
CERN

Primary electron beam facility at CERN

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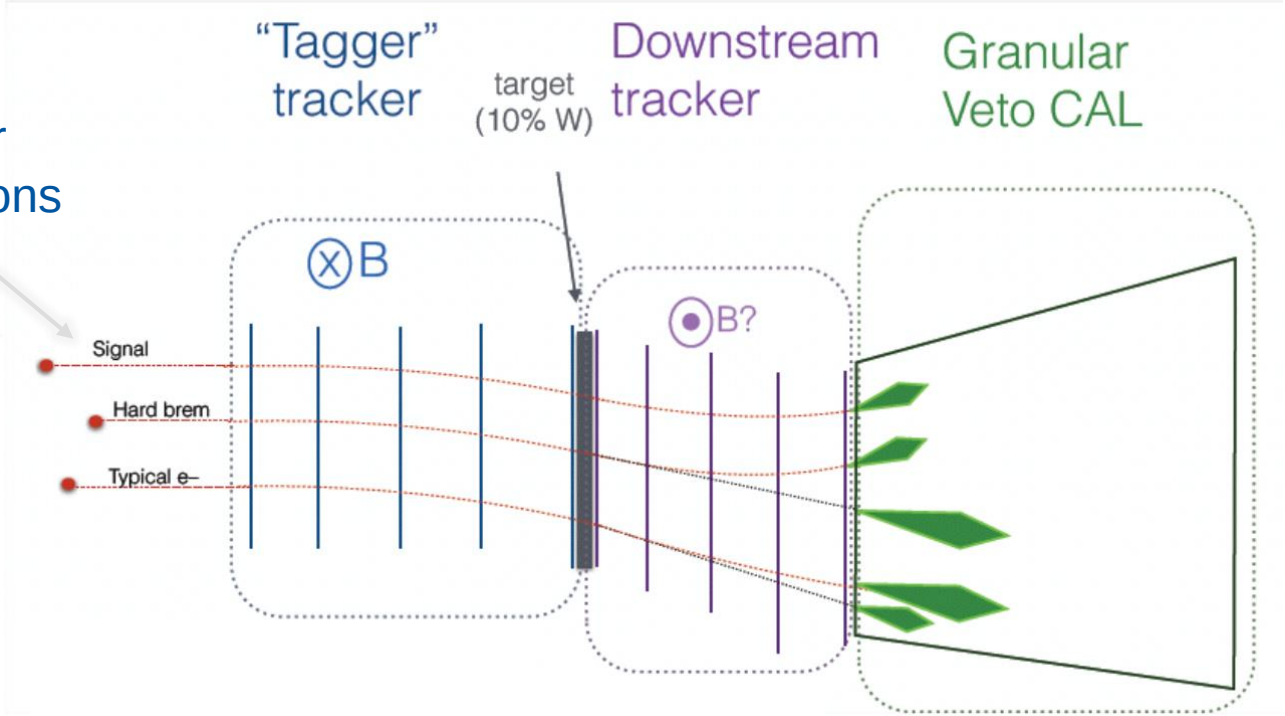
Outline

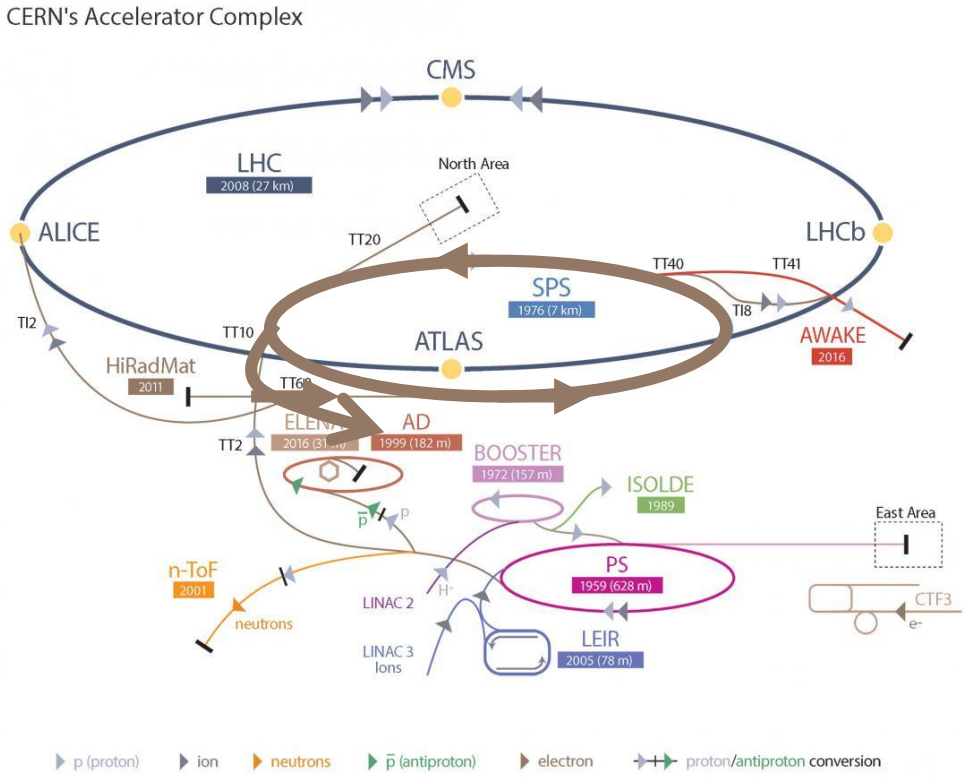
- Light Dark Matter eXperiment (LDMX)
- Electron complex
  - Linac
  - SPS
  - Extraction
- Beam structure
- Example of user groups for the CERN primary electron beam facility
- Conclusion

