LHC Injectors Upgrade

New Baseline Design for the H^0/H^- Beam Dump

Wim Weterings TE-ABT

Presenting work from: Bruno Balhan; Elena Benedetto; Jan Borburgh; Chiara Bracco; Melanie Delonca; Robert Froeschl; Marco Garlache; Brennan Goddard; Jan Hansen; Klaus Hanke; Cesare Maglioni; Bettina Mikulec; Antony Newborough; Alexandre Ouzia; Benoit Riffaud; Federico Roncarolo; Laurent Zucalli; Francesca Zocca

Introduction

The ISSUE:

- Low Z material initially specified for RP considerations;
- SiC was selected;
- Problems with swelling and risk of breaking;
- Estimates are 1-2 years lifetime, before preventive maintenance is needed;
- Goal to have a 4 year operational lifetime to match LHC cycle;

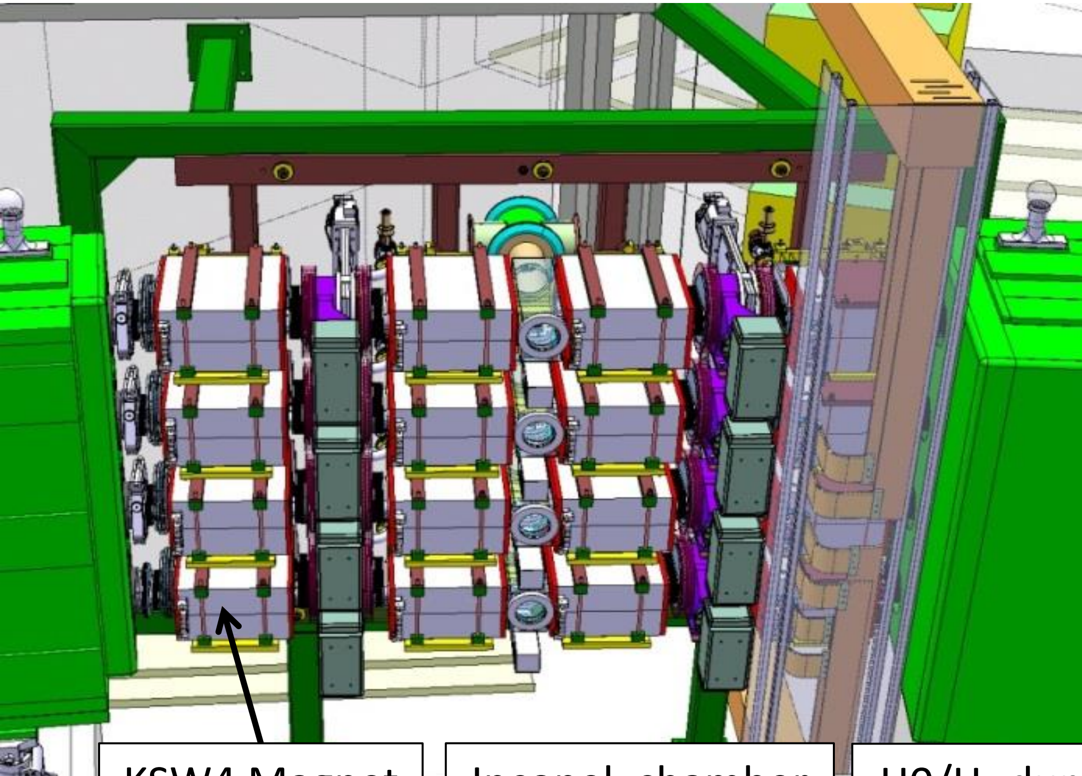
Friday Morning PBU Injection Meeting:

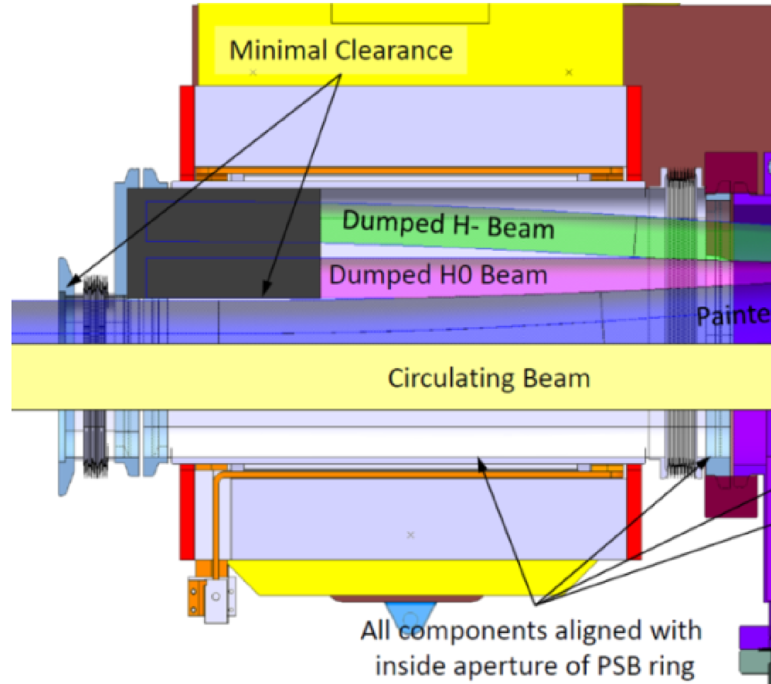
➢ **Proposal for external metallic dump, using Titanium, but some potential issues to solve….**

