A Cryomodule for PERLE

Frank Gerigk, CERN,
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Material from:

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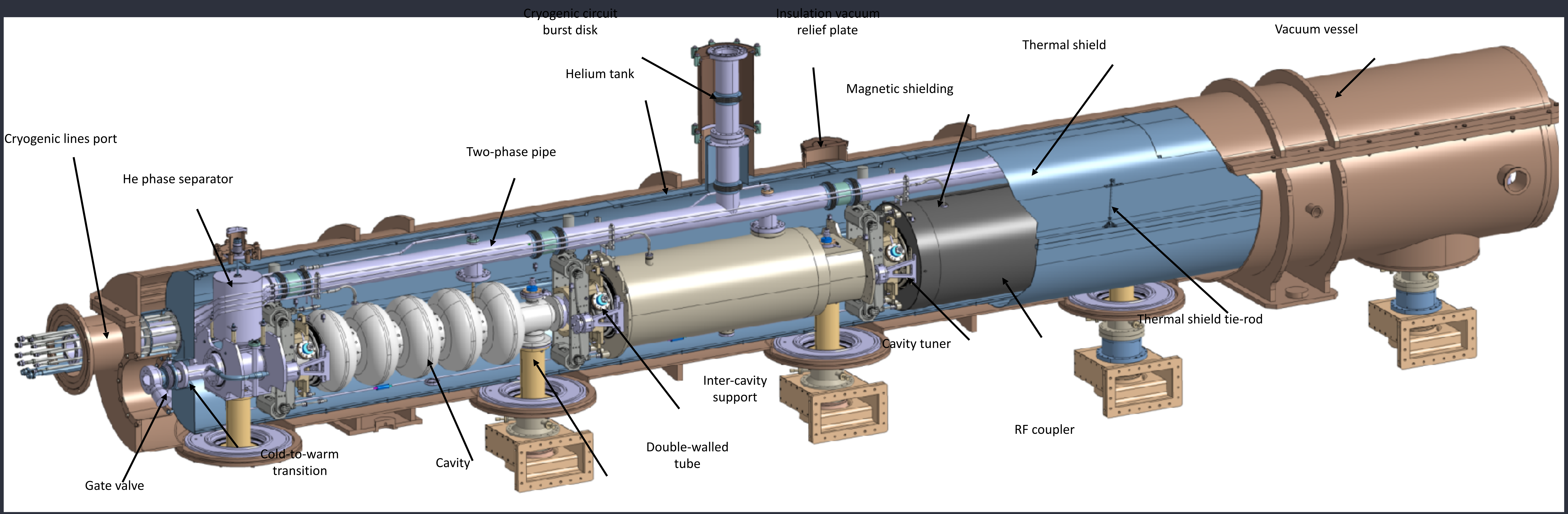
… and probably more

Content

History of the High-Gradient CM

2000	First ideas for a SC Proton Linac (SPL) at CERN (re-using LEP SC cavities), CERN 2000-012
2006	2nd SPL conceptual design report (bulk Nb 5-cell cavities), CERN-2006-006
12/2007	Council approval for “new initiatives”: preparation of a SPL technical design report and cost estimate.
12/2008	1st SPL collaboration meeting: **need to build SC Nb cavities and upgrade SM18 infrastructure** (clean rooms, 704 MHz RF, vertical bunkers, etc.), ground breaking of Linac4,
2009	•SPL & Linac4 are part of sLHC •ESS will be build in Lund •ESS/SPL looking for synergy and cost sharing, planning for an 8-cavity cryo module at CERN to transform XFEL/TESLA technology to 704 MHz and to demonstrate 25 MV/m @ $Q>10^{10}$, start of infrastructure upgrade at CERN, start of coupler work
2010	Decision not to build SPL but to upgrade existing injectors. However: build a 4-cavity R&D cryomodule as an R&D program with the goals: i) to preserve potential for alternative physics programs, ii) preserve possibility of new injectors for the long term, iii) update CERN competences in SRF