Light Dark Metter eXperiment

Search for dark photons



Electron complex



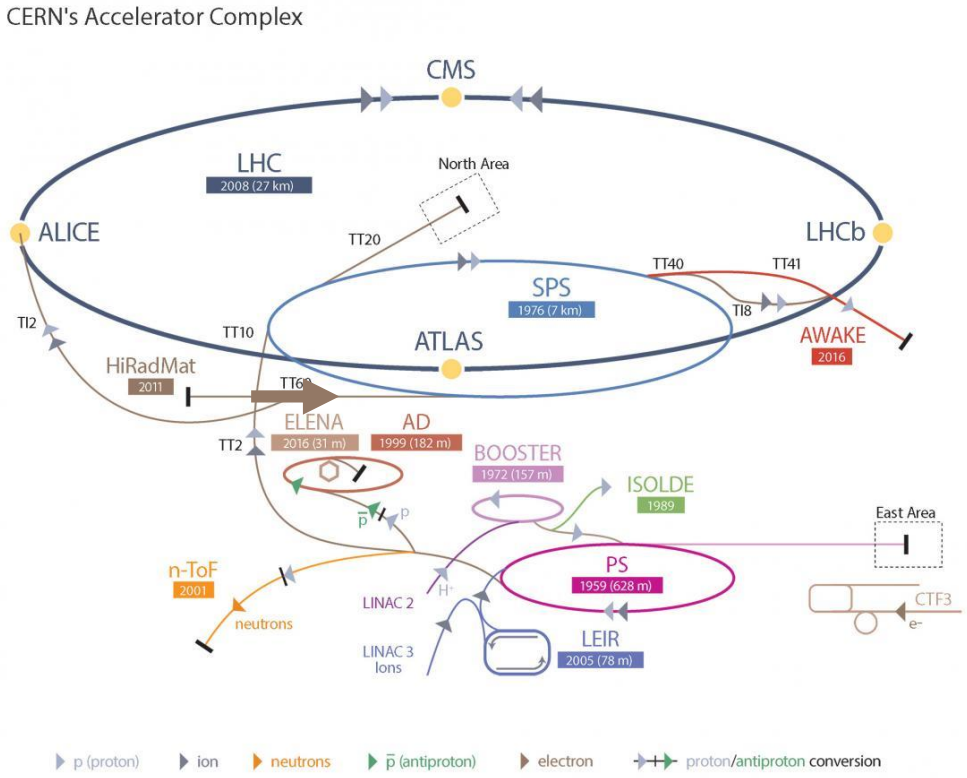
3.5GeV Linac

Acceleration to in SPS

Extraction

Electron complex

3.5GeV Linac

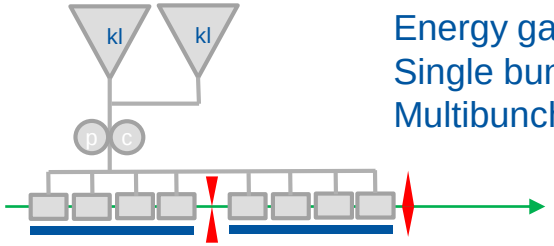


Layout e-linac to SPS (single bunch => multi bunch)
Based on the initial desing for EuSPARC (Frascati)

parameters			comments
<a> [mm]	3.2		
d [mm]	2.5		
Ls [mm]	500		
Qe	21400		
vg/c [%]	2.5 – 0.77		
Tf [ns]	121		
R'_PC [MΩ/m]	350		$=G^2/(Pkl/L)$
	Single bunch	Multi bunch	
Number of bunches	1	40	
Bunch spacing [ns]		5	
Pulse length [ns]	121	325	
Active gradient: G [MV/m]	84	66	
N structures	104	104	
Total active length: Lt [m]	52	52	
Energy gain: Vt [MeV]	4368	3432	
Total klystron power: Pt [MW]	1056	1000	On crest, No losses in WG
N klystrons	26	26	

Cell R'/Q
R'/Q~95 MOhm/m
Q ~ 6500

Layout of one RF unit

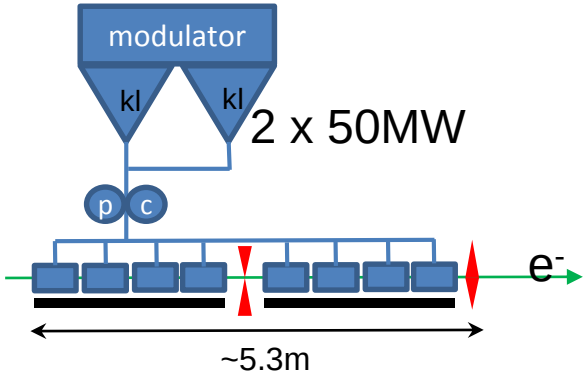


Energy gain:
Single bunch: 336MeV
Multibunch 200ns: 264MeV

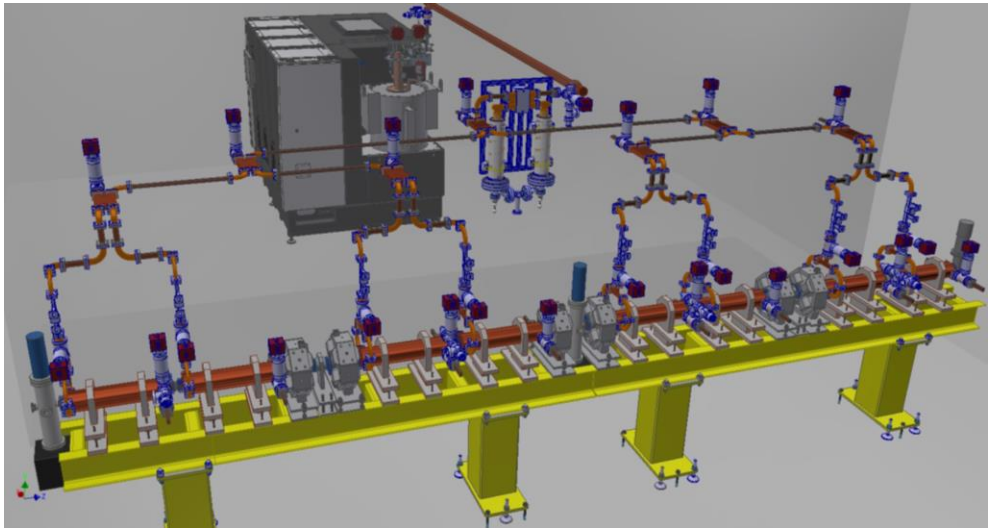
Active gradient for multibunch:
Tp = 325ns => 200ns bunch train
2x40MWx1.6us + CLIC pulse compression ~3 =>
240MWx325ns => 30 MW/AS => Gacc = **66 MV/m**

Linac parameters

- 0.1GeV S-band injector
- 3.4GeV X-band linac
  - High gradient CLIC technology
  - 13 RF units to get 3.4 GeV in ~70 m



Possible parameters	
Energy spread (uncorrelated*)	<1MeV
Bunch charge	52 pC
Bunch length	~5ps
Norm. trans emittance	~10um
N bunches in one train	**40**
Train length	**200 ns**
Rep. rate	100 Hz



