DE LA RECHERCHE À L'INDUSTRIE

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Recent results on single cell 704MHz cavity

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TTC2022 Aomori

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Outline

- **Motivation** (from R&D to ESS)
- **704MHz cavity program at CEA**
  - **Vertical electropolishing (VEP)**
- **704MHz Single cell**
  - **VEP results**
  - **Vertical test results**
- **Outlook**
  - **Single cell**
  - **5-cells** (high beta ESS)

MOTIVATION AND 704MHZ “HISTORY”

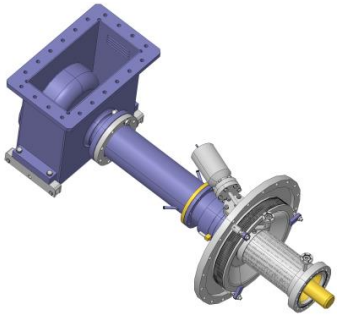
Motivation for recent studies:

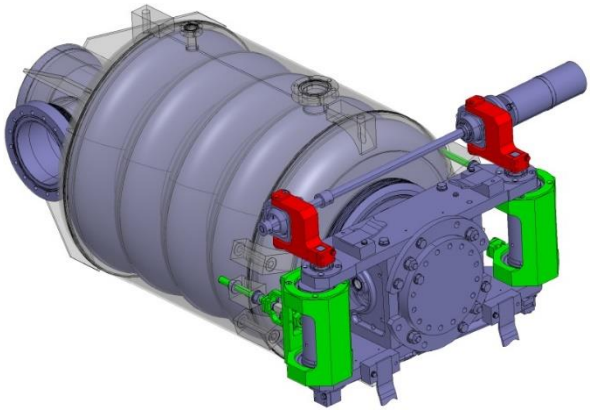
We have a long R&D history with 704MHz cavity that lead us to ESS prototypes and series, we now want to pursue further topics:

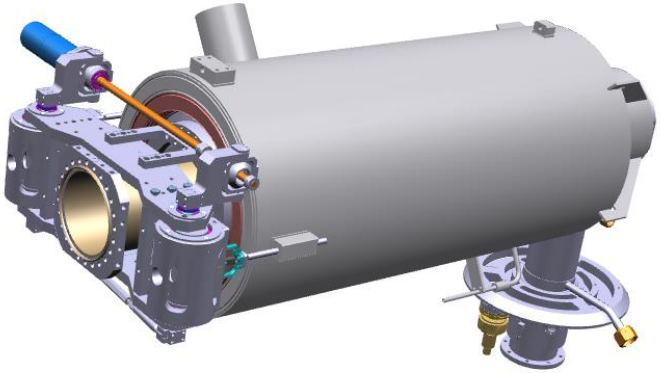
- Improving the performance of 704MHz resonators for future applications
- Study improvements of Vertical electropolishing with respect to standard BCP
- Investigate the effect of different thermal treatments

Timeline:

ESS-CONCERT	ASH (β=0.65)	HIPPI (β=0.45)	HIPPI-SPL (β=0.47)	SPL(β=1)	**ESS (β=0.67 and 0.86)**	ESS proto/series
2000-2001	2002	2002	2005	2009	**2009**	2015-2020







704 MHZ LINAC PROGRAM (SPL→ESS)

EUROPEAN SPALLATION SOURCE

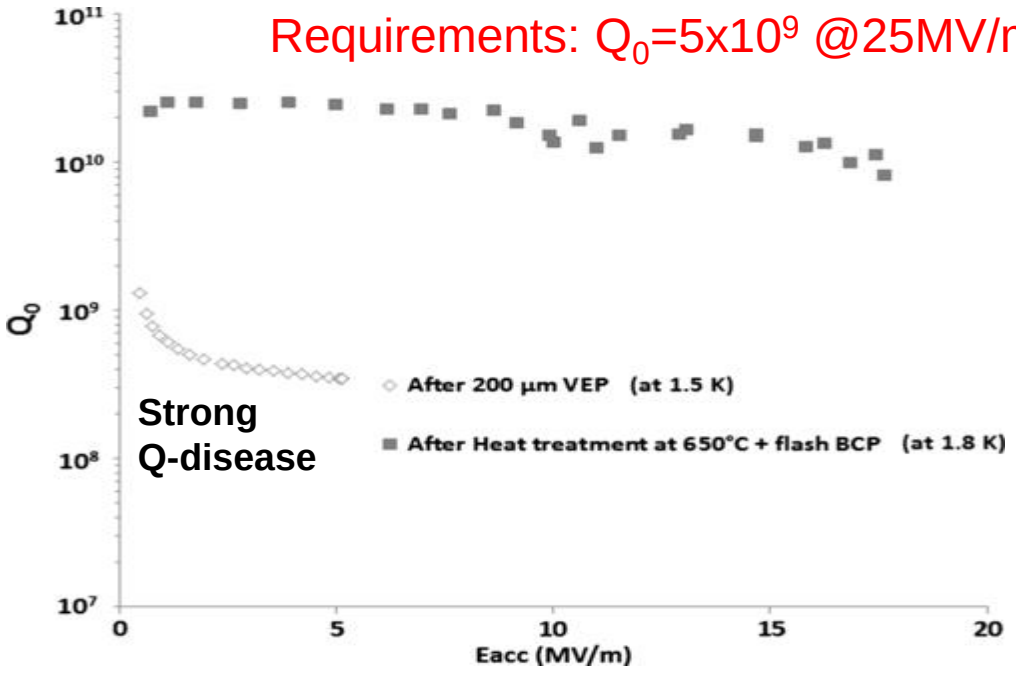
At CEA we were in charge of cavity, coupler design and preparation recipe validation. Procurement of all components but cavities, integration of 32 cryomodules. Power test on 6 CM

