Beam transfer lines for Run2c

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Project milestones

2021 C&S review milestones:

- Technical feasibility of noise reduction on TT40/41 power converters OK
- Assessment of the performance reach wrt specifications of TLs OK
- Start procurement/construction of magnets and PC NOT DONE
  - Need to freeze specifications and ensure compatibility with available space OK (Unless we change energy)
- Installation of 150 MeV new electron line LS4
- Installation of 18 MeV refurbished electron line LS4
- Commissioning of HE electron line 2028
- Commissioning of LE electron line 2028
- Commissioning of proton line 2028

2. Electron line PC specifictions

Strategy

Powering requirement

- 2 Dipoles circuits (unipolar converters),
- 8 Quadrupoles circuits (unipolar converters),
- 6 Sextupoles circuits (unipolar converters with polarity change),
- 4 Octupoles circuits (unipolar converters with polarity change),
- 10 Correctors (bipolar converters),
- **Total: 30 circuits – DC Mode of operation**
- Magnet characteristics (preliminary studies) provided by TE-MSC (P.Schwarz),
- Precision class: 3 as per proton line,

SY-EPC proposal

- Use of the MEXICO family:
  - ✓ bipolar converters,
  - ✓ Few circuits could potentially require some converters operating in parallel or series,
  - ✓ Uncertainty on DC cabling: final tunnel integration and voltage drop on DC cables are required for validation of the proposal,

- Included in SY-EPC proposal:
  - ✓ Converters and set of recommended spare parts,
  - ✓ FGCEther infrastructure (Gateway, switch, cabling)
  - ✓ Contribution to design effort (synergia with other CONS programs),
  - ✓ Rack internal equipment and any specific work,

Risks

The **specifications provided are very challenging** and the present p+ line is far from it

- With best today's knowledge of instrumentation, power supplies, alignment tolerances, operational procedures, calculations suggest a possible improvement in case 8 key PC would be in Class 3 in terms of ripple (7.5 ppm rms) up to 15% of the p+ pulses delivered to AWAKE will be in specs [the error on this estimation is up to 100% as relies on many assumptions and unknows at this stage]
- ➔ Good chances to get to 33% (including MSE upgrade) (See EPC slide)

Matching of the beam size at the plasma entrance depends on very accurate alignment of active elements around electron beam

- Quadrupole shunt iterations, dispersion free steering and 6/8poles alignment to be done => it relies on accurate movement of quads and high order lenses. Possible in simulations with realistic errors, but to be seen with the real elements and their errors
- To achieve the requested beam size at the experiments strongly depends on the alignment of the active elements down to 1 um level => possible and done at ATF2 but still rather challenging
- ➔ After kickoff meeting with N. Chritin it looks feasible. To be confirmed by detailed study

Changes in specification < 4 years from start of commissioning will cause shift of possible data for installation, commissioning, spending profiles and start of physics

- We are getting there!

Budget profiles – SY-EPC

SY-EPC ➔ Power converters for 150 MeV electron line SPECIFICATIONS UNCHANGED

➔ Upgrade power converters for TT41 proton line STILL UNDER EVALUATION

Old profiles

	2022	2023	2024	2025	2026	2027	2028	2029	Total
Proton line	20	175	225	45					465
Electron line		25	25	30	490	100			670
Total	20	200	250	75	490	100	0	0	1135

New profiles

	2022	2023	2024	2025	2026	2027	2028	2029	Total
Proton line			245	220					465
Electron line			25	55	490	100			670
	0	0	270	275	490	100	0	0	1135

Main changes are:

- MSE upgrade (not done in 2022, will shift to 2024)
- Provision risk for upgrade of RBI circuits (change filter, 350 kCHF) moved to 2025
- Shift of one year in electron line development budget

Budget profiles – SY-EPC

Possible savings are

New profiles

	2022	2023	2024	2025	2026	2027	2028	2029	Total
Proton line			245	220					465
Electron line			25	55	490	100			670
Total	0	0	270	275	490	100	0	0	1135
Savings			-195	-175					-370
	0	0	75	100	490	100	0	0	765