PSB Upgrade
LIU Project

EDMS: 1163508

Current Baseline Concept

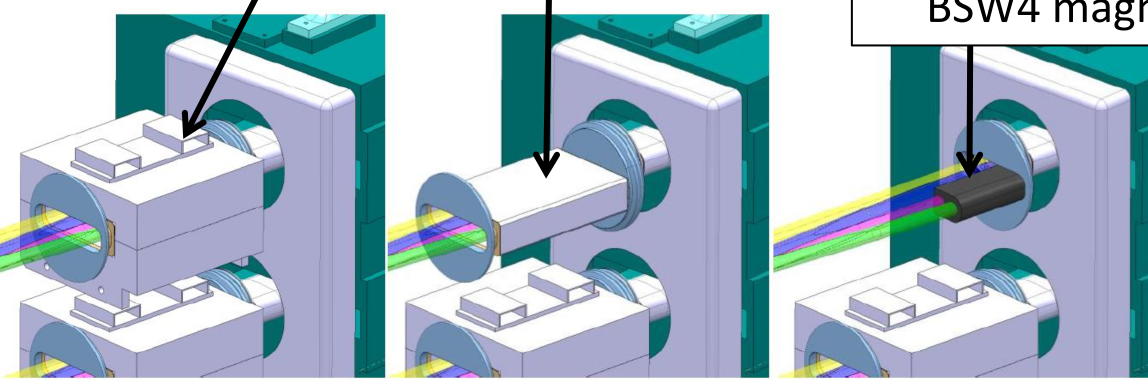




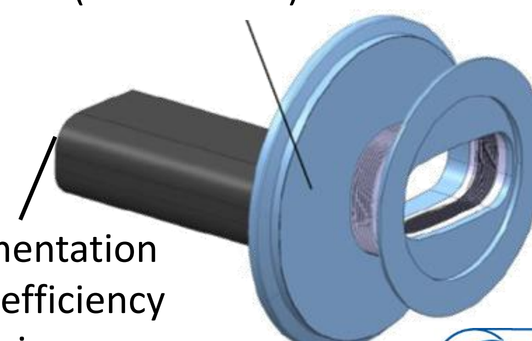
KSW4 Magnet

Inconel chamber

H0/H- dump inside
BSW4 magnet



Cooling system
(on the back) ?



Instrumentation
for foil efficiency
monitoring
(on the front)

History of changes

- **2010** - First conceptual study, AlN, BN or Graphite – Graphite is retained due to RP and other considerations here, here , here and here.
- **2011** – No pumping is possible for the added degassing from a graphite dump, brazing is problematic → new material study started
- **2012** – Al_2O_3 : high risk of electrical charging
- **2013**– SiC : baseline retained by reviewers, swelling issue to be studied

Outcome of Internal Review, INDICO 244116

Possible design concepts

Actual Baseline :

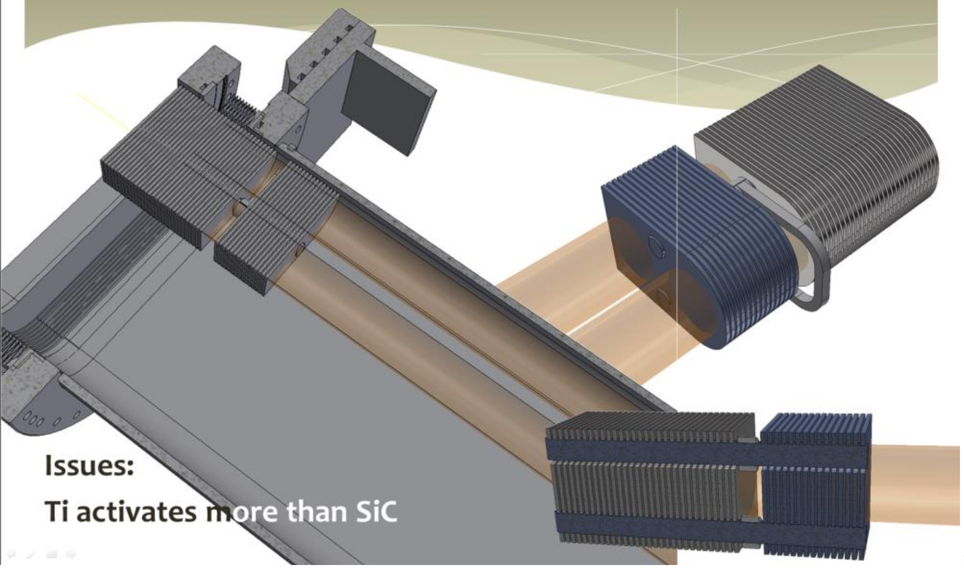
- Bulk SiC dump inside the magnet (review)

Under study :

- Alternative 1) Sliced SiC dump inside the BSW4
- Alternative 2) outside⊕ metal + sliced SiC dump inside
  → need 5cm behind BSW4
- Alternative 3) Full metal dump outside⊕ the magnet
  → need 8-9cm behind BSW4

⊕ outside = in the space between BSW4 and BHZ11

Alt1) Sliced dump ?



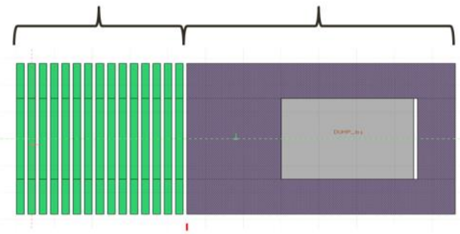
Issues:

Ti activates more than SiC

Alt2) SiC sliced + bulk core

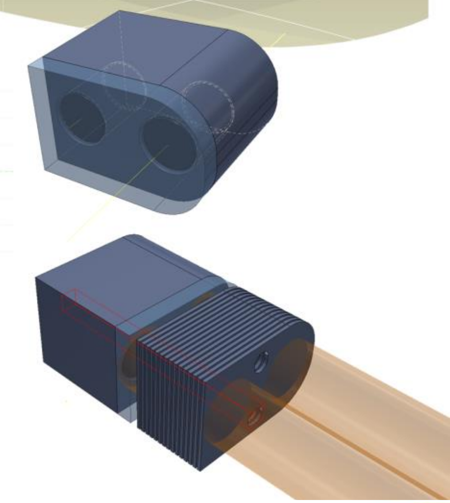
primary core SiC, 15 x 2mm

bulk metal jacket + secondary internal core



Inside magnet (in vacuum)

outside magnet (in vacuum)



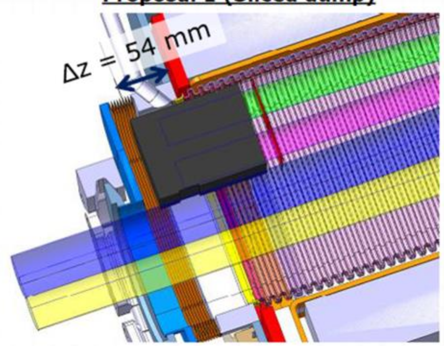
Alt3) Full metal dump

* **Titanium** is the only viable and safe option → need approval from Mag, Vac, RP, BE
* Need a layout change (change in BHZ11 vacuum chamber) to allocate space (it does not need the dump outside of the ring!)
* 7-9cm needed depending on presence of internal insert
* A dedicated shielding can be put in place, no problem of lifetime/preventive maintenance
* If SiC irradiation tests highlight a worse scenario for S%, it's the only viable option

Dump design: Integration proposals

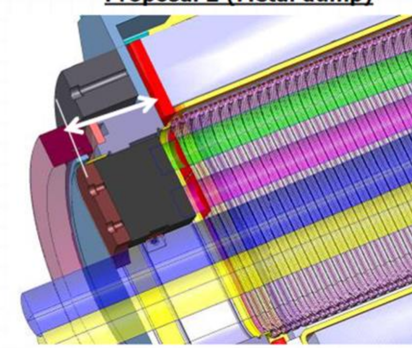
CERN

Proposal 1 (Sliced dump)



* Edge-welded bellow on BSW4 side
* Δz = 54 mm

Proposal 2 (Metal dump)



* Edge-welded bellow on BHZ11 chamber
* Δz = (15+70+15) mm

OPEN QUESTION: which is min Δz for not disturbing $\vec{B}$?