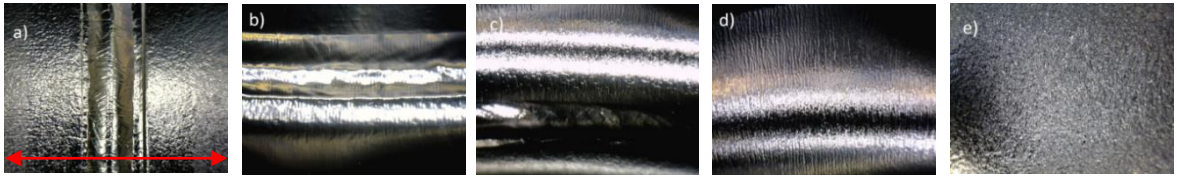
Treatment of β=1 SPL Cavity (2014) (EuCard): Vertical Electropolishing (VEP) with fixed cathode

Treatment of ESS proto M-beta (2016): Standard 'BCP' Chemical polishing

VEP FIRST TRIALS (2014)

Requirements: Q_0=5x10^9 @25MV/m ☹





~20mm

*Phys. Rev. ST Accel. Beams **17**, 083501*

IMPROVEMENT OF HYDROGEN EVACUATION AND ACID CIRCULATION IN THE CELLS ARE MANDATORY

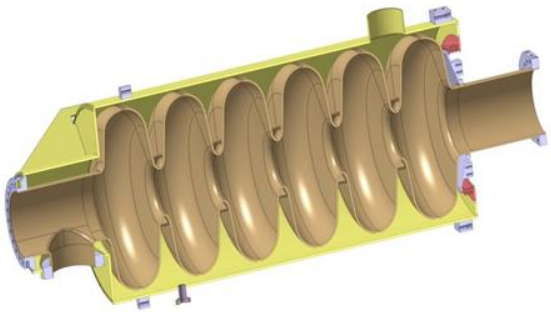
Typical surface morphologies after >100µm VEP at different locations.
- The weldings at a) equators, and b) irises are smooth.
- Bubbles stripes are observed at the proximity of irises c) and d).
- In the areas between equators and irises e) the surface is rougher.

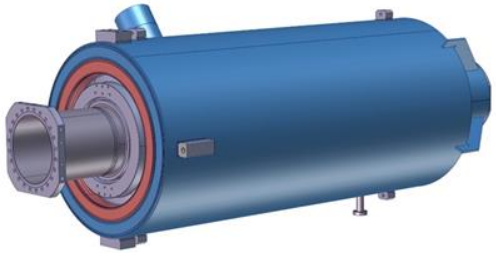
ESS BASELINE WITH BCP

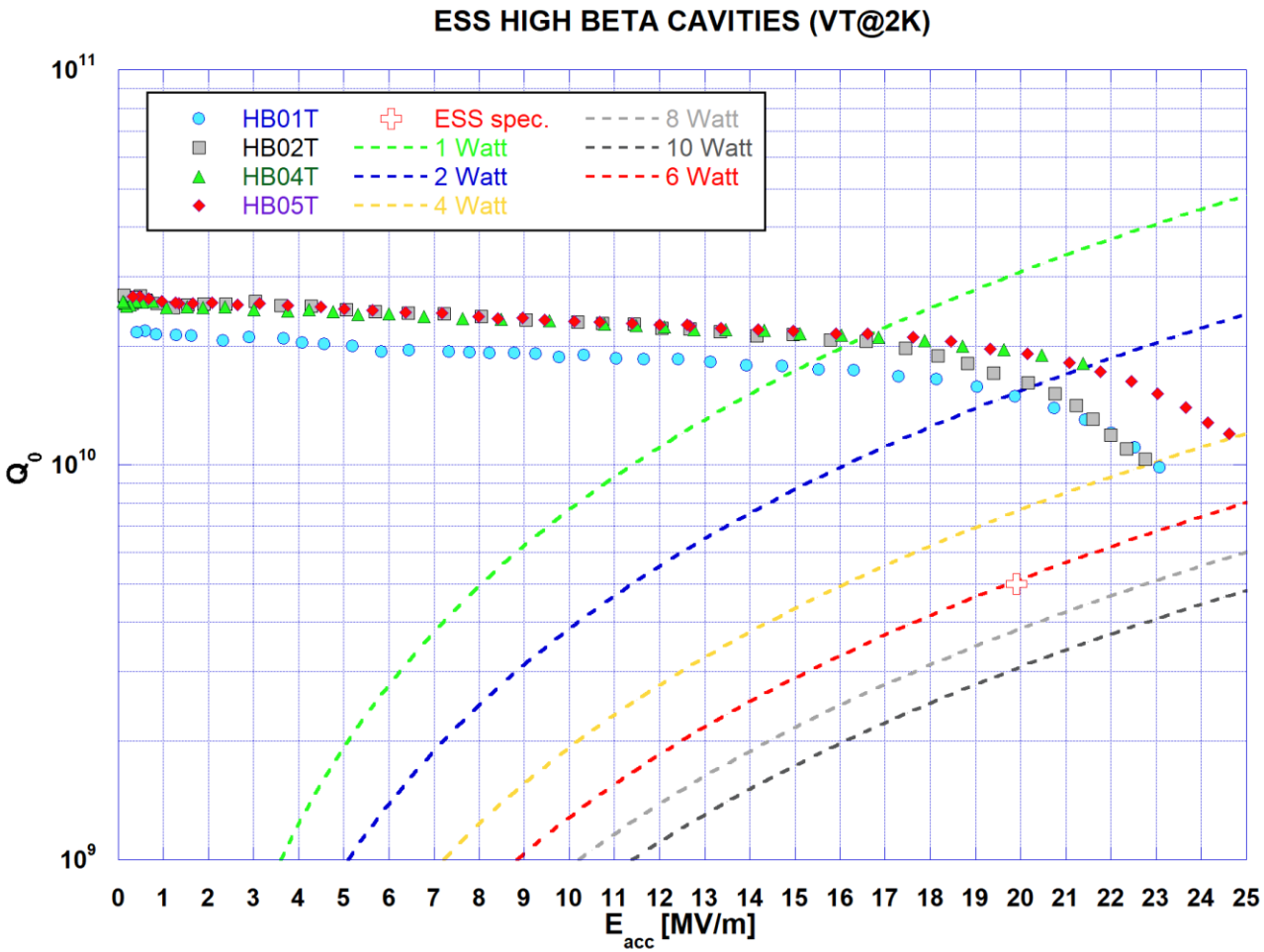
Baseline recipe for ESS prototypes cavities

