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WP11: Sustainable Concepts and Technologies

iFAST Kickoff meeting

Mike Seidel, PSI/EPFL, 4.5.2021

WP11 Overview

task 1: **Sustainable Concepts for RIs**: networking, workshops on selected topics
deliverable: report

1) System Efficiency of Accelerator Concepts (E.Jensen ai. CERN, PSI/EPFL)
2) Key Technologies and Components for High Efficiency (C.Martins ESS)
3) Cross Linking Accelerator R&D with Industrial Approaches (P.Spiller GSI)
4) Ecological Concepts (D. Voelker DESY)

task 2: **High Efficiency Klystron** (E.Jensen CERN, THALES, ULANC)

- deliverable: industrial prototype
- replacing klystrons in LHC

task 3: **Permanent Combined Function Magnets for Light Sources** (B.Shepherd, UKRI, DLS, KYMA, DESY)

- deliverable: magnet prototype, applicable for Diamond upgrade,PETRA-4
- several advantages of permanent magnets, not just power consumption

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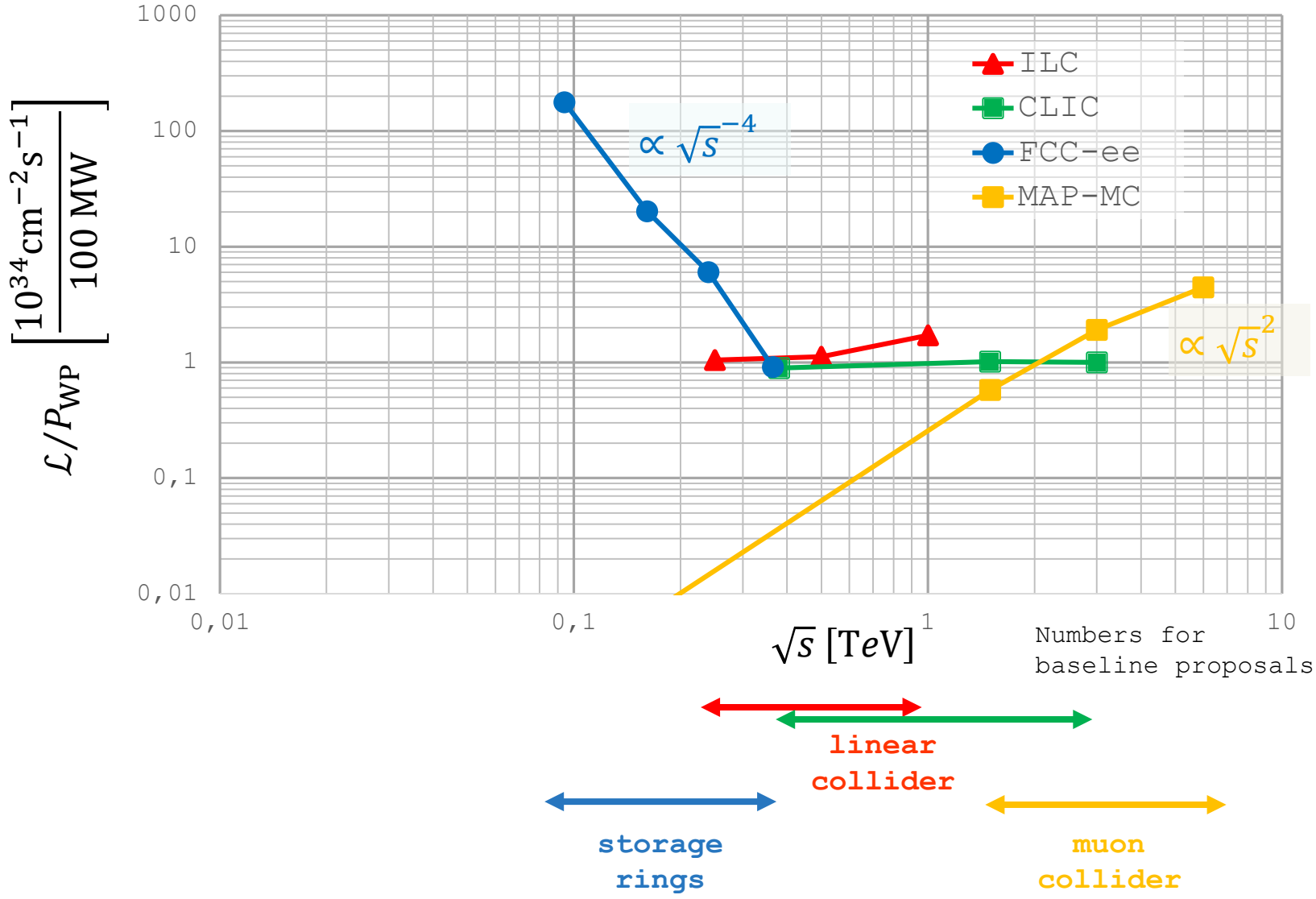
Task 1.1: System Efficiency of Accelerator Concepts