Source of savings

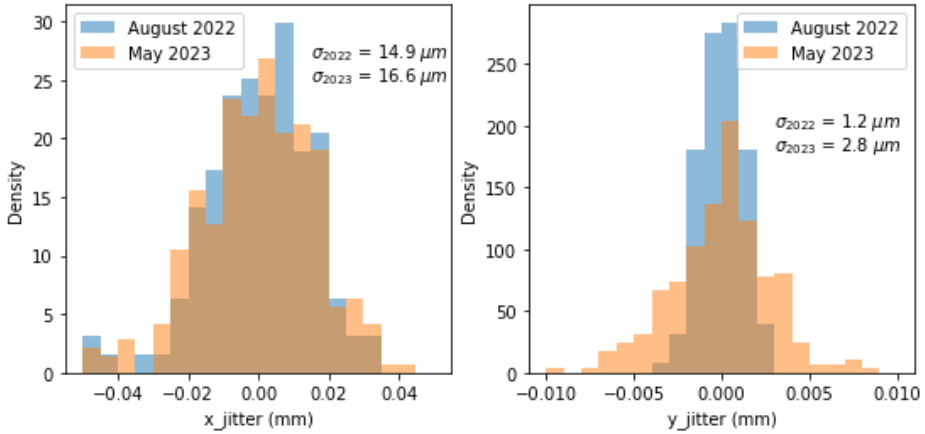
- Filter change in RBI circuits are to be confirmed. EPC would prefer not to di it. Thanks to recabling on RBI.410010 (2023) the ripple should be improved. If it is enough, **AWAKE could save 350 kCHF.** Very important to check this. The 350 kCHF are still to be considered as a risk provision.
- MSE upgrade probably not necessary. Intervention by EPC allowed to reduce the ripple by a factor 2/3. To be checked.

MEASURMENTS NEEDED TO ASSESS EFFECT OF INTERVENTION ON PROTON BEAM

Preliminary analysis on proton jitter

Bad news

Comparing jitter measured in August 2022 and May 2023 no differences were observed in beam jitter:



Scaled values at focus

$\sigma_{x,2022} = 13.96\ \mu m$

$\sigma_{x,2023} = 15.56\ \mu m$

$\sigma_{y,2022} = 1.13\ \mu m$

$\sigma_{y,2023} = 2.64\ \mu m$

Good news

The beam jitter at the focal point is much lower than what described in https://arxiv.org/pdf/2109.12893.pdf

$$\sigma_{x,ref} = 41 \mu m$$

$$\sigma_{y,ref} = 8\ \mu m$$

Outcome

Check in simulation what is the number of good shots assuming the measured jitter to evaluate the need for the upgrade.

Budget profiles – TE

TE-MME ➔ Magnets for 150 MeV electron line SPECIFICATIONS UNCHANGED

		2023	2024	2025	2026	2027	Total
Old profiles	electron line	170	326	357.5	63	20	936.5
New profiles	electron line	0	289	560.5	67	20	936.5
	Savings	0	-39	-100	-2		-141
		0	250	460.5	65	20	795.5

Main changes:

- Shifted one year

Source of savings:

- Sextupoles are available at CERN for free. Apparently, they match the line requirements.
- Further savings may be possible **if quads and dipole are also found** (work in progress) ➔ Maybe other institutes?

Simulations with new sextupoles

Studied effects of including existing sextupoles:

	Bore Ø [mm]	Gradient [T/m²]	Magn. Length [m]	Int. gradient [T/m]	Usable spares	Water cooling required?
PXMXNAANWC	108	180	0.1	18	8	Yes
PXMXNABNWP	108	180	0.1	18	8	Yes
PXMXNBAFWP	135	256	0.195	50	7	Yes

Comparing with design specs

Magnet	Label	Int. field strength			Length [m]	Central field strength			Bore diam. CHOSEN [mm]	Field at pole tip [T]		Gradient [T/m]	
		MIN	MAX	*Units*		MIN	MAX	*Units*		MIN	MAX	MIN	MAX
Sextupole design	s_1	2	60	T/m	0.2	3	100	T/m2	70	0.000333	0.01	0.005	0.14
Sextupole option 1	s_1	2	18	T/m	0.1	7	180	T/m2	108	0.010667	0.288	0.099	2.67
Sextupole option 2	s_1	2	50	T/m	0.195	10	250	T/m2	135	0.01225	0.30625	0.091	2.27
Optics design max	s_1						47	T/m2					

The proposed sextupoles should be ok!

Budget profiles – TE

TE-VSC ➔ Proton line/electron lines/laser/plasma source

		2022	2023	2024	2025	2026	2027	2028	Total
Old profiles	Full project	10	594	881	1070	505	25		3084
New profiles	Full project	0	0	10	594	881	1070	505	3084

Main changes:

- Shifted one year

Summary and next steps

Power converters:

- Confirmed specifications for electron line PC
- Still need to investigate if measured beam jitter is good enough for Run2c

Magnets:

- Confirmed requirements for dipoles, quadrupoles and octupoles
- We could use existing sextupoles
- Is it possible to keep an open design option for the dipoles? Specifications could change…

Vacuum:

- No changes w.r.t to original specifications

- It is now the time to start design and procurement!