Δz : max distance between downstream surface of red plate and downstream surface of dump

Engineering

EN

EDMS: 1320006

Solution Comparison

New Proposal

	Baseline: SiC bulk	Alt 1: sliced SiC	Alt 2: sliced Sic + metal	Alt 3: full metal
Swelling - lifetime	1-2y*	1-2y*	~4 y*	√
RP	√ (with no PM)	√(with no PM)	?	?
Shielding	BSW4	BSW4	BSW4 + difficult	Dedicated
LAYOUT	Baseline / op1	Baseline / op1	Baseline / op1	Op2**
optics / field	√	√	?	?
VACUUM	√	✕	√	√
BSW4	inside	Inside	Partly outside	outside
Chamber cooling	needed	needed	needed	needed
BHZ protection	—	—	—	—
Monitor support	feasible	feasible	feasible	easy

* Need preventive maintenance. Figure may change after SiC irradiation campaign results.
** Following misalignment measurement, BHZ11 chamber may need to be changed anyway, see PSB H- Injection Tech Meeting, 03/10/13, here

C. Maglioni, M. Delonca, A. Ouzia

Issues to be Solved

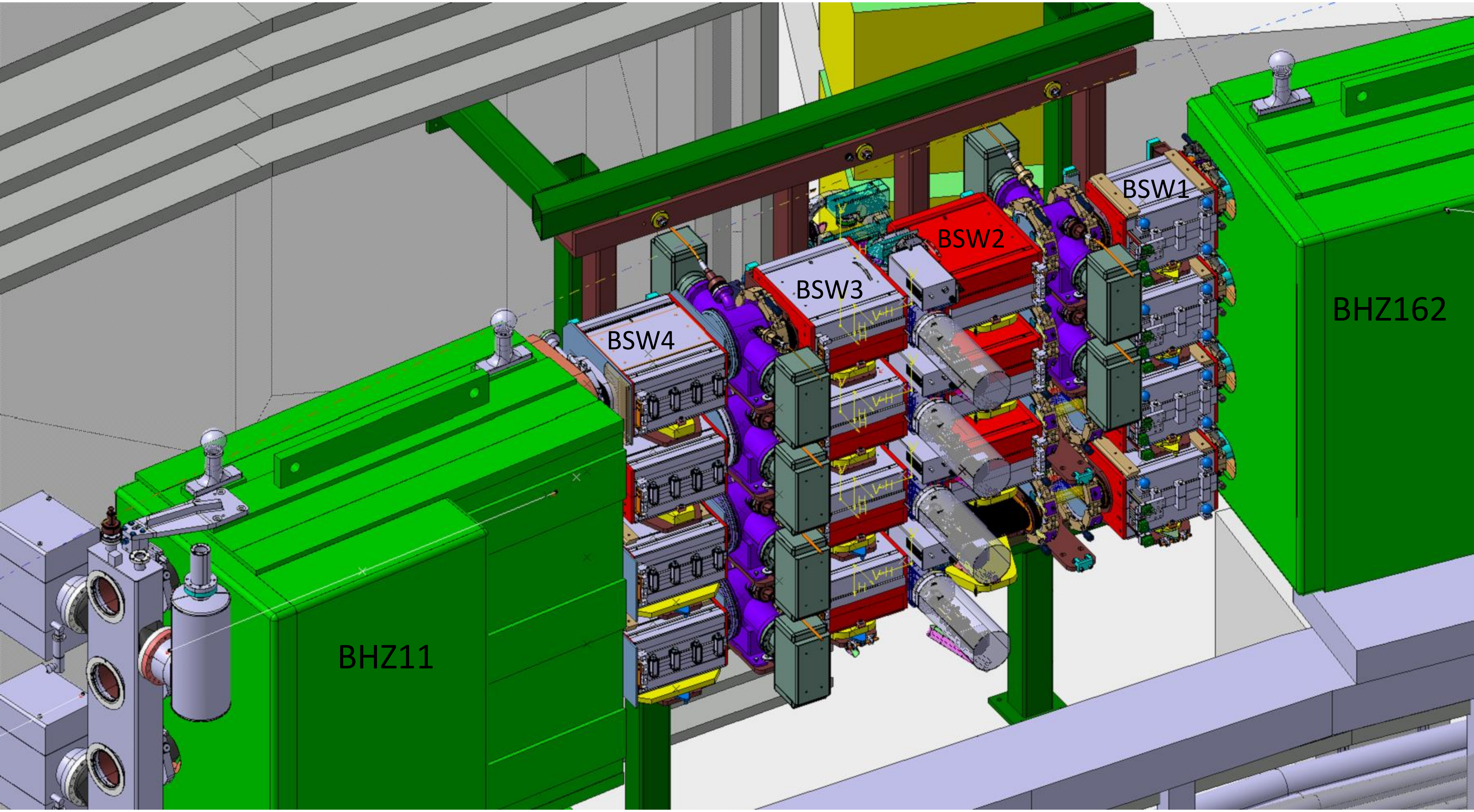
PBU Injection Meeting of 29/11/2013; a proposal for <u>new baseline</u> was made:

Full metal dump outside the magnet

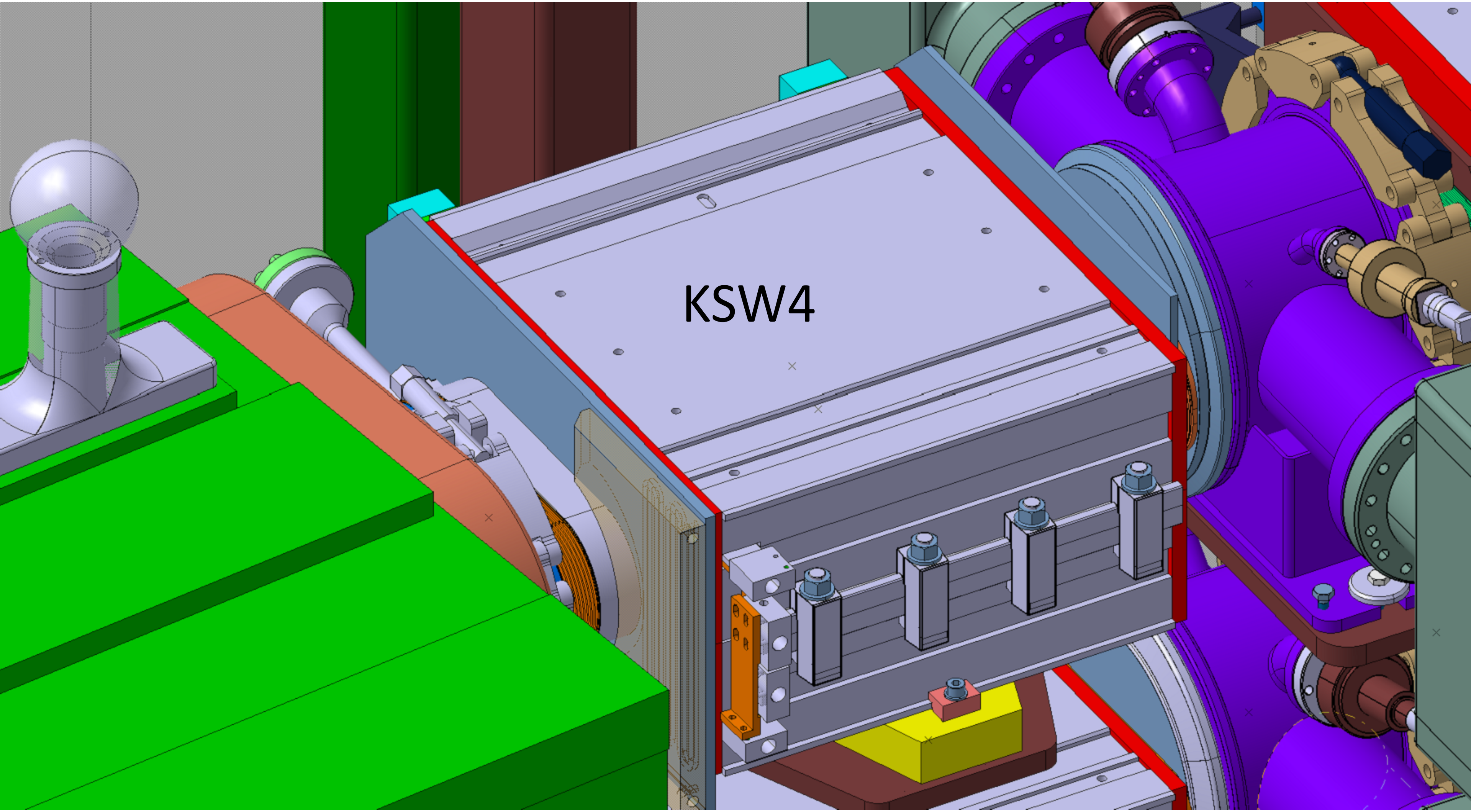
Main <u>outstanding issues</u> were identified:

- Integration feasibility study (A.Ouzia, B. Riffaud)
- RP, Activation and intervention scenarios (R. Froeschl)
- dose to downstream BHZ coils (R. Froeschl, A. Newborough)
- Magnet field perturbation (B. Balhan)
- Optic perturbation (E. Benedetto)
- Position of Instrumentation (F. Zocca)
- Vacuum, (J. Hansen, declared OK)

