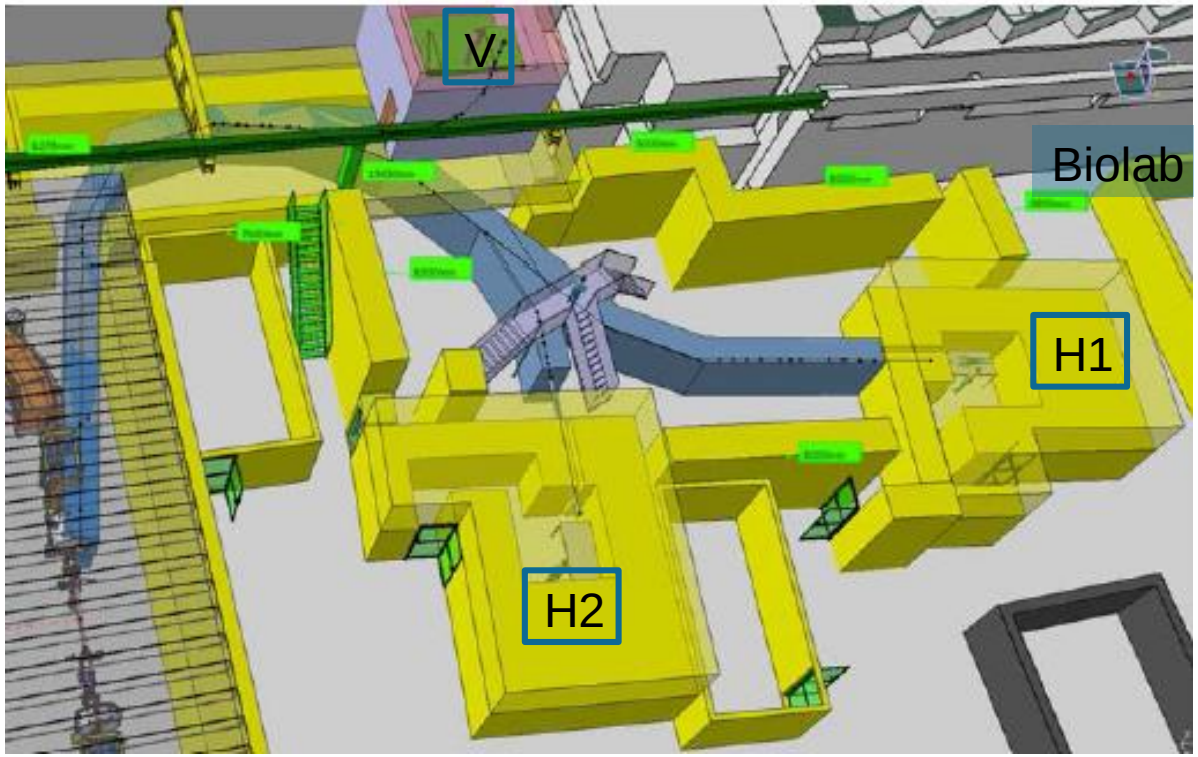
LEIR power converter upgrade

- Currently ion energy limitation
  beam rigidities limited to 4.8Tm:
  i.e. 246 MeV/u for Carbon ions
- Bending magnet design limit 6.7 Tm



Biomedical Experimental Area

- Local BioLEIR control/counting rooms (access/area control, beam on/off)
- Provide common instrumentation & sample/detector mounts



Robotic placement system

Provision for cell imaging

independent user access to irradiation areas

Extensive integration aspects (overhead crane, existing structures..)

Collaboration with Oxford University, UK B. Jones, B. Vojnovic

BioLEIR Staging Scenarios

***Stage 1** (2021, 2022)*

- LINAC3 (Argon, Oxygen, Carbon?) + Extraction + 3 beamlines + Biolab
- LEIR energy 246 MeV/u max
- Dedicated running of BioLEIR possible for **4 months/year**
- **Switching time: weeks** (or hours if Oxygen)

***Stage 2** (2023 -)*

- **New Light Ion Frontend** added: LINAC5 and source, full range of light ions accessible: protons to Oxygen
- **BioLEIR operation** further **uncoupled from LHC/NA** heavy ion operation
- **Beamtime: ~7 months** w/ switching time of minutes

***Stage 3** (2024 -)*

Upgrade LEIR power converters for **maximum energy up to 440MeV/u**

Option: Interleaved operation

Possibility to further maximize beam time with transfer line (PPM) & injection septa upgrade

- **Controls complexity** of short common Linac4 & Linac5 transfer line
- Detailed **cost-benefit analysis** needed

NB

A **delay** in project start **beyond mid-2017** means that LS2 window is missed ☞ **BioLEIR start in 2026**!!

Cost estimate – full facility

System	[kCHF]	Uncertainty
Ion source baseline	1100	
LINAC5	7000	
Transferline to LEIR	1800	
LEIR power converter upgrade	700	
Slow extraction	1200	
BioLEIR beamlines	6100	
Experimental Area	800	
Infrastructure	5100	
Vacuum	3600	
Radiation protection	400	
Controls system	300	
Safety system	600	
Total [kCHF]	**28700**	30%

System	[PY]	Uncertainty
Ion source	7	
LINAC5	23	
Transferline to LEIR	8	
LEIR power converter upgrade	2	
LEIR beam dynamics studies	5	
Slow extraction	9	
BioLEIR beamlines	21	
Experimental area	2	
Infrastructure	10	
Vacuum	9	
Radiation protection	4	
Operations	2	
Controls system	5	
Safety system	1	
Project management	11	
Total [Person-Years]	**119**	10-15%

Estimated cost of a "green-field" facility:

- Average construction cost ~140MCHF (without personnel cost)
- ~30% for clinical overhead
- Estimate to ~100 MCHF
- Significant **cost saving** through **re-use of existing** CERN **infrastructure**

Study Conclusions

- Technical designs are found to be sound
- **No technical showstopper** identified

- Cost estimated at **29 MCHF, 120 person-years**
- **Earliest beam** to BioLEIR possible in **2021**
- Delivery in **3 stages** with increasing capability and complexity

- Project start date > mid-2017 ☞ BioLEIR 2026!
- Optimization in next project stage

- Yellow Report: 180 pages with good level of detail
- https://doi.org/10.23731/CYRM-2017-001