Four cavity cryomodule

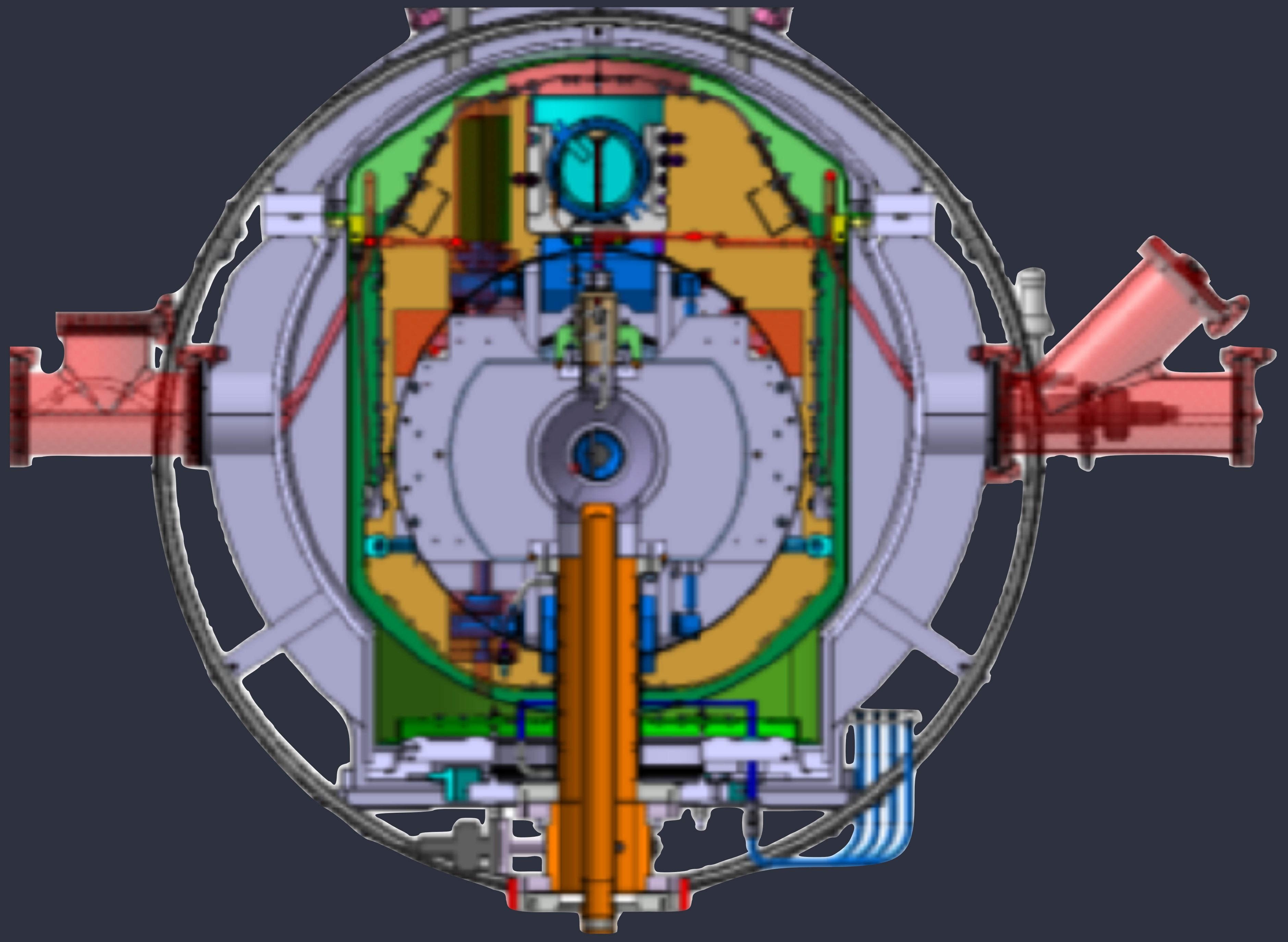


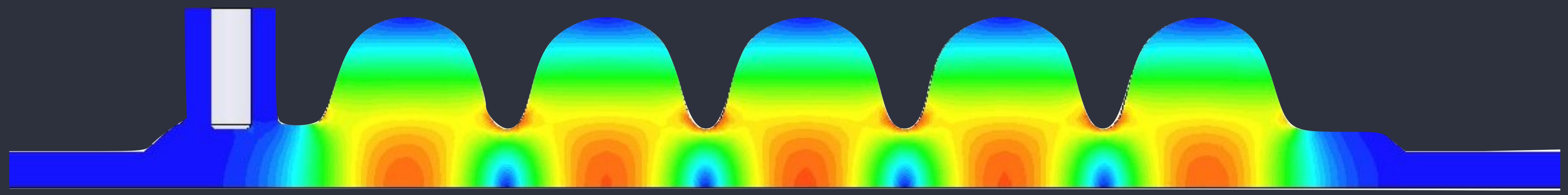
Strong support by ESS (fellows, klystron modulator, …) and CNRS (integration drawings & vacuum vessel). Present development fully under CERN control.

Cavity parameters

from SPL conceptual design report

frequency	704.4 MHz
number of cells	5
nominal gradient	25 MV/m
field flatness ΔV/V	< ± 2.5%
quality factor at nom. gradient	10^{10}
active length	1.065 m
cell-to-cell coupling	1.92%
min iris diameter	129 mm
R/Q	566 Ω
E_{peak}/E_{acc}	2.0
B_{peak}/E_{acc}	4.2 mT/MV/m
geometry factor	270 Ω
tuning range	± 300 kHz
Δf/ΔL	164 KHz/mm
Lorentz force detuning constant	-1 Hz/(MV/m)^2
number of HOM couplers	2





HG cavities and other proposals

from PERLE design report

	JLAB1	JLAB2	CERN1	CERN2	HG	HG-doped
frequency [MHz]	802	802	801.58	801.58	**704.4**	**704.4**
number of cells	5	5	5	5	5	5
active length [mm]	922	918	935	935	1064	1064
gradient [MV/m]	20.28	20.37	20.00	20.00	17.58	17.58
voltage [MV]	**18.7**	**18.7**	**18.7**	**18.7**	**18.7**	**18.7**