RF DESIGN OF THE X-BAND LINAC FOR THE EUPRAXIA@SPARC_LAB PROJECT
M. Diomede Et al., IPAC18

X-band Linac components available

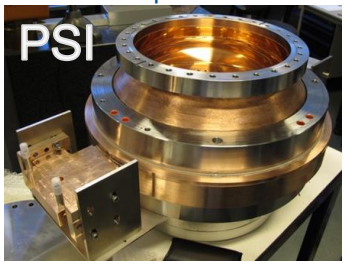
- Examples

Klystron

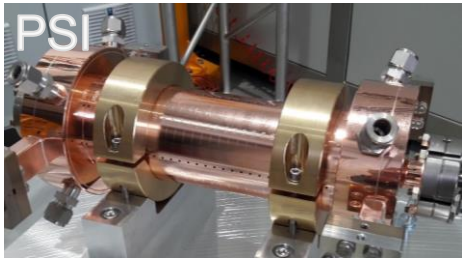
+

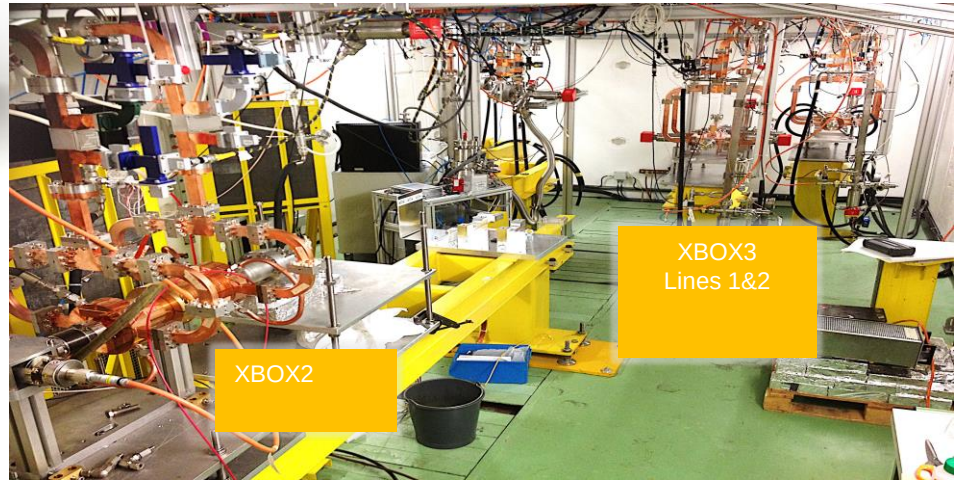
Modulator

Pulse compressor



Accelerating structure



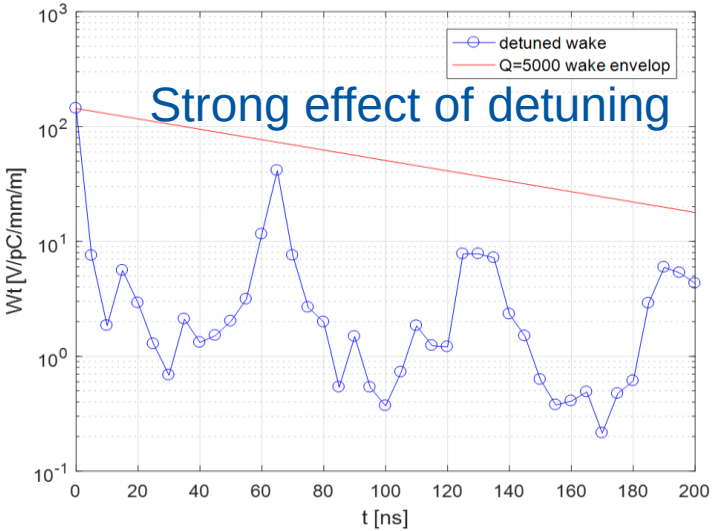


- One RF unit accelerates 200ns bunch train up to 264 MeV

Assembled systems in continues operation at CERN

Transverse Long-range wakes

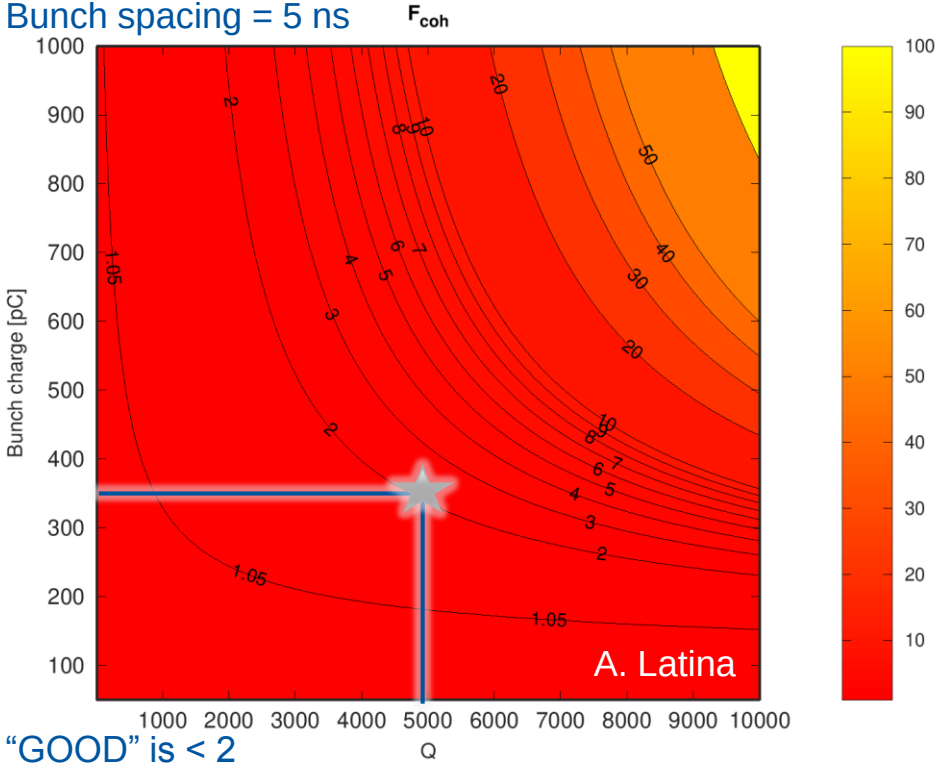
Q = 5000;



	1st cell	60th cell
a [mm]	3.636	2.764
d [mm]	2	2
Amplitude [V/pC/mm/m]	117.1	168.2
Frequency [GHz]	**16.08**	**17.03**

