Cold Collimator Preliminary Study at CERN: Issues and Challenges

Preliminary Meeting on 11 T - Cold Collimation Interface
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Engineering Department

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OUTLINE

- Context
- Alternative designs of DS collimators
- Cold Collimator Preliminary Design
- Issues and challenges
- Conclusions

CONTEXT

- This presentation is almost entirely based on the pre-study carried out in May-June 2010 for LS1 DS Collimators.
- Two different technical approaches were assessed for the design of DS collimators:
  1. **Warm collimator** with cold-warm transitions and cryogenic by-pass.
  2. **Cold collimator** with jaws at cryogenic temperature.
- Cold Collimator study abandoned once the alternative design (Warm Solution) was endorsed by the July 2010 Review. Many critical aspects not thoroughly treated yet. **Take all provided information with due caution** …
- Cold Collimator preliminary design has been developed by **D. D. Ramos** (Engineer) and **Ch. Mucher** (Designer). They should get the credits …

FUNCTIONAL SPECIFICATION

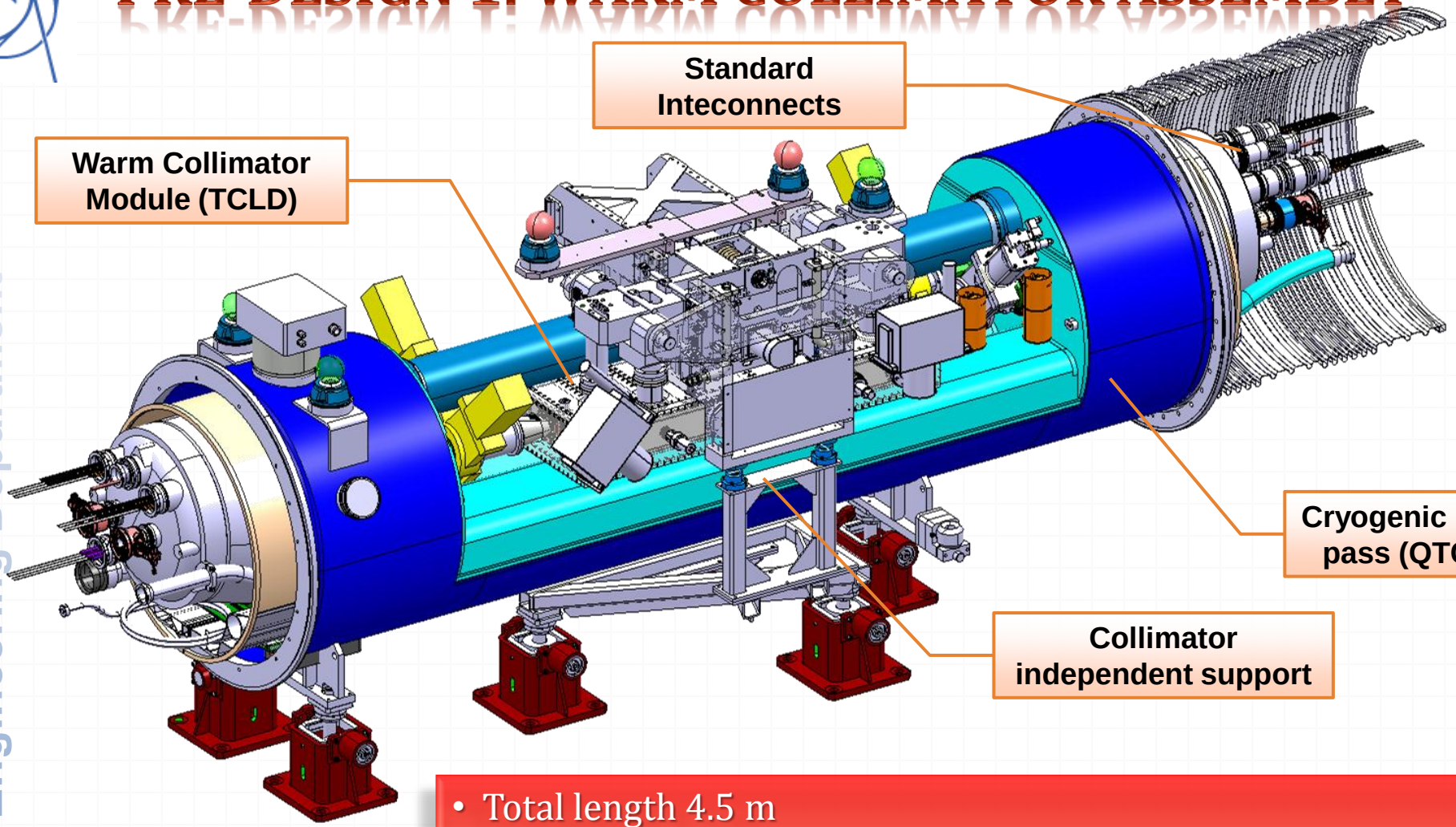
Main goal:

- Gain a factor ~10 in (peak) power deposition on DS magnets (SC coils) both for protons and ions

Major complication for Collimator design

- Two jaws per collimator (because of back-scattering and positive $\Delta p/p$ for ion fragments).
- 1m long Tungsten jaw.
- 40 W (steady-state), 200 W max (10 s transient) per jaw.
- Jaw stroke $0 \div 25$ mm (horizontal). No vertical adjustment.
- Jaw tapering 100 mm.
- Jaw flatness ~50μm (manufacturing) + 50μm (in working conditions) .
- UHV Compliant

PRE-DESIGN 1: WARM COLLIMATOR ASSEMBLY

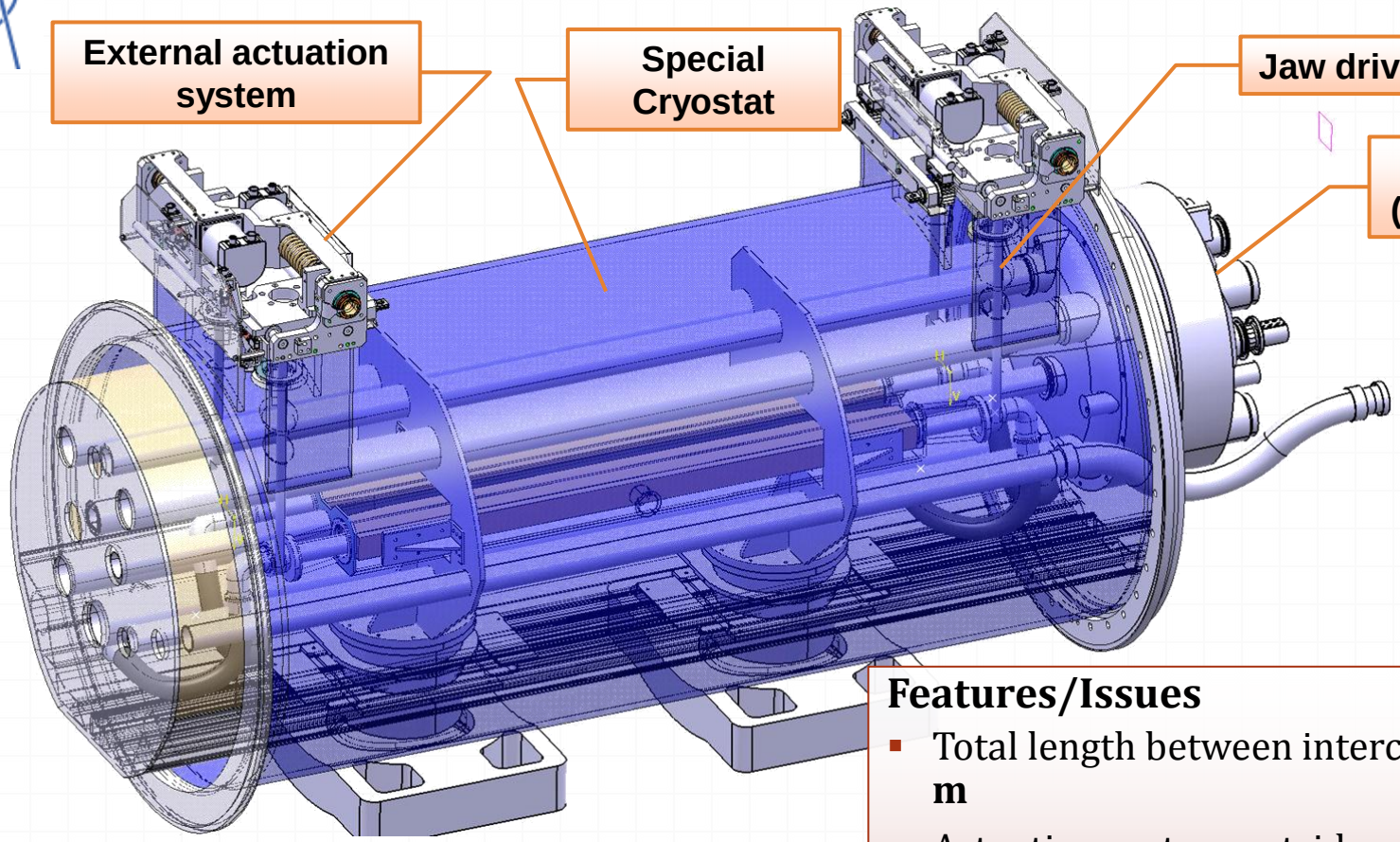


- Total length 4.5 m
- Solution endorsed by the Collimation Review (July 2010)
- Design approved by Technical Review (May 2011)
- Cryogenic By-pass (QTC) under prototyping