E_p [MV/m]	42	46.1	45.1	48	35.15	35.15
B_p [mT]	81.1	85.5	95.3	98.3	73.9	73.9
power [kW]	50	50	50	50	50	50
Iris [mm]	115	130	150	160	129	129
Assumed Q [10^{10}]	2	2	2	2	**1**	**2**
R/Q / cavity	583	524	430	393	566	566
cell2cell coupling [%]	2.14	3.21	4.47	5.75	1.92	1.92
Dynamic load @ 2K/cavity	35.28	39.59	46.51	50.89	54.57	27.29
assumed static loss [W]	30	30	30	30	30	30
Total module loss [W]	171.12	188.38	216.05	233.56	248.29	139.15

not ideal but feasible

Innovations/developments

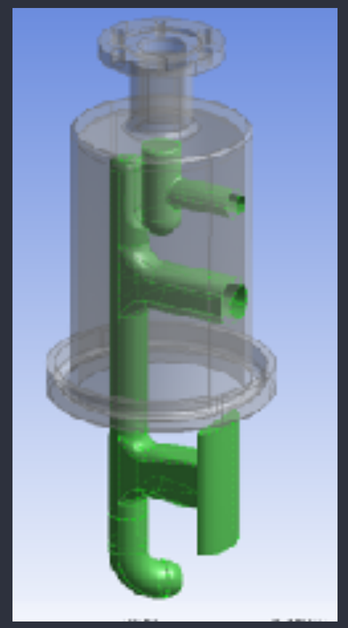
over almost 10 years

Successful development and application of **vertical Electropolishing**. Unique facility worldwide (Leonel Ferreira)

Successful mock-up test of **Cavity support via power couplers**. (Rossana Bonomi, Wojciech Zak, Vittorio Parma)

Optimised set-up for **High Pressure Water Rinsing** (A. Macpherson, K. Hernandez Chahin)

Development of cavity shaping via **Electro-Hydro-Forming**. (Said Atieh, Elisa Cantergiani)



Development of **Higher Order Mode Suppressors (HOMS)** for proton linac (Kai Papke).