- Bulk BCP ~200µm (15°C)
- Heat treatment @650°C x 10hours
- Final BCP ~20µm (15°C)

E_{acc} +10-20% w.r.t. Specification
Q_0 x3 w.r.t. Specification





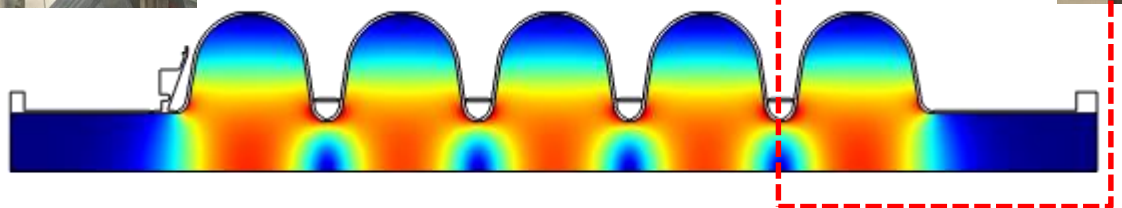


Cavity design

Single cell cavity, geometry from **ESS** high beta (β=0.86) end cell

Design parameters	Value
G [Ω]	250
R/Q [Ω]	113
E_{pk}/E_{acc}	1.88
B_{pk}/E_{acc} [mT/(MV/m)]	3.86
Inner surface [m²]	0.55
Nb RRR	>300
Nb Supplier	Tokyo Denkai
Cavity manufacturer	Zanon R&I

Beam tube extension

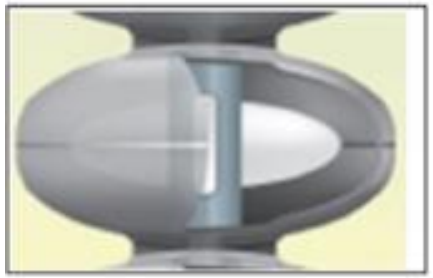


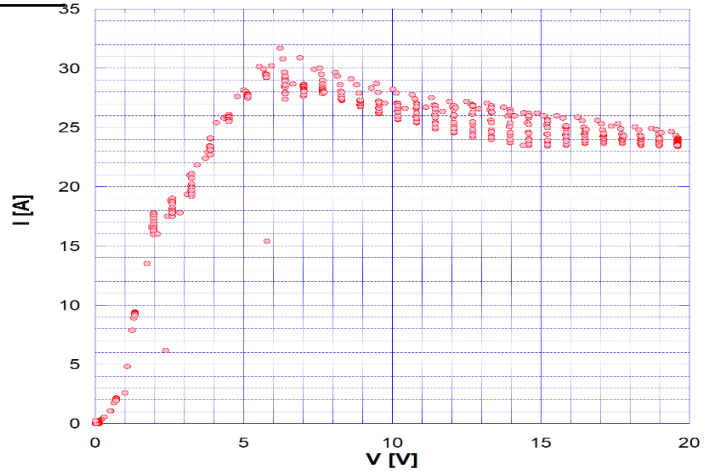
CATHODE DEVELOPMENT (→NINJA CATHODE)

Polishing Parameters	Value
Acid temperature (tank)	<15°C
External cooling water temperature	<12°C
Acid flow	15-20 l/min
Acid Volume	200 l
Voltage	19-20 V
Current	25 A
Removal rate	0.1 µm/min
Electrolyte mixture	HF-H_2SO_4
HF mass concentration	0.5%
Ethanol rinsing (static)	60 h

Ninja Cathode Parameters	Value
Number of wings	4
Al cylinder diameter	70 mm
Cathode rotation speed	20 rpm
PVC external cylinder diameter	114 mm
Cavity surface	0.55 m²
Cathode/cell surface ratio	0.2