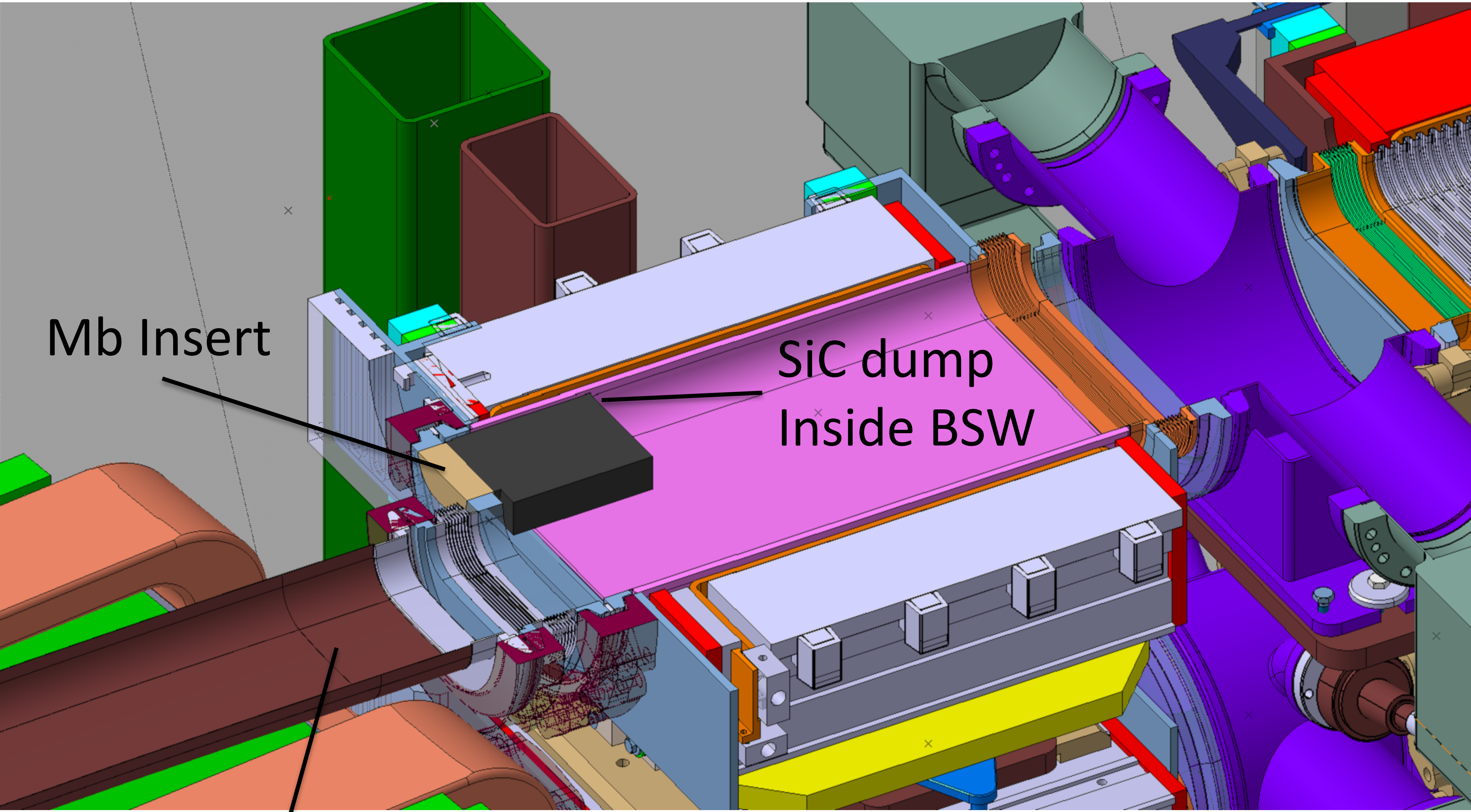
Mechanical Design



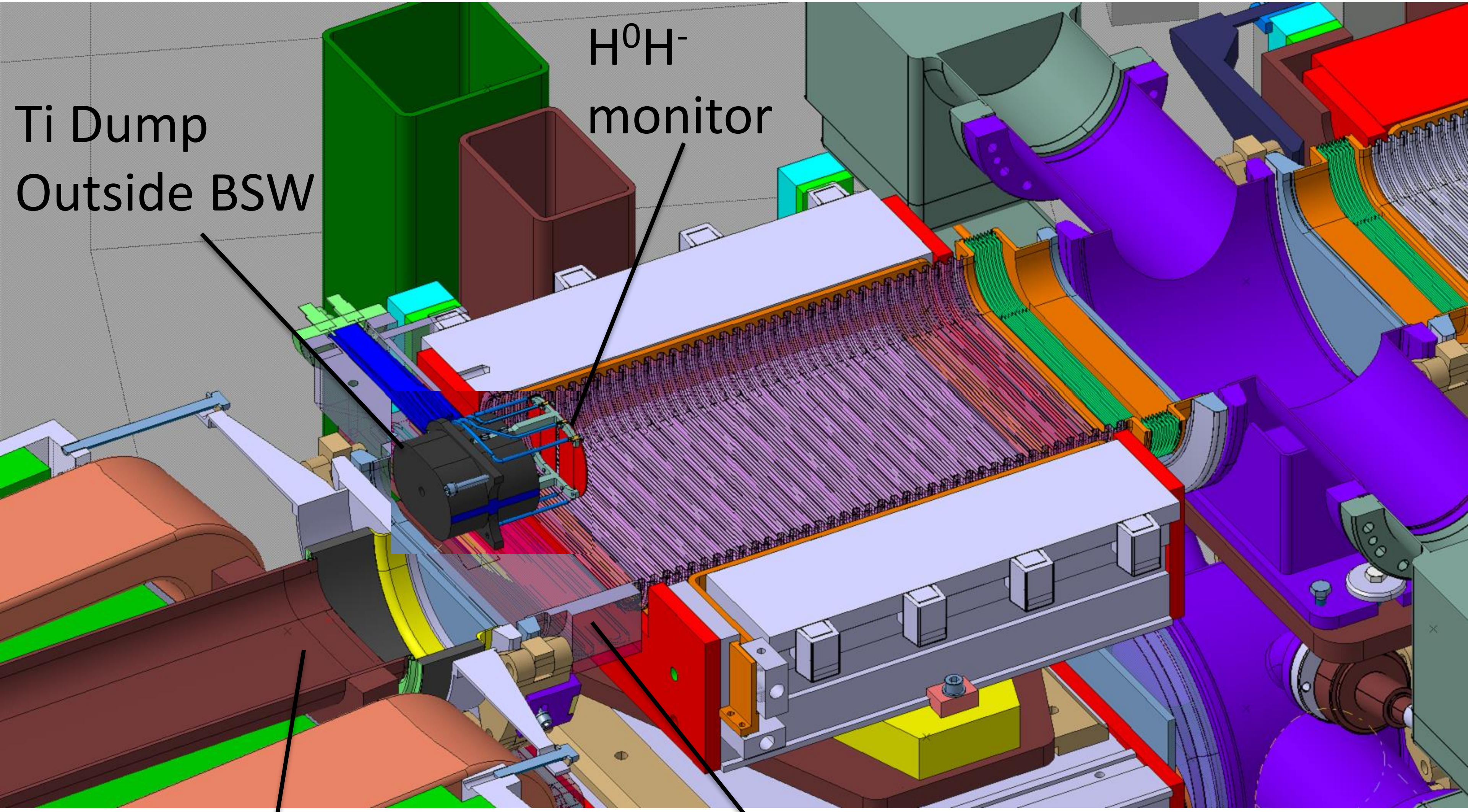
Mechanical Design, KSW Magnet



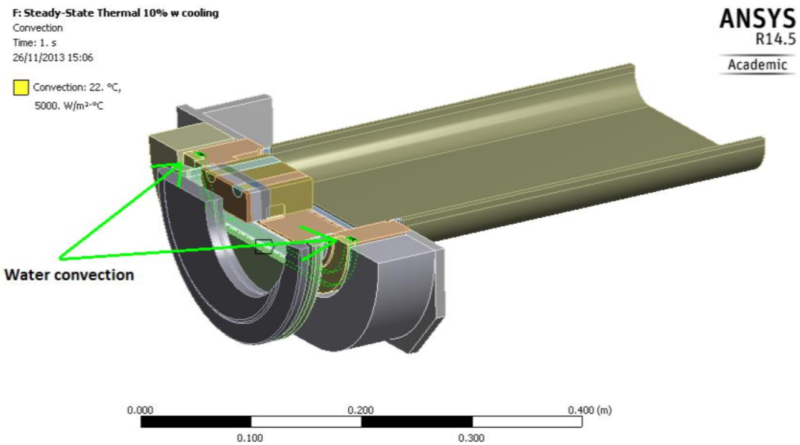
Mechanical Design, Current Baseline



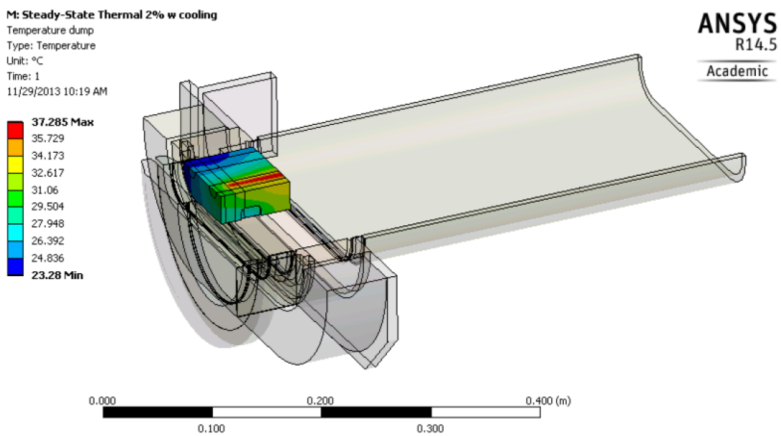
Mechanical Design, Proposed Baseline



Dump integration and cooling



ANSYS simulation : Steady-State 2 %



ANSYS simulation : Transient 2 %

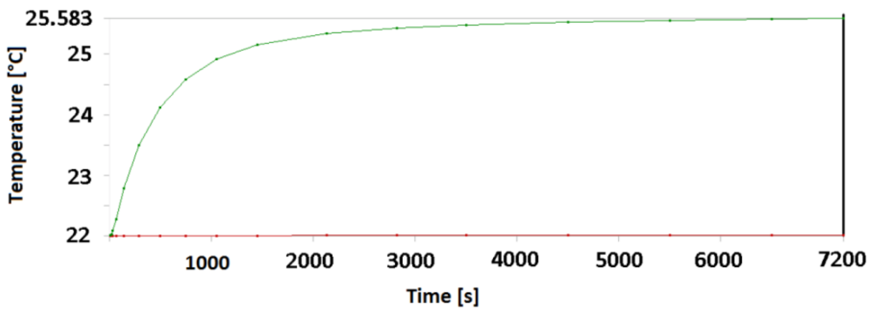
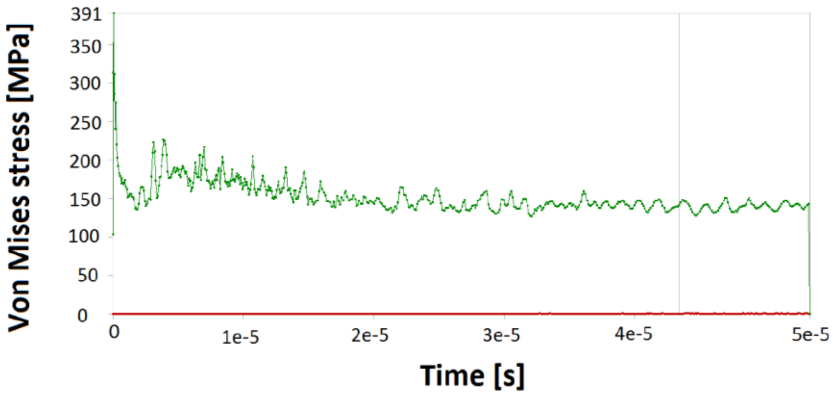


Figure: Maximum temperature on the whole assembly (dump excepted)

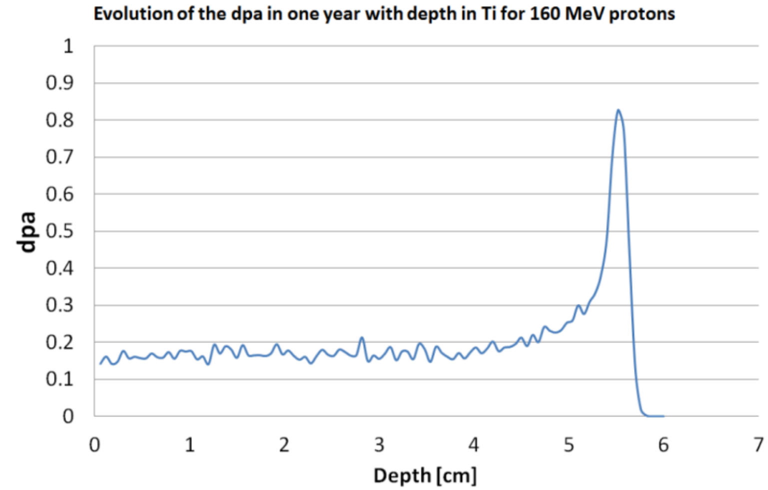
ANSYS simulation : to sum up

Max T [°C]	2%	10%
Dump	37.3	137.9
Other	25.5	48.9
Flange	22.5	26.1

ANSYS simulation : One shot accidental case



Titanium dump : radiation damages



Titanium dump : radiation damages

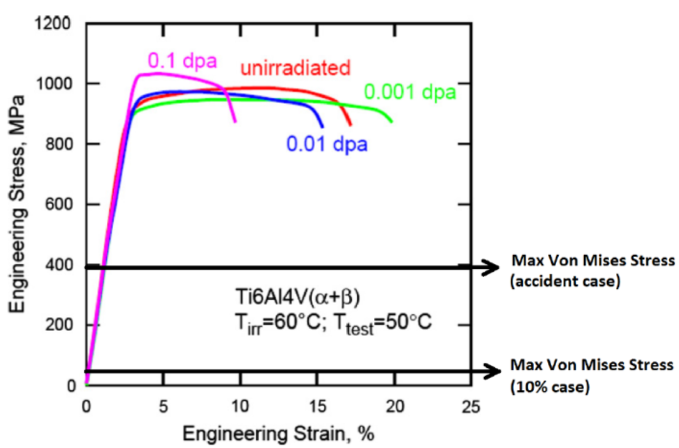