Coaxial type

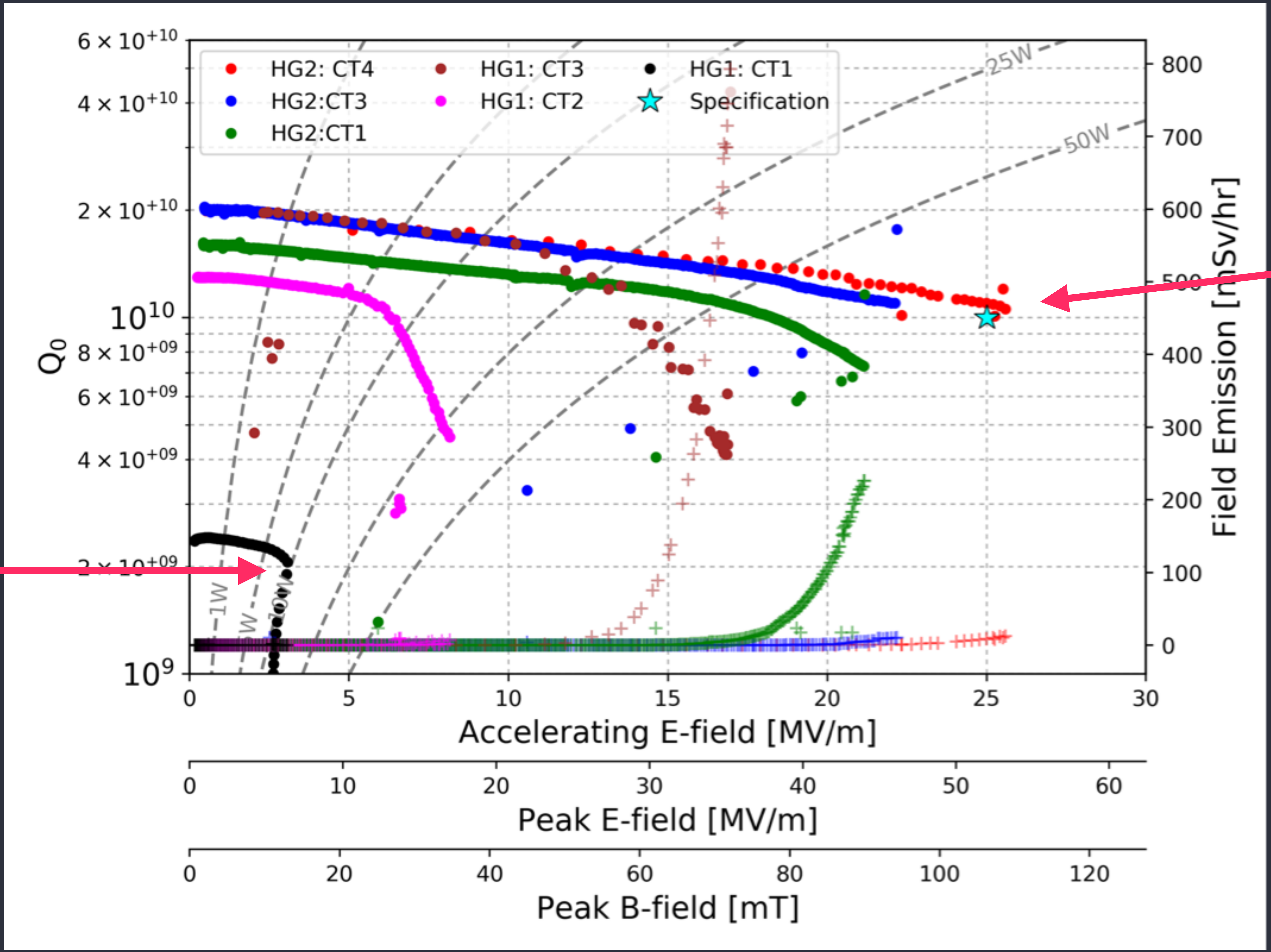
Disc type

Development of 2 **Fundamental Power Couplers**. Disc type is more robust, 3d generation under development (Eric Montesinos)