Scan Q vs bunch charge

Bunch spacing = 5 ns



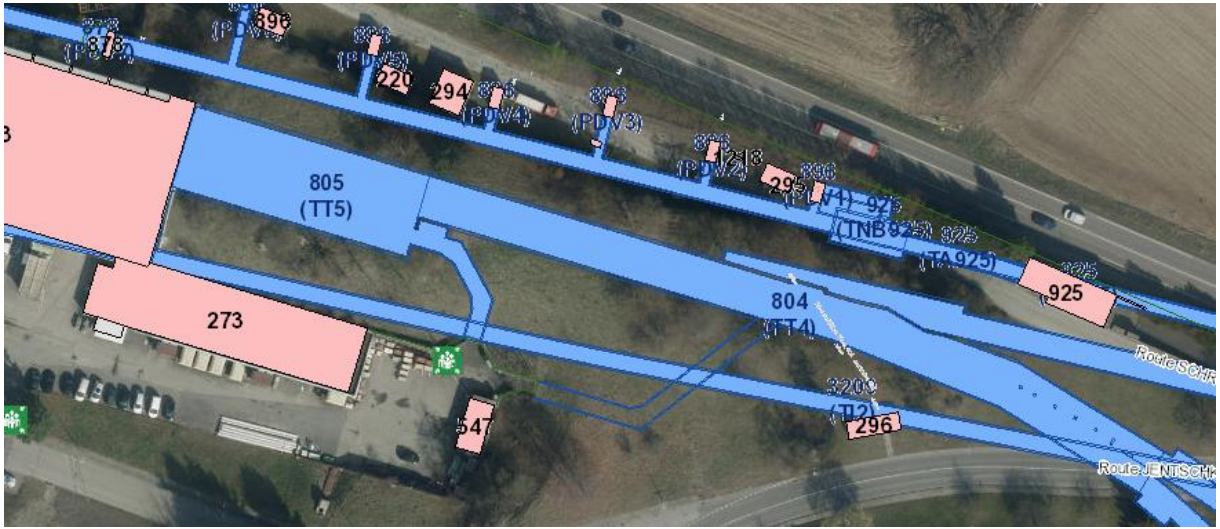
"GOOD" is < 2

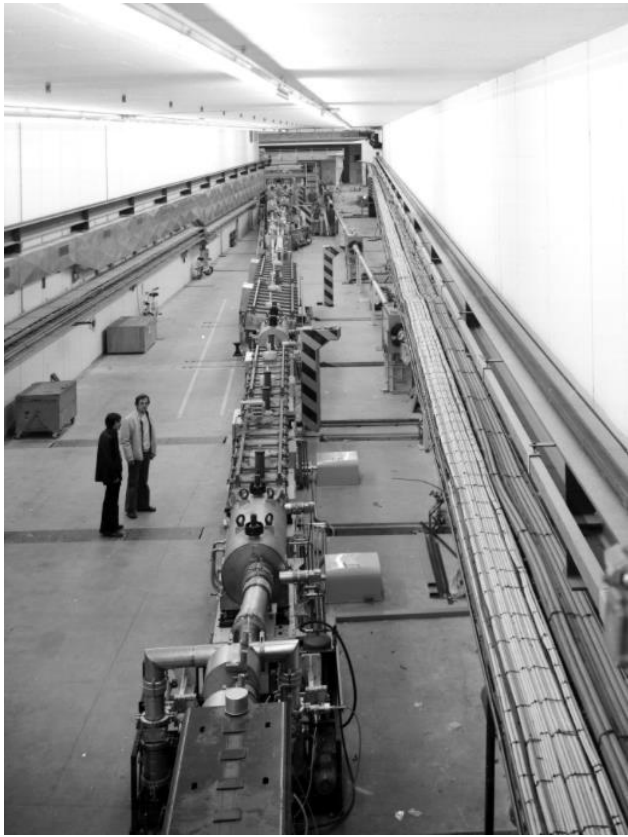
Undamped: Q ~ 5000;