COLD COLLIMATOR: VERY FIRST IDEAS

2009 Conceptual Review: movable beam pipe with integrated one-sided jaw

PRE-DESIGN 2: COLD COLLIMATOR



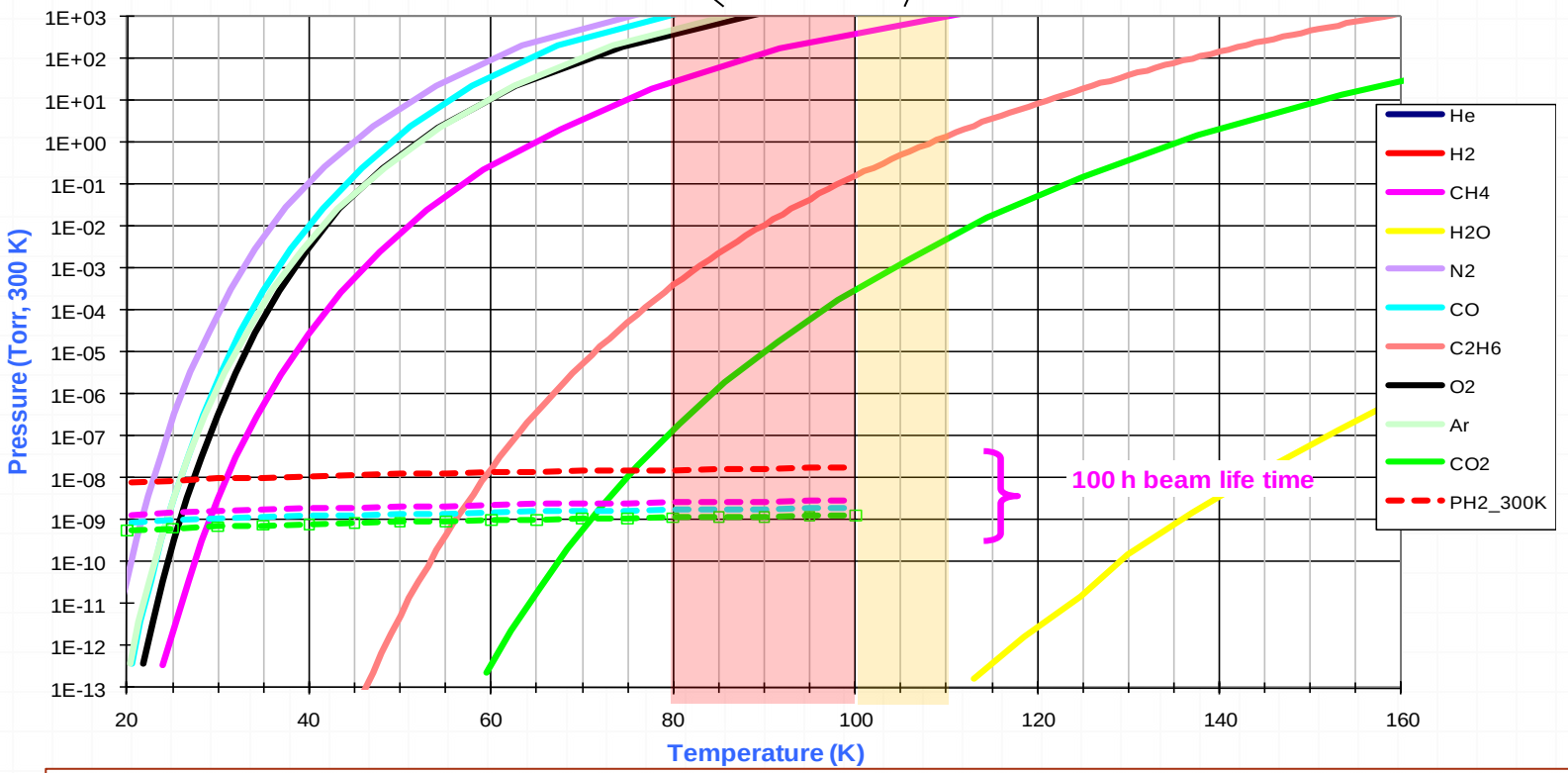
Features/Issues

- Total length between interconnection plans: **3.1 m**
- Actuation system outside cryostat ⇨ Accuracy of jaw positioning?
- Special cryostat. No W bellows sliding possible.
- Lyras required to compensate bus-bar contraction ⇨ taken up by adjacent 11T magnets?