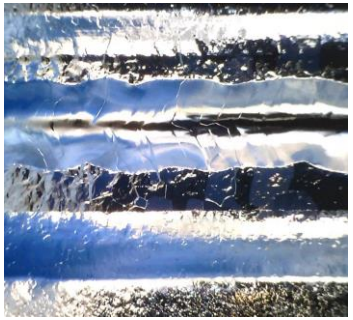
ROTATING TECHNOLOGY
'Ninja' Cathode

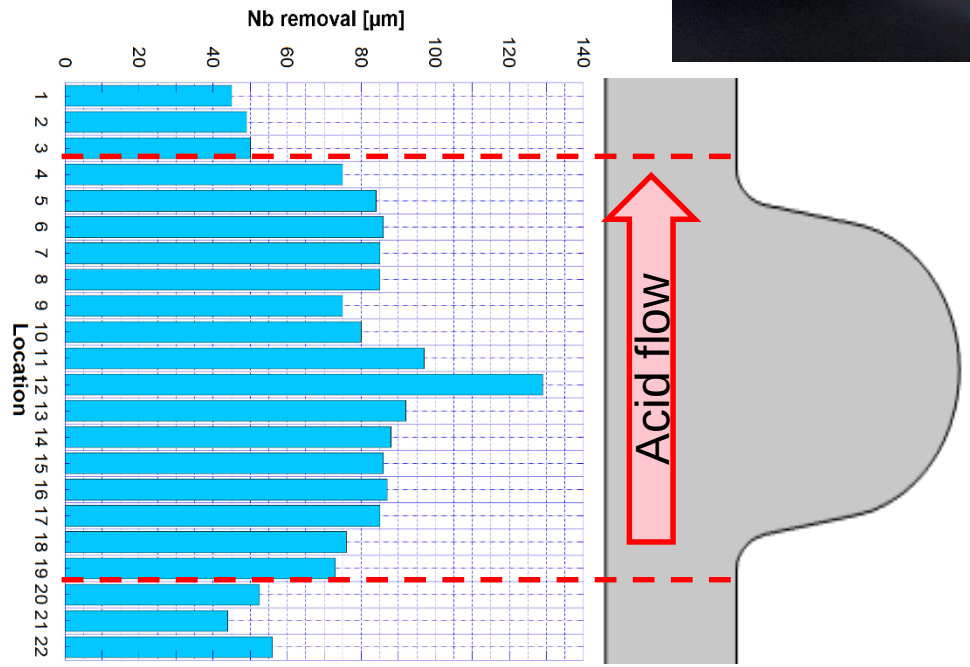




FJPPL
France-Japan Particle Physics Laboratory collaboration

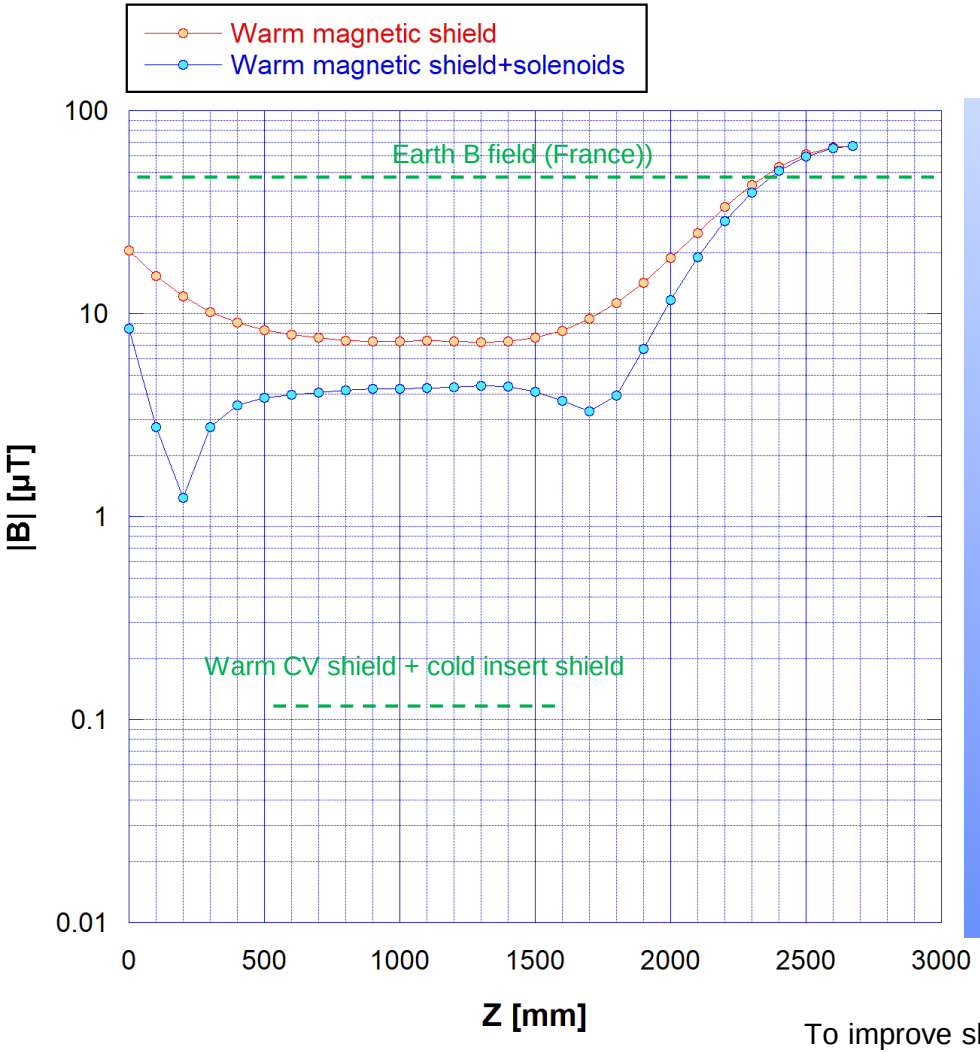
Removal	µm
Average	76.3
Max	129
Min	44
Average BT	49.4
Average cell	86.4
Max/min cell	*1.76*