- metrics of energy efficiency: compare RI concepts for the same research;
  i.e. Collider COP (Ph.Lebrun); topical workshops, e.g. with WP5
- **example high intensity [megawatt class] proton driver accelerators**
  - rapid cycling synchrotron
  - s.c./n.c. linear accelerator
  - isochronous cyclotron
  - fixed focus alternating gradient accelerator (FFA)
- **example lepton colliders**
  - ring collider
  - linear collider
  - energy recovery linac
  - muon collider

Example 1.1:
System Efficiency of Lepton Colliders: Luminosity per Grid Power



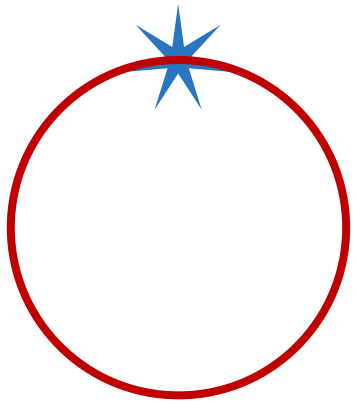
μ coll. :

$$\sigma_z \propto \frac{1}{\gamma}$$

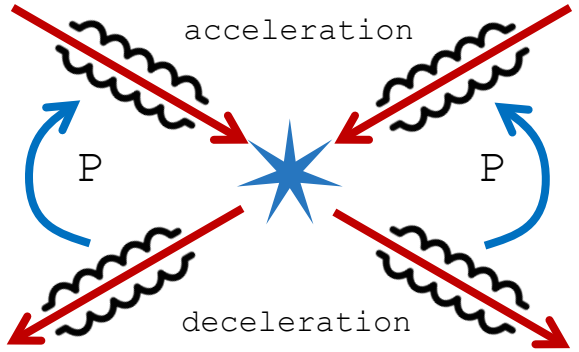
[E.Jensen, Granada]

Colliders and Energy Recovery Scheme

Ring Collider
beams circulate



ERL
power re-cirulated



Linear Collider
beams collide once

- beam used once
- but power recirculated
- ambitious collision parameters lead to low beam intensity

→ **overall low energy consumption, but higher initial investments**

attainable collision parameters (design reports)

	FCC-ee$_{365GeV}$	CLIC$_{380GeV}$
σ_x [nm]	38‘000	150
σ_y [nm]	68	3
σ_z [μm]	2‘500	70
N [10^9]	230	5,2
f_b [kHz]	17,6	147
P_b [MW]	985	2.8

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Task 1.2: Key Technologies and Components for High Efficiency (Carlos Martins ESS)

assess the relevance of particular technologies and identify important R&D directions, challenges and opportunities; quantitative assessment of the achievable gains for certain technologies

example topics from brainstorming:

- **Renewable Energy Sources**, integration in RI; for example injecting PV power directly at the DC-link busses of the main power supplies.