Figure: Stress-Strain Curve evolution with dpa for Ti6Al4V

Titanium selection : conclusions

Conclusions :

Hydrogen embrittlement

α-Ti will become brittle ... but only in a limited volume

β-Ti does not embrittle

Radiation damages

Yield strength ↗

ductility ↘ but is never totally lost

other properties do not evolve much

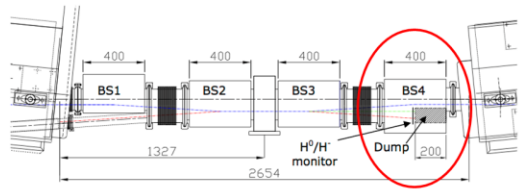
swelling is not a problem

H^0/H- current monitor: development status

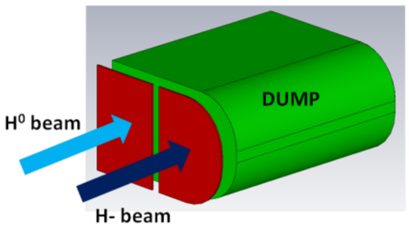
F.Zocca, F.Roncarolo

PSB H- injection meeting – 12th November 2013

H^0/H- current monitor in BSW4

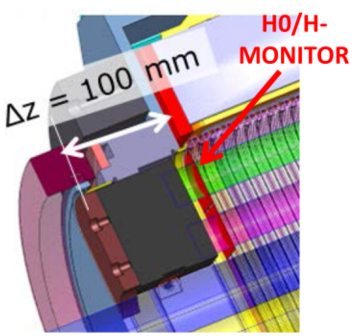


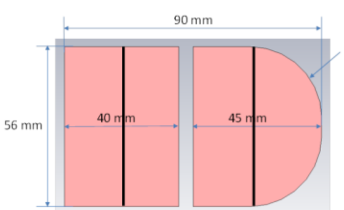
GOALS : - monitor the efficiency of the stripping foil (detect degradation and failure)
- protect the dump by providing an interlock signal in case of 10% detected beam load