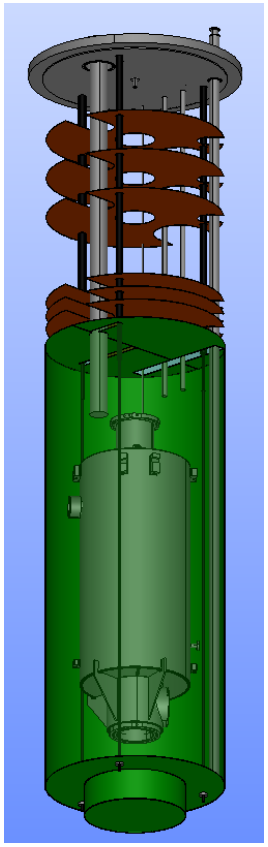


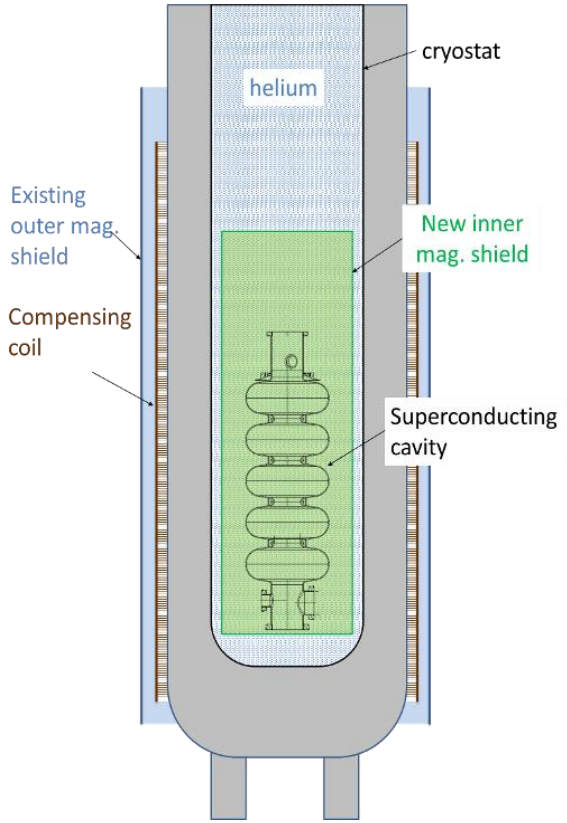


VERTICAL TEST SETUP

COLD MAGNETIC SHIELDING

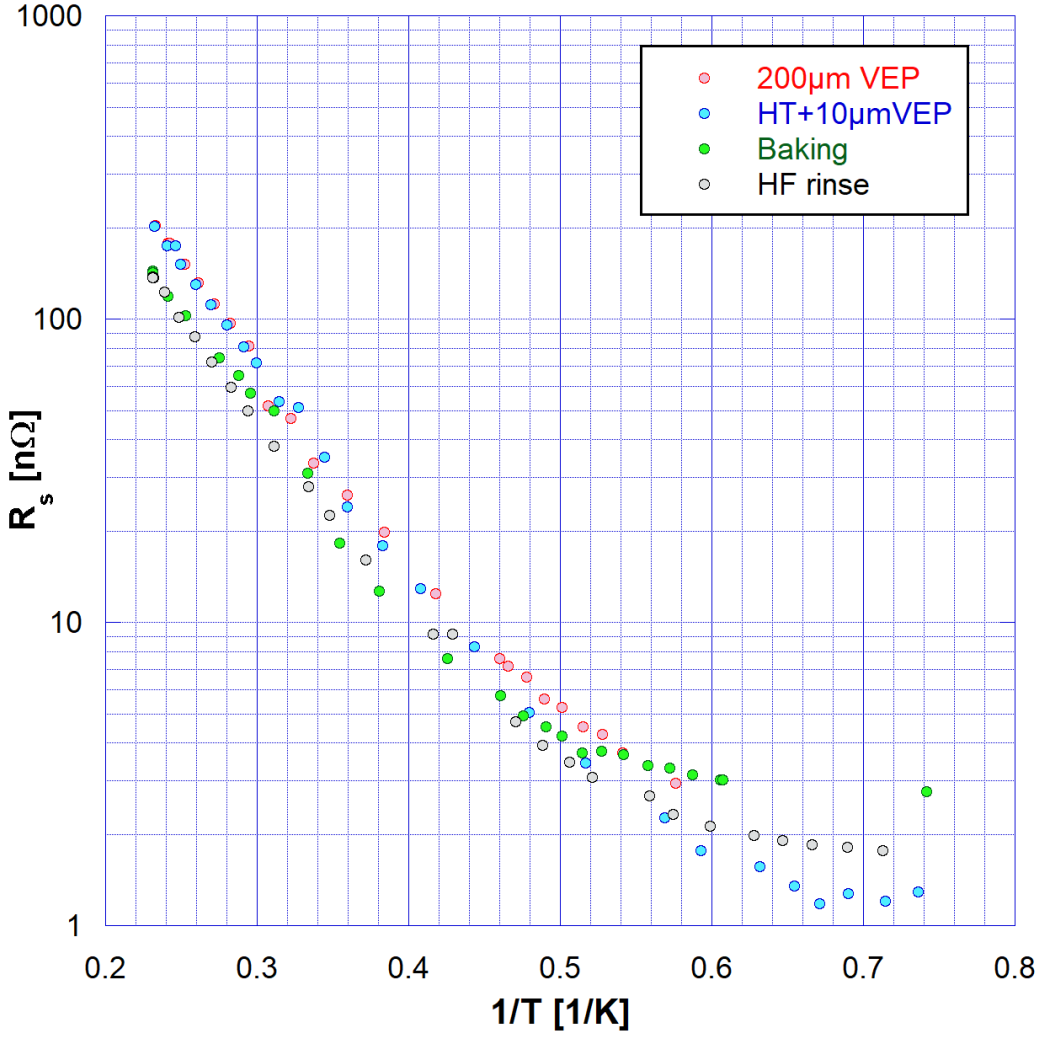






To improve shielding, a cold 2mm CryoPhi shield is added around the cavity on the insert -> allows to have way less then 1 µT remnant field (typically 0.1 µT = 1 mG)

Surface resistance with respect to temperature @1MV/m



Cavity preparation baseline:

- 200µm bulk VEP*
- HT 650°C x 10h+10µm flash VEP*
- Baking 120°C x 48h
- HF rinse