Max charge = 300 pC

Linac location

- To be installed in the available transfer tunnels TT4, in line with the SPS



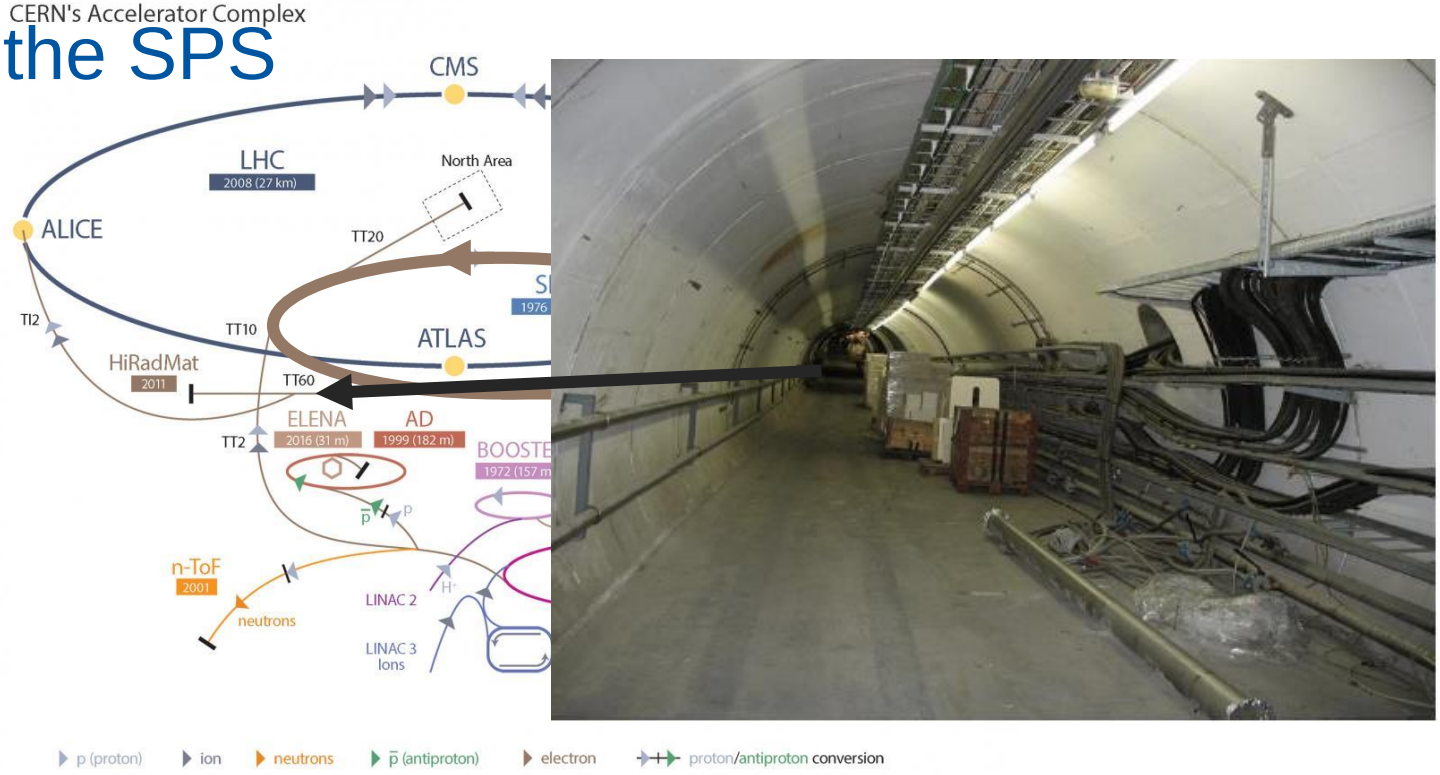


Transfer tunnel, TT60, from the Linac into the SPS

Injection into the SPS

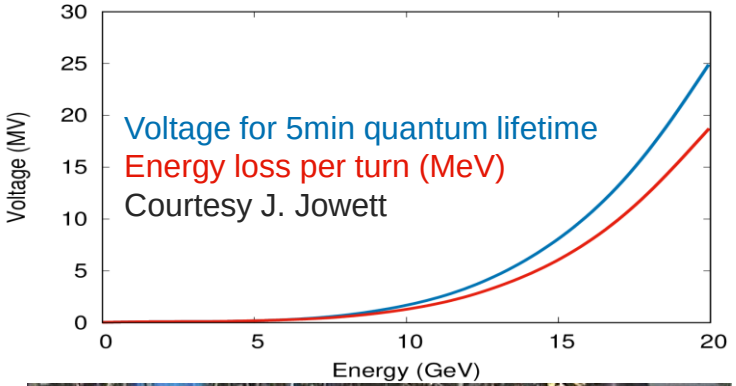
Bunch to bucket injection in the 200MHz SPS longitudinal RF structure.

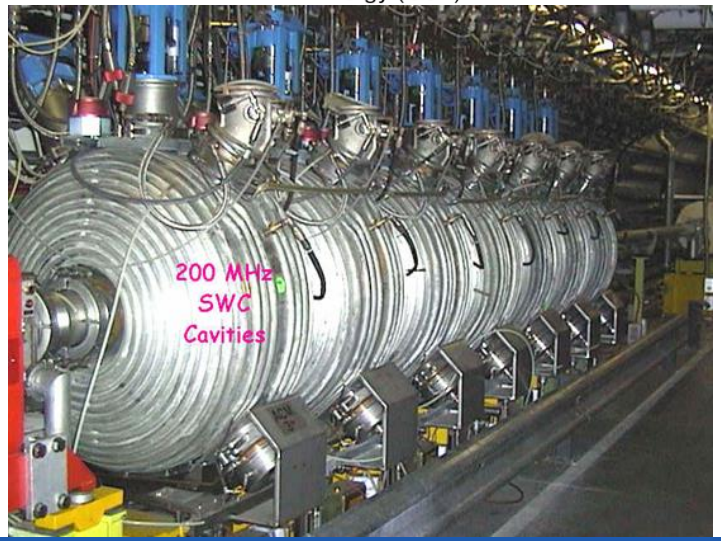
Total of 75 trains of 40 bunches
3000 bunches
10^{12} electrons in the ring



SPS RF system

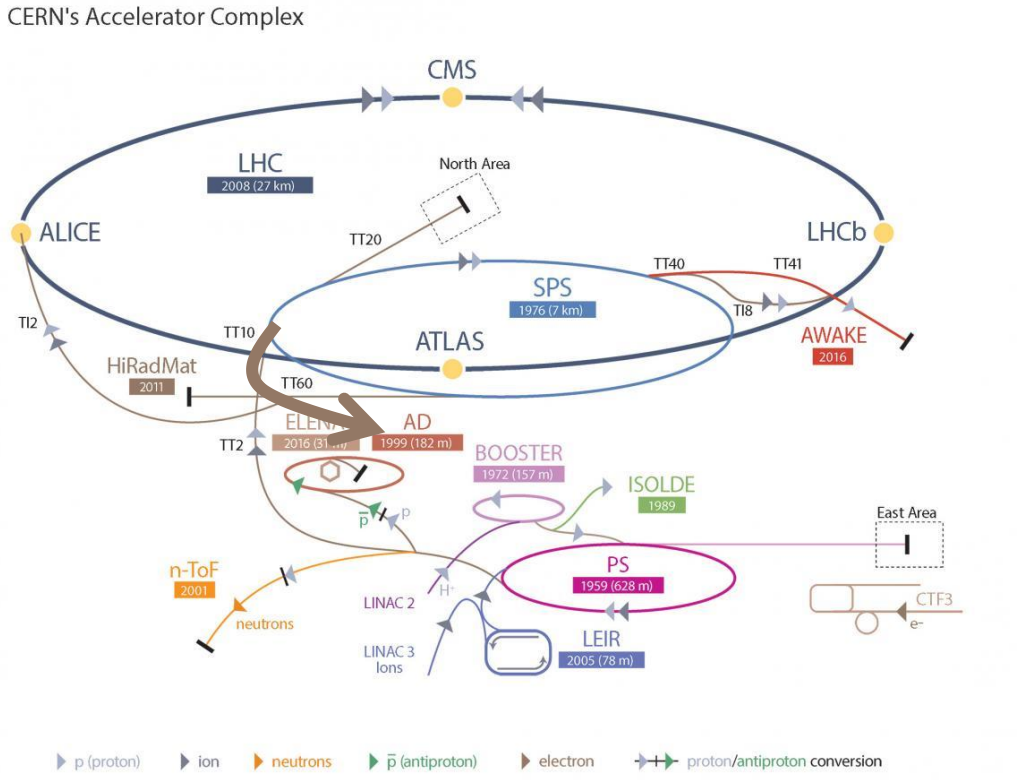
- Acceleration to 16 GeV can safely be achieved
- Existing 200 MHz cavities from LEP era to be re-installed
  - Need 10MV for 16GeV electrons
  - (12 + 1) 200 MHz Standing Wave Cavities [1 MV per cavity] available
- Space is available to install them
- 5ns, 10ns, … 40 ns longitudinal structure is imposed by the available cavities
- Trains of 200ns (linac) separated by 100ns gaps (injections kicker)