CONCEPT : plates intercepting the H^0 and H^- ions and acting as a Faraday cup for the stripped electrons (stripping & collection)

In case of external metal dump (1)





- Just outside the magnet (after the end plate) vertical field component B=0.05T

  curvature radius : low-energy secondaries = 0.2 mm
  backscattered = 2 cm, delta-rays = 5 cm
- 15mm further away (@ dump) vertical B=0.01T :

  curvature radius: low-energy secondaries = 1mm
  backscattered = 9 cm, delta-rays = 24 cm
- If we assume only vertical B-field component, the low-energy secondaries are captured-back, the backscattered may produce cross-talk between the 4 half-plates
- In case of stray horizontal B-field component, we may loose signal (up to 30 % in the worst case) and/or receive secondaries from the dump

  → Better to reintroduce polarization frames between the dump and the plates !
- The dump-monitor distance (15mm) could be reconsidered (increased) to let the monitor be in a more uniform B-field region

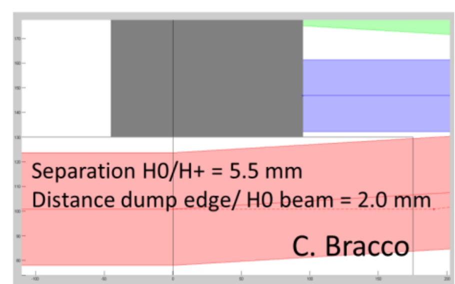
In case of external metal dump (2)

Positive aspects:

- The polarization frame, being outside the magnet, could be thicker → the E-field more effective → the biasing voltage eventually lower
- Easier integration: it could be easier to mount the monitor to the metal dump and eventually to machine the dump to let more space free for monitor cabling (?)
- The distance between the monitor and the circulating proton beam is slightly increased (unwanted effects reduced)

Cabling:

- Internal: 9 cables (4 signal read-out + 4 test signal/spares + 1 frame bias), cable type → ceramic beads or kapton insulated
- External: request already done for 8 BNC + 1 SHV (per ring)



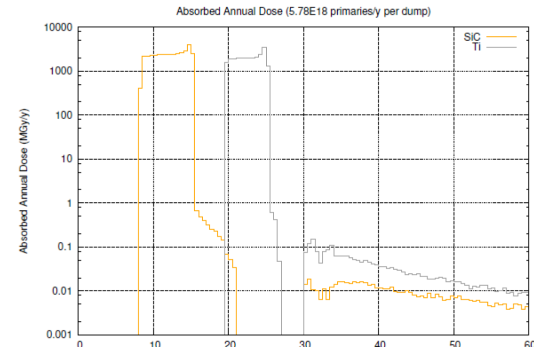
Radiation Protection Assessment of the Titanium Option for the future PSB H^0/H^- Injection Dumps

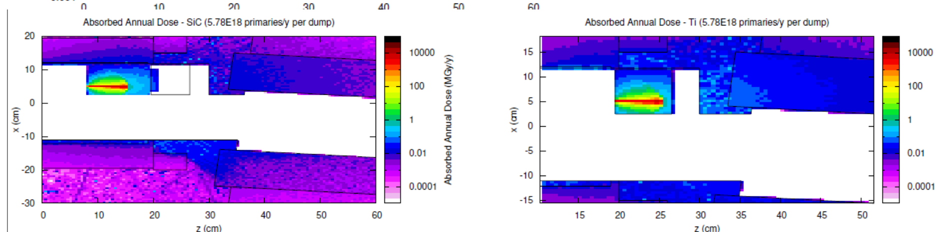
Robert Froeschl (DGS-RP-AS)

January 10, 2014

Beam parameters (EDMS 963395 v3.1)
Geometry (EDMS 1157402)

Annual Absorbed Dose to Resins in the Coils



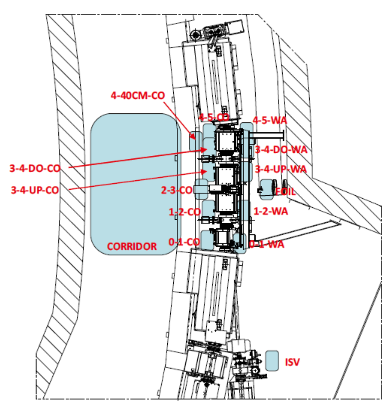


- Max. ~0.1-0.2 MGy/year for Titanium Option
- Factor of ~3-10 for annual absorbed dose between Ti and SiC

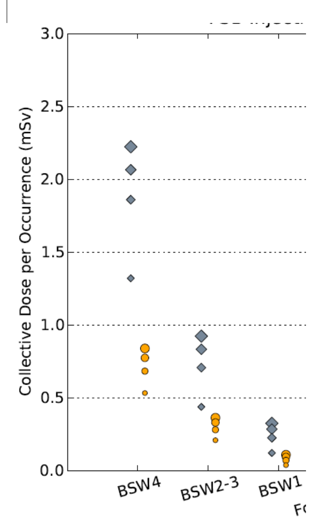
Resin limit is 20 MGy
(PSB integrated ~1MGy)

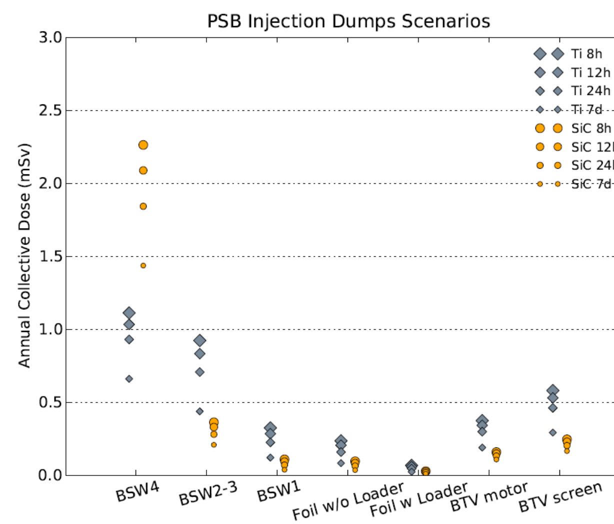
Intervention locations - Definition

- 15 locations have been defined
- Number of persons and expected time for each task attributed to a specific location
- Together with dose rates at a given cooling-time, the dose for each intervention is calculated