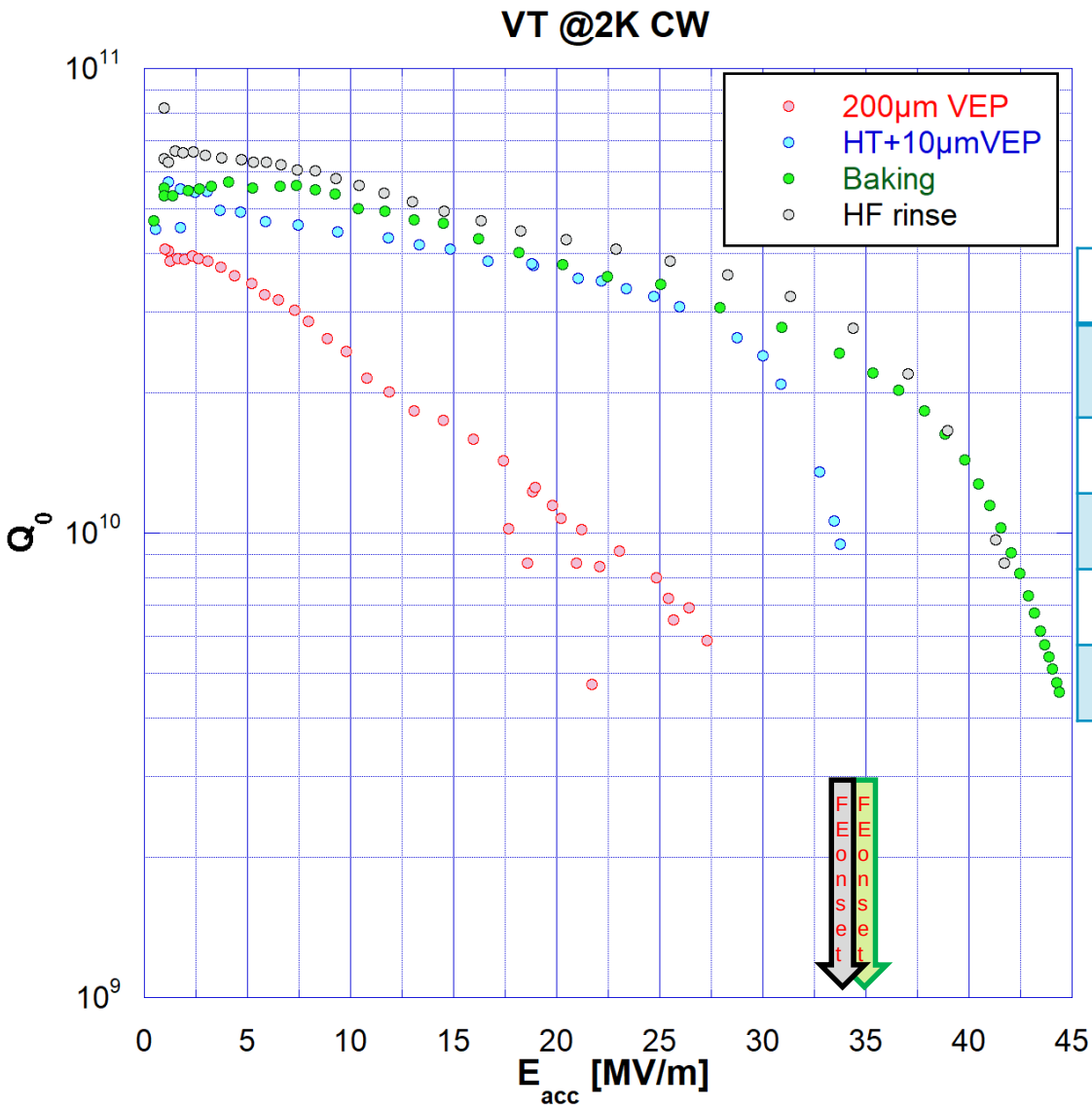
**all VEP performed below 15°C*

	Bulk EP	HT+EP	Baking	HF rinse
R_0 [nΩ]	2.38	1.2	1.36	1.79
Δ [K]	18.94	18.84	20.02	18.96
Eg [meV]	1.63	1.62	1.73	1.63

Fitted with

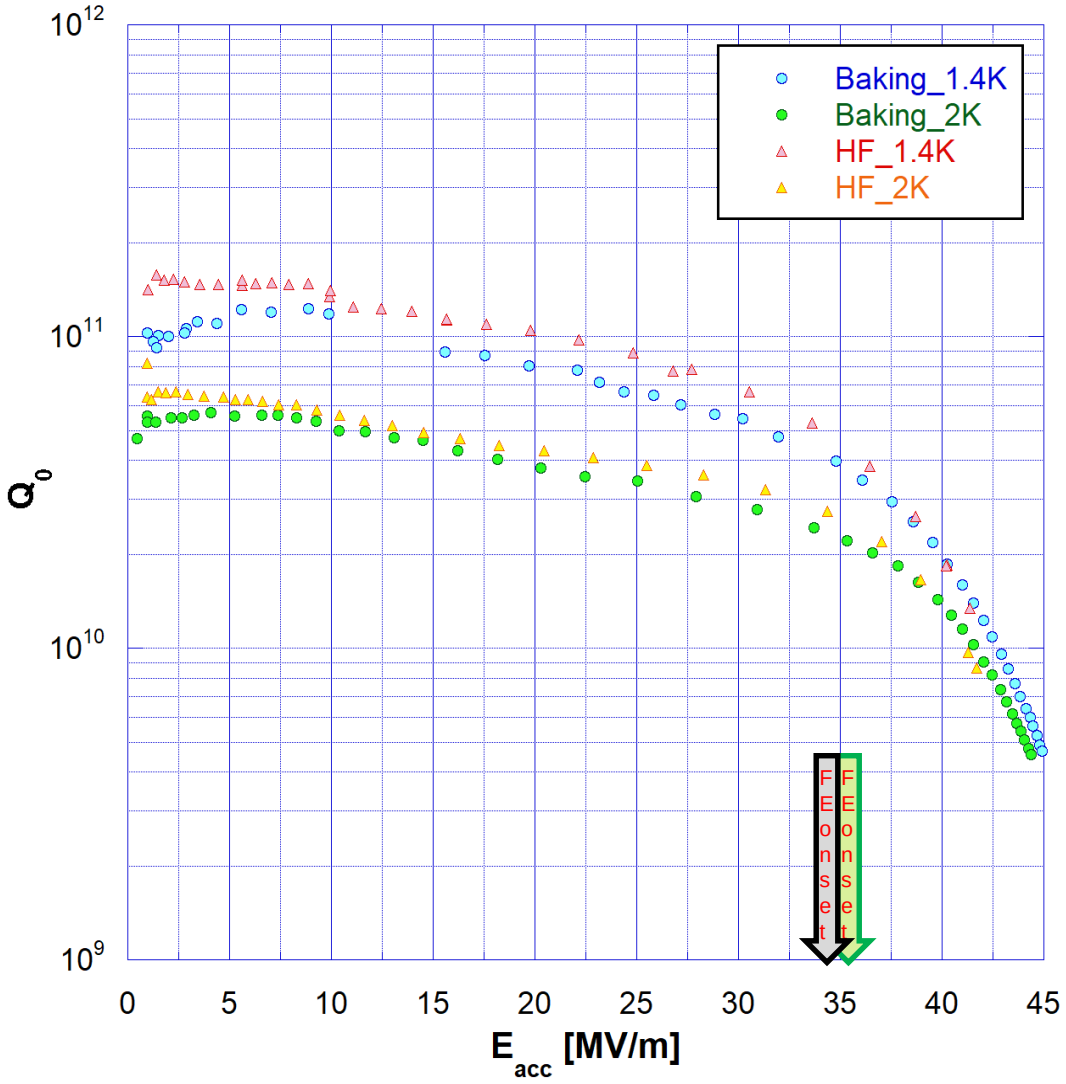
$$R_S = \frac{A}{T} \times e^{-\frac{\Delta}{T}} + R_0$$

VERTICAL TESTS “HISTORY”