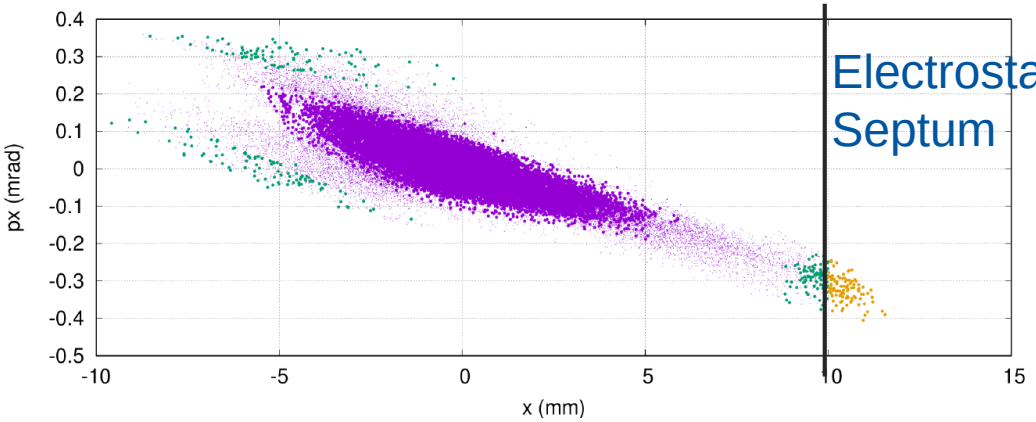
Slow extraction to experiments

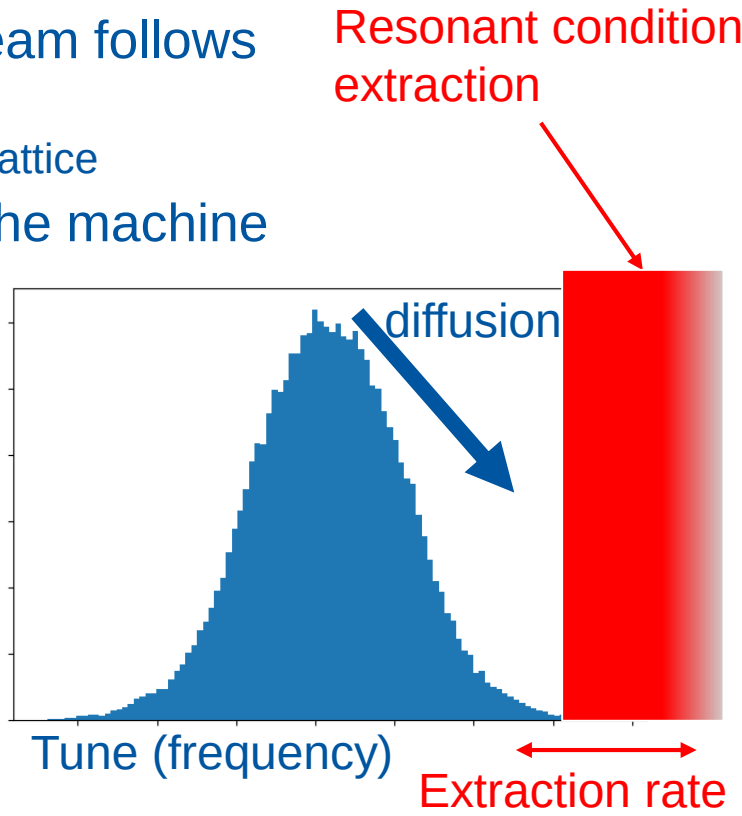
Extraction



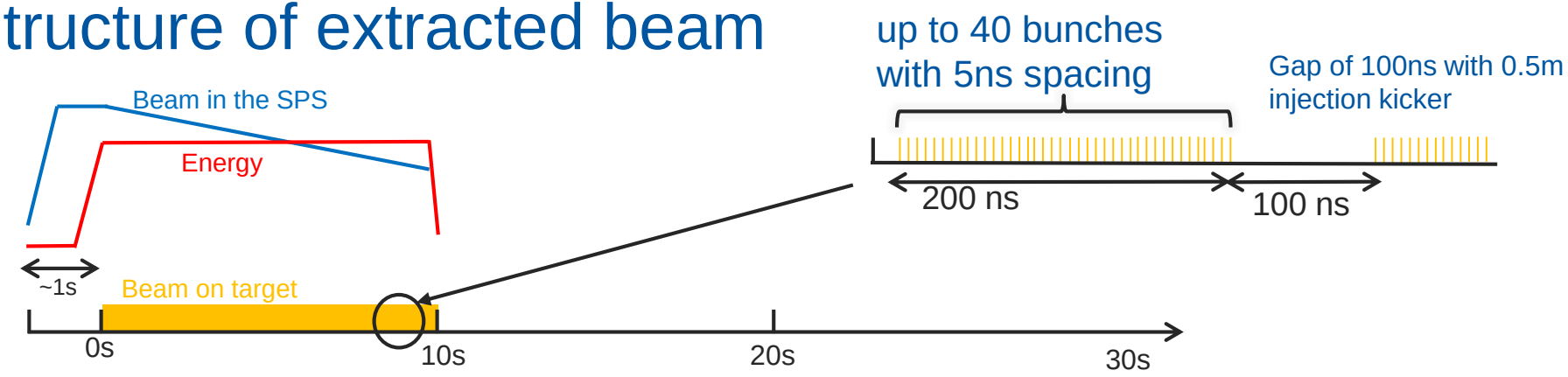
Slow extraction principle, in frequency space

- Spread in oscillation frequency within the beam follows
  - Transverse distribution
  - Longitudinal distribution in presence of chromatic lattice
- Position of the resonant condition is set by the machine
- Quantum excitation constantly diffuse the particles, hence frequencies,