Cold test results

A. Macpherson, K. Turaj, A. Castilla, K. Hernandez Chahin

Evolution over 10 separate cold tests



September 2014

May 2017

First cavity @25 MV/m with Q>10^{10}

➜ Bulk Nb testing re-established at CERN

Existing components:

- 4 cavities + tuners fabricated. 5th cavity under fabrication by MME.
- Vertical Electropolishing is developed and done on 3 cavities.
- First cavity has reached nominal specs (25 MV/m @ $Q>10^{10}$).
- Vacuum vessel procured.
- 4 fundamental power couplers ready, 3d generation of couplers under development.
- Procurement of magnetic (cold + warm) and thermal shields started.
- HOM suppressors under fabrication. (adapted to SPL requirements)

possible timeline to complete 704 MHz

Cryostating can only start once the SM18 extension is available (late 2018/2019).

<table>
<tr><th colspan="3">2017</th><th colspan="4">2018</th><th colspan="4">2019</th></tr>
<tr><th>Q2</th><th>Q3</th><th>Q4</th><th>Q1</th><th>Q2</th><th>Q3</th><th>Q4</th><th>Q1</th><th>Q2</th><th>Q3</th><th>Q4</th></tr>
<tr><td colspan="6">Cavity testing & He tank welding, tooling, cryogenic piping, material orders</td><td colspan="5"></td></tr>
<tr><td colspan="5"></td><td colspan="2">clean room string assembly</td><td colspan="4"></td></tr>
<tr><td colspan="6"></td><td colspan="3">cryostating</td><td colspan="2"></td></tr>
<tr><td colspan="8"></td><td>SM18 shut down</td><td colspan="2">cold testing</td></tr>
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Cryomodule costing

Luca Dassa (MME)

R&D investment: design, procurement, assembly of existing module

Includes:
- 4 power couplers and 2 HOMS per cavity,
- copper models, Nb mono-cell, forming tests with electro-hydro-forming
- tuning machine,
- tools for: welding, clean room, chemistry, cathodes
- design office, drawings, manpower for assembly

5.6 MCHF

Scenario 1: stay with 704 MHz: procurement & assembly of one more module

Includes:
- material, production, HOMS, FPCs, tuners, assembly
- without R&D

price of a ESS high-beta 4-cavity module: **3.2 M€** (series of 21)

3.2 MCHF

Scenario 2: install 800 MHz cavities instead of 704 MHz (additional cost)

Includes:
- new cavity design & drawings, new cavities,
- new insert for cryostating,
- new power couplers and 4 HOMS per cavity
- new cryogenic piping
- replacement of magnetic shielding (worst case)

1.9 MCHF

Scenario 3: install 800 MHz cavities after 704 MHz has been tested (additional cost)

Includes:
- all of scenario 2
- + removal of 704 MHz string

2.2 MCHF

What now?

- The HG cryomodule contains a considerable R&D effort and several innovative approaches. It is an R&D object that has no operational future at CERN.
- CERN management needs to decide wether they want to contribute this module to PERLE.
- PERLE needs to decide if they want it. Is there a timeline?
- Do we need to change to 800 MHz? In that case we need ~1.9 MCHF (includes cavities) to do that.
- CERN has an interest to use 800 MHz, but again there is a funding question.
- The 704 MHz cavities only have 2 HOMS, can the ERL beam dynamics survive? can a new HOMS design do the trick? or will this be one of the reasons to go to 800 MHz.
  ➡ someone has to do a HOM study for PERLE
- CERN has modulator and klystron (1 MW) for a high-power pulsed test at 704 MHz, for 800 MHz pulsed a new klystron, circulator, waveguides, RF loads would be needed. Alternatively use IOTs or solid state.

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THANKS

FOR

Listening