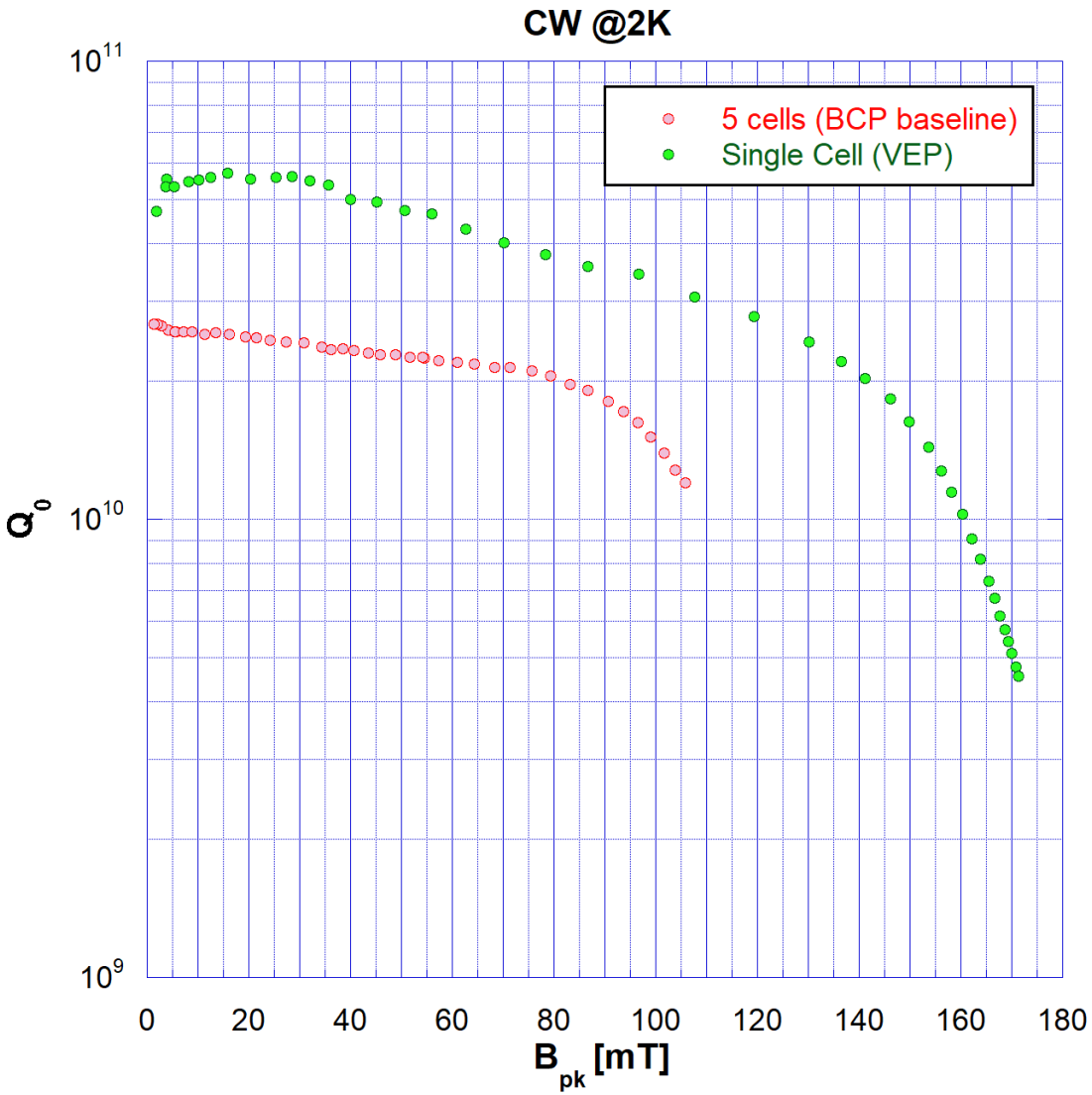
CW@2K				
VT#	Max E_{acc} [MV/m]	Max Q_0 [/10^{10}]	E_{acc} @10^{10} [MV/m]	Limit
1	27.3	4.09	20.2	Quench
2	33.8	5.7	33.5	Admin.
3	**44.4**	**5.7**	**41.5**	**Power**
4	41.7	6.4	41.3	Admin.

LATEST TESTS @1.4K CW



CW@1.4K			
VT#	Max E_{acc} [MV/m]	Max Q_0 [/10^{10}]	Q_0 Max field [/10^{10}]
Baking	**44.9**	**12.3**	**4.7**
HF rinse	41.4	15.7	1.34