Annual Collective Dose



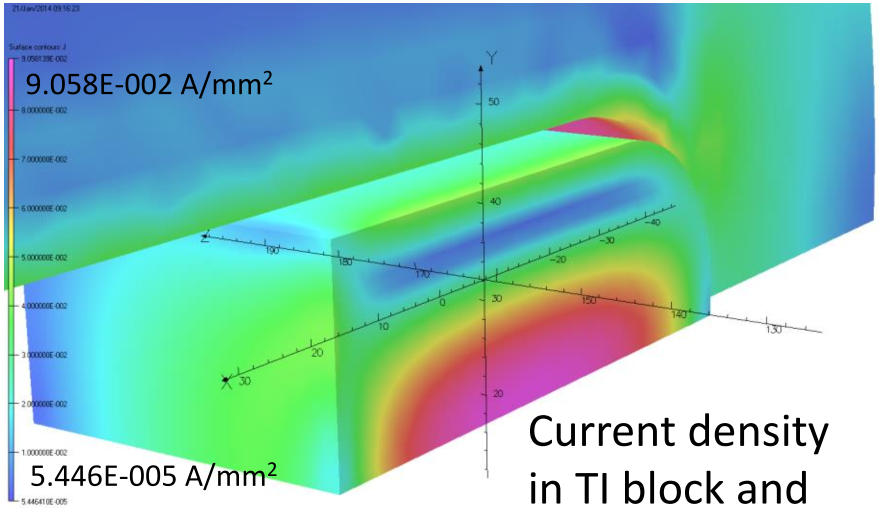


Conclusions (RP Issues)

- Improved WDP leading to reduced uncertainties
- Dose rates comparable to the current dose rate levels in PSB
- Collective annual doses of 2-5 mSv
- Titanium and SiC comparable wrt. collective annual dose with a larger variation for Titanium
- Titanium has highest maximum individual dose for *Replacement of BSW4 magnet* scenario
  - Still compatible with 2mSv/person/intervention requirement
- No intervention above ALARA Level 2
- Tasks have to be performed in a way so that goal of maximal 2mSv individual annual dose is reached

B. Balhan

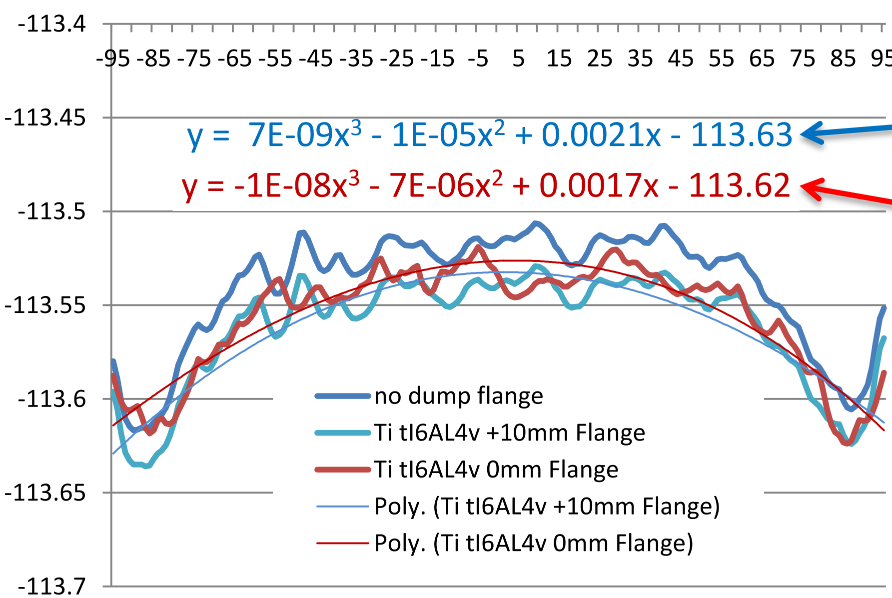
Influence of dump position on Field homogeneity using Ti6al4v block, with electric conductivity of 6E5 [S/m]



Current density in TI block and external flange

Dissipated Energy and Forces in Ti block has been evaluated vs position

		0 mm from end plate	10 mm from end plate
Energy (∫B.H/2 dv)	[J]	2.9E-02	7.4E-03
Power loss (∫J.E dv)	[W]	2.2E-01	7.8E-02
x-Lorentz force (∫JxB dv)	[N]	1.8E-03	7.5E-04
y-Lorentz force (∫JxB dv)	[N]	0.0E+00	0.0E+00
z-Lorentz force (∫JxB dv)	[N]	-4.3E-02	-1.3E-03



Mid-plane integrated Field distribution along z axis

- Differences in field homogeneity, using a simplified model, without Inconel chamber, compared to having no dump installed:
  - Dump at 0 mm from endplate, no significant differences.
  - Dump at 10 mm from endplate, no influence.
- In order to extract accurate polynomial component, a global calculation with the full geometry and instrumentation is foreseen when design will be frozen.

Summary (1)

Mechanical design

- New design is feasible.
- But modification of BHZ11 vacuum chambers will be required.

Dump Design:

- Cooling can be integrated in the shielding design.
- In this case, no real heating issues are identified.
- Mechanical forces and radiation damage are negligible.

H^0H^- Current Monitor

- New position creates more aperture for PSB circulating beam.
- Distance between dump and screen give minor changes to H^- beam trajectory.
- Monitor in uniform B-field, Polarization frame not required.

Summary (2)

Radiation & Shielding considerations:

- BHZ resin gets ~0.1-0.2 MGy per year, factor 3-10 worse than for SiC.
- Resin limit is 20 MGy (integrated today ~1MGy), so even 0.2 Mgy/year is acceptable.
- BSW4 magnet replacement (dump change) 5 times lower.
- No ALARA level 3 interventions for any scenario.
- Annual collective dose for Ti or SiC ~2-3 mSv (comparable to current PSB annual collective dose levels for this region)
- Shielding shall be included and fixed to the BSW4 magnet.

Effect on magnetic Field and Optics:

- Front face of the dump ~10 mm from the end of the magnet field clamp.
- Negligible effect, but still waiting for the multipole expansion (should be no show-stopper).

Conclusion

We propose to approve as new baseline:

- Full metal Ti dump;
- Starting at least 1cm outside the BSW4 magnet;
  - Thus outside the BSW magnetic field;
- Located inside the vacuum chamber;
- With the H^0H^- monitor ~5cm in front of the dump;
  - Thus inside the BSW magnetic field
- Dump Shielding should be at least equivalent ~5cm Pb collar;
- Shielded transport container for BSW4, including dump, is required;
- Modify BHZ11 chambers to create required space;
  - Is not included in Cost to Completion (approx. 150kChF)