- **Efficiency of power converters**: survey around different facilities; new components: silicon carbide MOSFET's & IGBT's, new more efficient passive devices inductors and capacitors, etc.); new more efficient topologies;

- **Power quality compensators**: harmonic filters, SVC's, STATCOM, ..; Active filters; "Active Front End" as a power supply embedded power quality compensator;

- **Efficient cooling circuits***:* Utilisation of Variable Speed Drives (VSD's) on water pumping; Automatically adjust the flow rates as a function of the heat loads, including stopping the pumps when the accelerator equipment are off

- **phase stabilized magnetrons***:* explore experience at Fermilab, JLAB

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Task 1.3: Cross Linking of Accelerator Facilities and Technologies with Industrial Approaches (GSI, P.Spiller)

Fostering “Dual-Use”: Developments for Accelerators applied to Energy Systems. Strengthening the communication with industry to evaluate potential collaborations, support developments and to attract interest.

Accelerator Technologies	Energy Systems
Development of (intermediate) **energy storage technologies** (e.g. fly wheels, capacitive or s.c. magnetic energy storage systems) for e.g. cheaper accelerator power converters.	Technologies for minimizing power grid interaction (disturbance) by energy intensive industries. Vice versa: Increasing independence of accelerator facilities and energy intensive industry from power grid fluctuations.
Development of a improved **HTS tapes and new s.c. cables** for next generation of fast ramped s.c. magnets.	Application of new HTS tapes in new s.c. cables for s.c. transmission lines or s.c. magnetic energy storage.
Protection of superconducting magnet strings by **DC circuit breakers**.	Protection of superconducting energy systems, e.g. s.c. transmission lines, s.c. magnetic energy storage or photo voltaic energy systems.
Development of diagnostic **technology for detecting defects** (synthetic TDR) in s.c. bus bar systems and in long accelerator cables.	Detection of defects in km long underground power cables.
Control of electrical power of large IT infrastructures in reasearch centers and operation of cryogenic plants	Provision of controlling power/balancing power for damping fast fluctuations in power grids.

DC ciruit breaker for s.c. magnet strings

Task 1.4: Ecological Concepts (DESY, Denise Voelker)

focus 1:

- materials for hightech components of accelerators
- i.e. rare earths for permanent magnets (i.e. Sm_2Co_{17})
- no alternative sources or certified mining and processing available
- industry has same challenge ahead (i.e. wind power stations)
- Idea: combine forces and push for certification system on European/global level

focus 2:

- life cycle thinking
- Specifically deconstruction plays no role in accelerator development
- To lose high level materials like rare earths is not only an ecological but also an economical problem
- Idea: find best practice for recycling of these materials and save a lot of money

Children as young as seven mining cobalt used in smartphones, says Amnesty

Amnesty International says it has traced cobalt used in batteries for household brands to mines in DRC, where children work in life-threatening conditions

▲ A cobalt mine between Lubumbashi and Kolwezi in the Democratic Republic of the Congo. Photograph: Federico Scoppa/AFP/Getty Images

Appendix: Milestones & Deliverables

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification	
MS50	Workshop on energy for sustainable science at research infrastructures, at ESRF	41 - PSI	6	Web site (task 11.1)	10/2021 → spring 2022 (Grenoble green cap.)
MS51	Workshop on efficient RF sources	1 - CERN	13	Web site (task 11.1)	July 2022
MS52	Workshop on efficient magnet- and RF power supplies	2 - ESS	22	Web site (task 11.1)	April 2023
MS53	Workshop on sustainable materials and lifecycle management for accelerators	12 - DESY	18	Web site (task 11.1)	December 2022
MS54	Workshop on industrial approaches for sustainable accelerators	13 - GSI	42	Web site (task 11.1)	December 2024
MS55	Design review	1 - CERN	12	Web site (task 11.2)	June 2022
MS56	Magnets constructed and tested	25 - KYMA	25	Magnetic measurements completed (task 11.3)	July 2023

Deliverables related to WP11	
D11.1: Sustainable Accelerators Report. *Report on strategies to improve sustainability and reduce environmental impact of accelerators.*	M45
D11.2: Klystron prototype completed and validated. *Report on the construction of the klystron prototype and on the test results.*	M36
D11.3: Prototype adjustable PM quadrupole and combined function magnets. *Two prototype PM-based magnets – one quadrupole and one combined-function magnet – designed, built and measured.*	M28