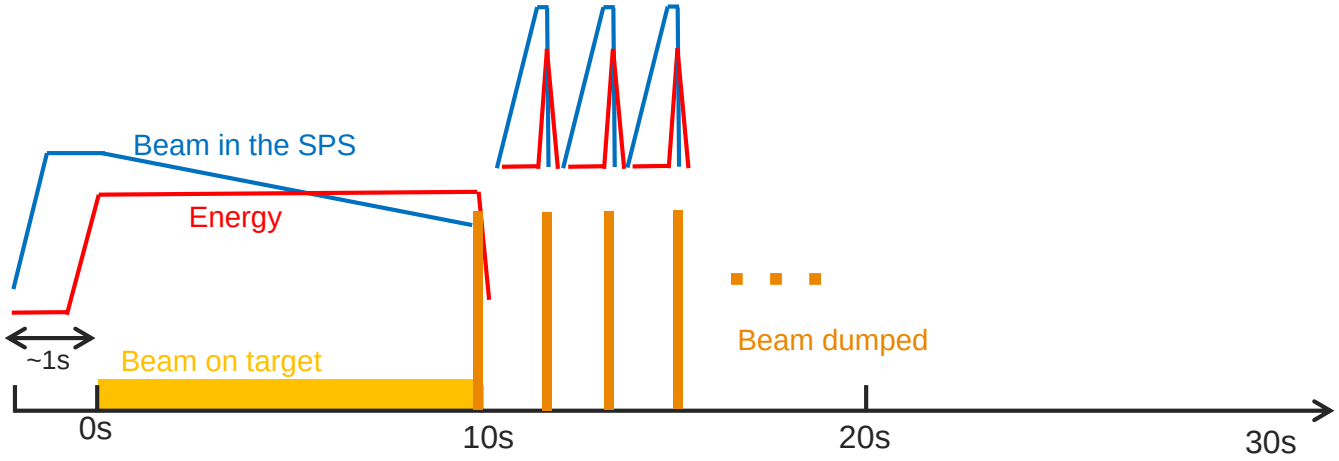
Structure of extracted beam



- Flexibility
  - Bunch spacing 5ns, 10ns, … 40ns
  - Average electrons per bunch can be chosen from <1 to anything
  - Transverse beam spot on target from very small up to hundred cm^2
- This flexibility can deliver the needs of LDMX
  - Phase 1 : 10^{14} electrons
  - Phase 2 : 10^{16} electrons

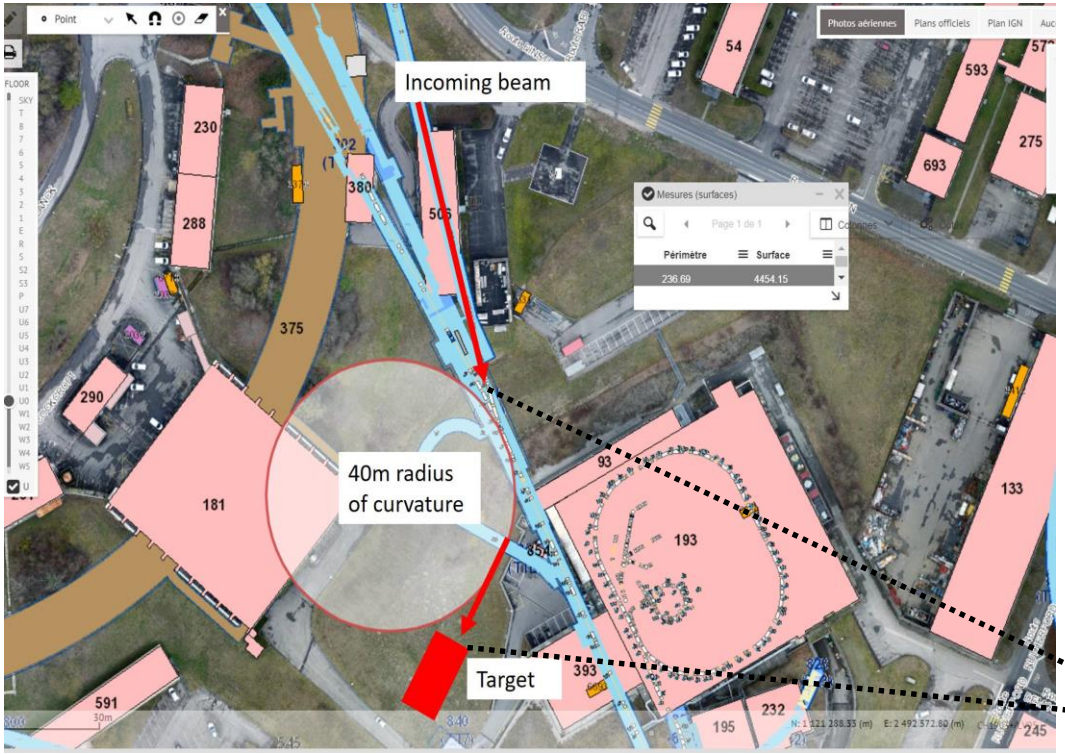
In addition

- After this beam has been delivered there is still a lot of electrons in the SPS
- These can quickly be dumped into a separate beam line
  - 10^{12} electrons within 25μs, possibly up to 4 times more



If there would be a high priority the dump can be repeated every 2 s

Extracted beam and experimental area



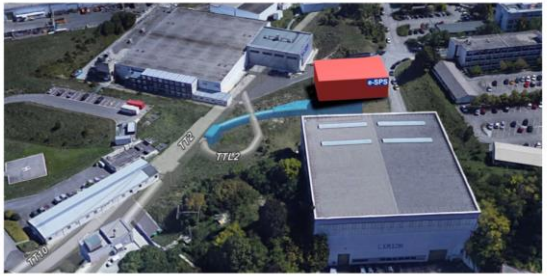
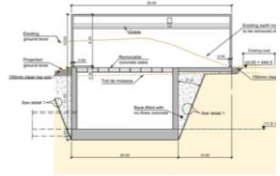
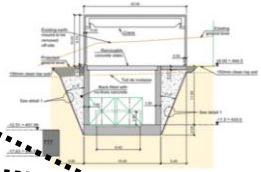


FIG. 43: Visualisation of the proposed underground (shown in blue) and overground (shown in red) facilities