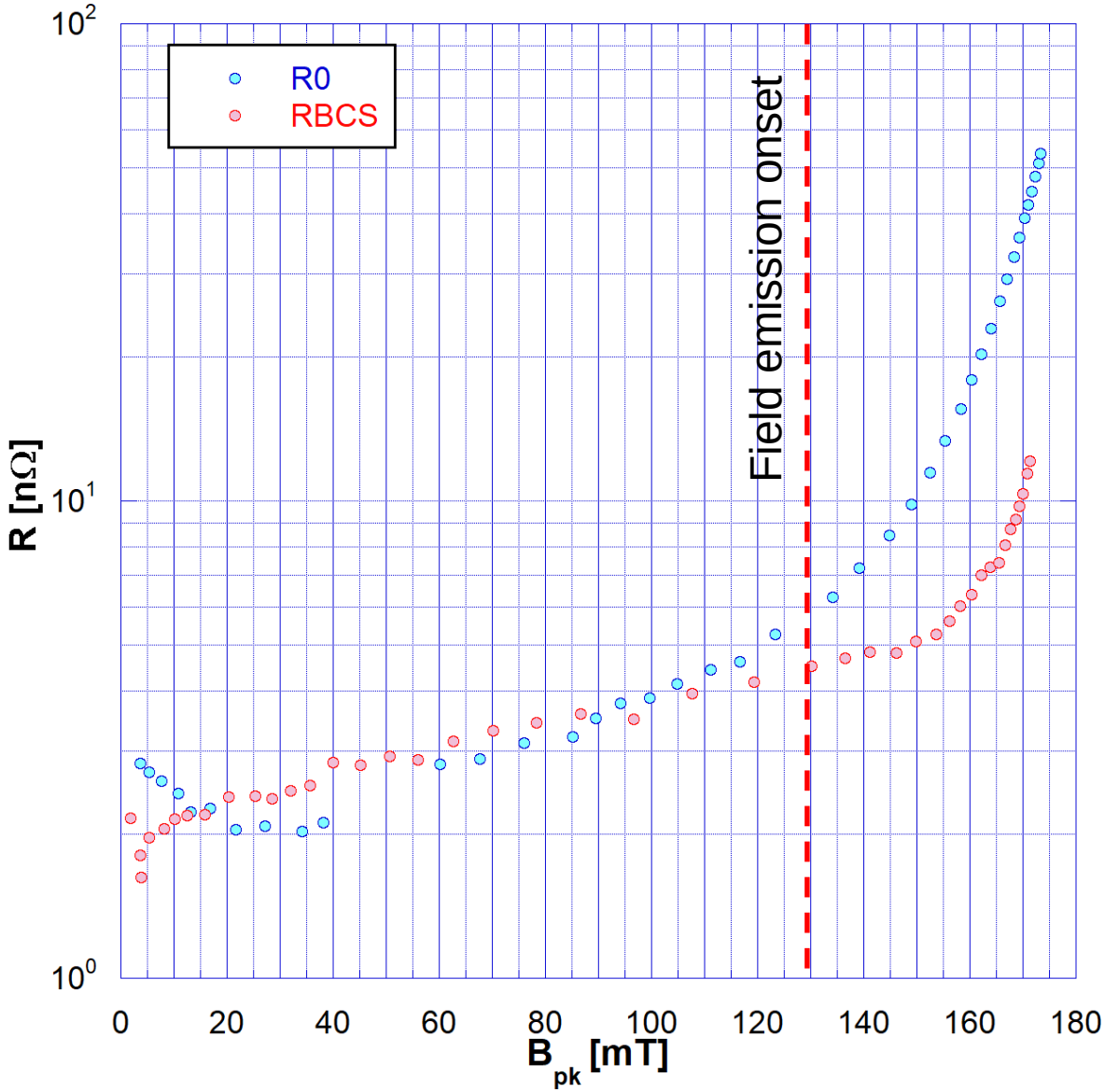
COMPARISON WITH BASELINE BCP

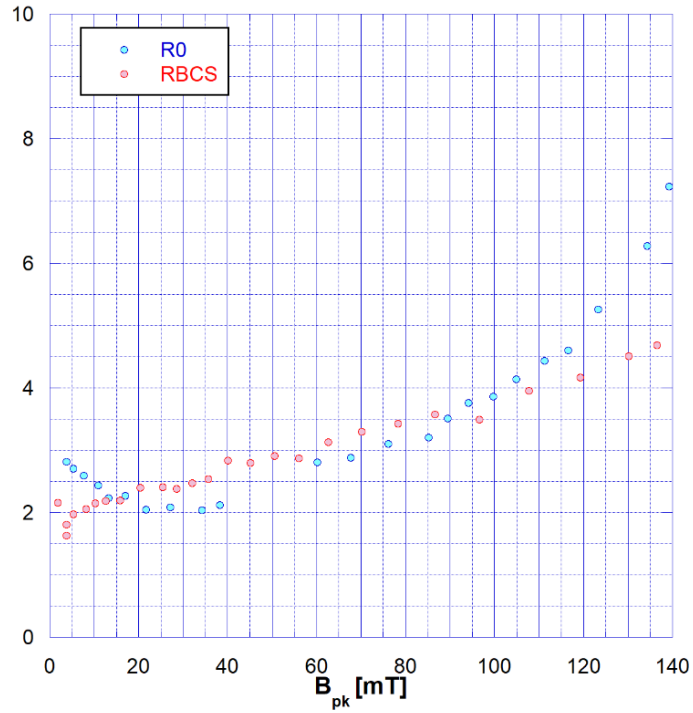


"…With a pinch of salt"

- Single cell has BT extensions
- Magnetic shielding is better for single cell
- Cooling and cooling speed is better for single cell, 5 cells has grater mass and it is tanked

SURFACE RESISTANCE DECOMPOSITION





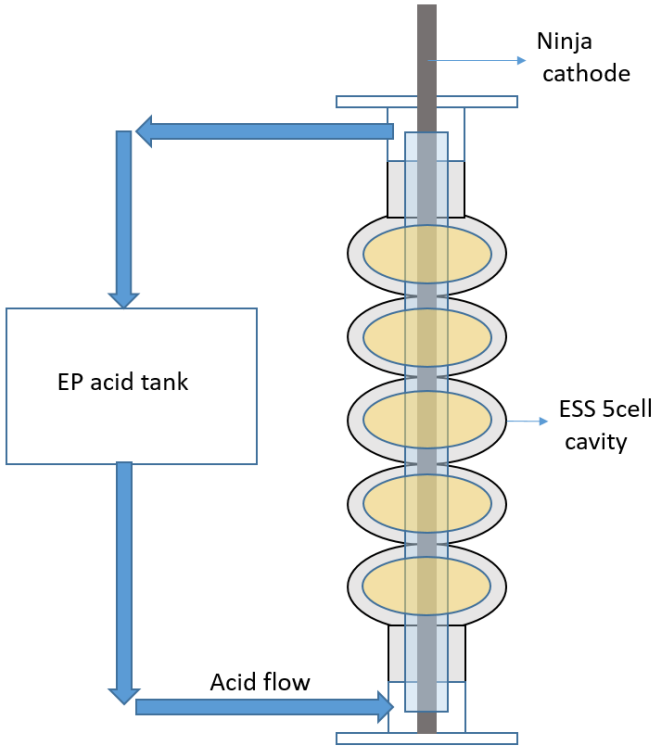
On Single cell follow up studies:

- EP 10-15µm “reset” (VT5)
- Two step baking (VT6)
- Effect of cooling speed (VT6b)

ESS high beta prototype (HBP03) cavity preparation up to now:

- Bulk BCP (200µm)
- Heat treatment
- Flash BCP
- HPR
- Ready for VT and BCP_baseline

VEP for multicell (cathode is ready)



THANK YOU FOR YOUR ATTENTION

Commissariat à l'énergie atomique et aux énergies alternatives
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