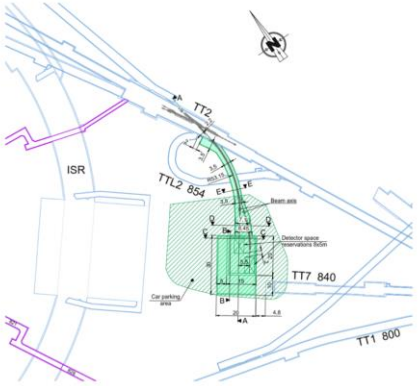
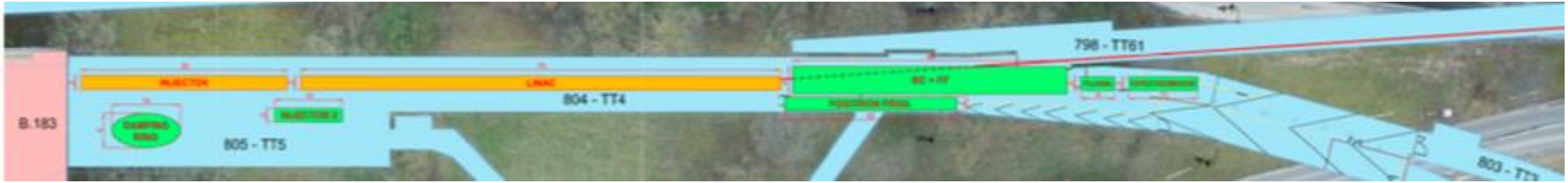


FIG. 38: Plan view of proposed layout

In total ~50 m new tunnel

Other user groups for the CERN primary electron beam facility

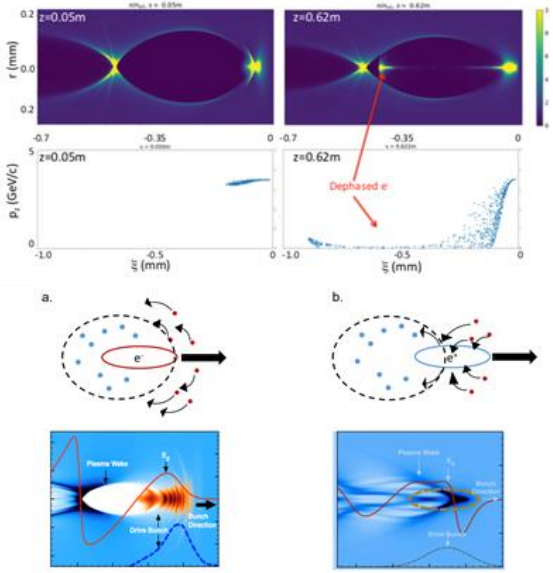


Physics

- LDMX
- Other hidden sector experiments, incl. dump-type experiments using available electrons
- Nuclear physics

Accelerator physics R&D:

- CLIC: Linac goes a long way towards a natural next step for use of technology (collaborate with INFN and others also using technology for X-band linacs in coming years)
- Relevant also for other potential future facilities using electrons (rings) considered at CERN
- Plasma studies with electrons
  - Use electron (3.5GeV) beam as driver and/or probe – study by AWAKE WG
- Positron production (interesting for LC, rings and plasma) and studies with positrons for plasma and LEMMA concept for muon collider
- General acc. R&D as in CLEAR today (https://clear.web.cern.ch)
  - Plasma-lenses, impedance, high grad, medical, training, instrumentation, THz, ESA irrad.
- General Linear Collider related studies
  - Example: damped beam for final focus studies (beyond ATF2)



References

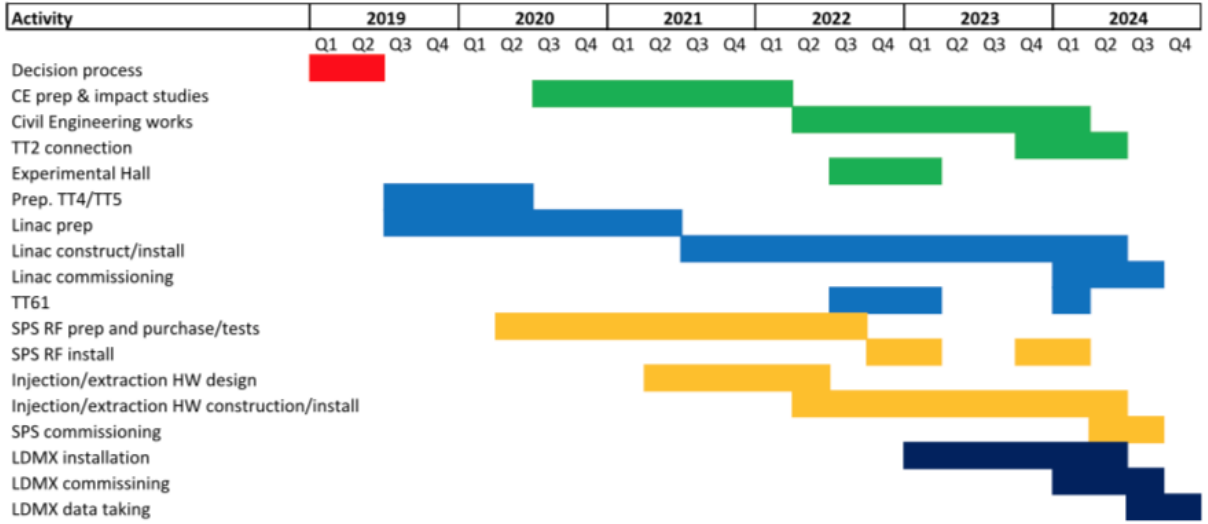
- https://arxiv.org/abs/1805.12379
- Expression of Interest (EoI) to the SPSC Oct 2018: https://cds.cern.ch/record/2640784
- Also submitted in “compact form” to ESPP update 18.12 (cannot find public link)
-

Cost and Schedule in the EoI to SPSC

- Expression of Interest (EoI) has been submitted to the SPSC in October 2018: https://cds.cern.ch/record/2640784
- It is also submitted in “compact form” to ESPP update 18.12 (cannot find public link)

TABLE I: Cost summary

PBS	Item	Cost MCHF
1.1	Source	6.0
1.2	X-band linac	34.1
2.1	Linac to SPS transfer	4.6
2.2	SPS fast injection	3.4
2.3	SPS ring	10.5
2.4	SPS slow extraction	3.3
2.5	Transfer SPS to Exp. Area	4.2
3.2	Civil Engineering	11.4
3.3	Exp. Area infrastructure	2.0
	Sum	**79.5**



Schedule is technically based … however

- Respects that efforts during LS2 has to be limited
- No major spending or commitments until Spring/mid 2020
- Final connection after end of LHC run in 2023
- Can run during LS3 when/if the SPS is available

Conclusion

- Based on previous usage of the CERN accelerator complex, and building on the accelerator R&D for CLIC an electron beam facility would be a natural next step

- No show-stoppers have been found when exploring this option

- This facility could deliver the beam needed for the LDMX program, deliver electrons to an electron beam dump experiment, and opens for a wide range of accelerator research and development studies with relevance for CERN

Thank you