COLD JAW OPERATING TEMPERATURE

He inlet to outlet

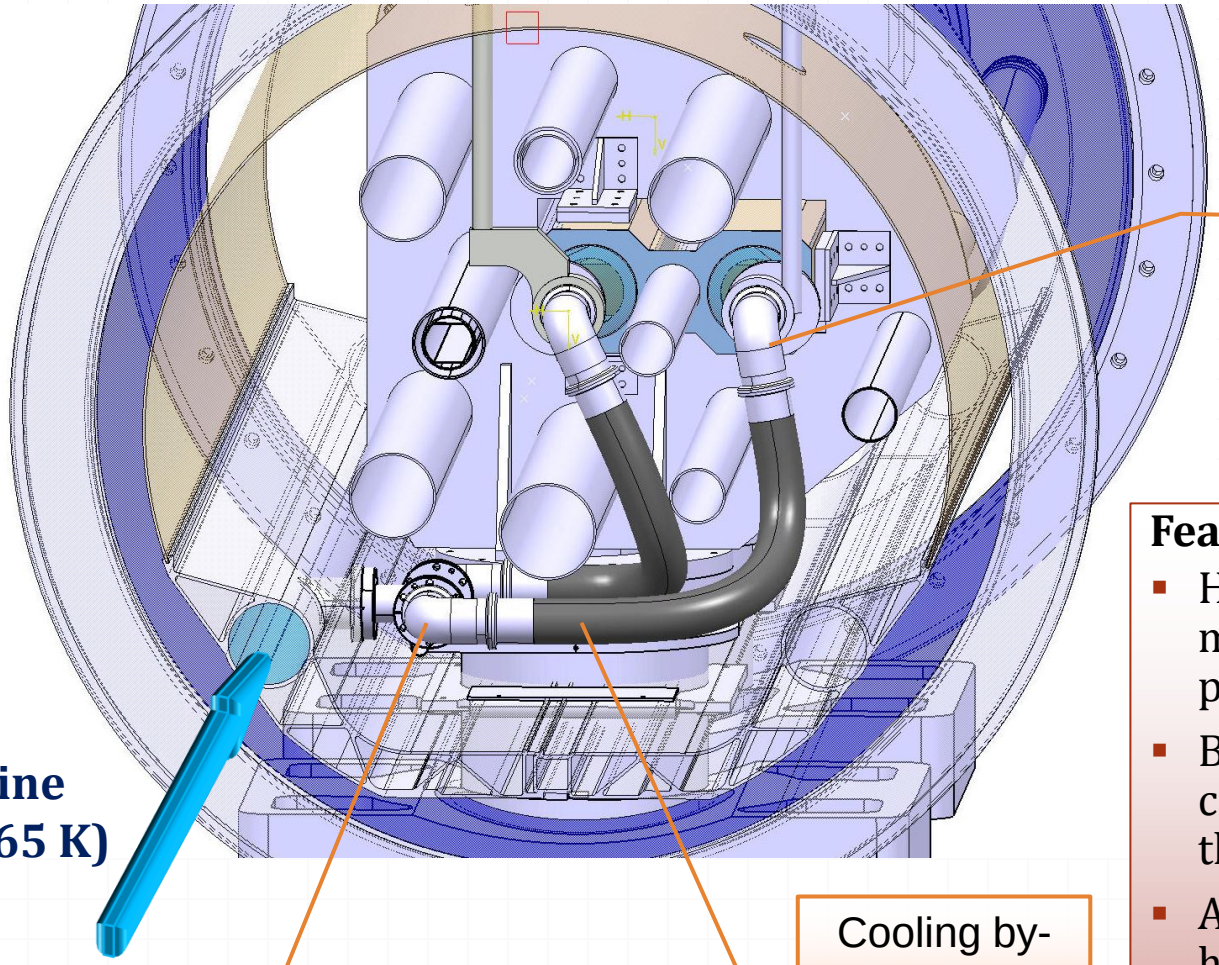
Heat diffusion gradient



Features/Issues

- Evacuating **200 W** is only possible relying on **line E** (50-65 K) ⇨ Cooling by-pass
- In order to avoid pressure instabilities due to $C0_2$, collimator must be kept above 80 K (see **V. Baglin**'s talk) ⇨ He heaters required.

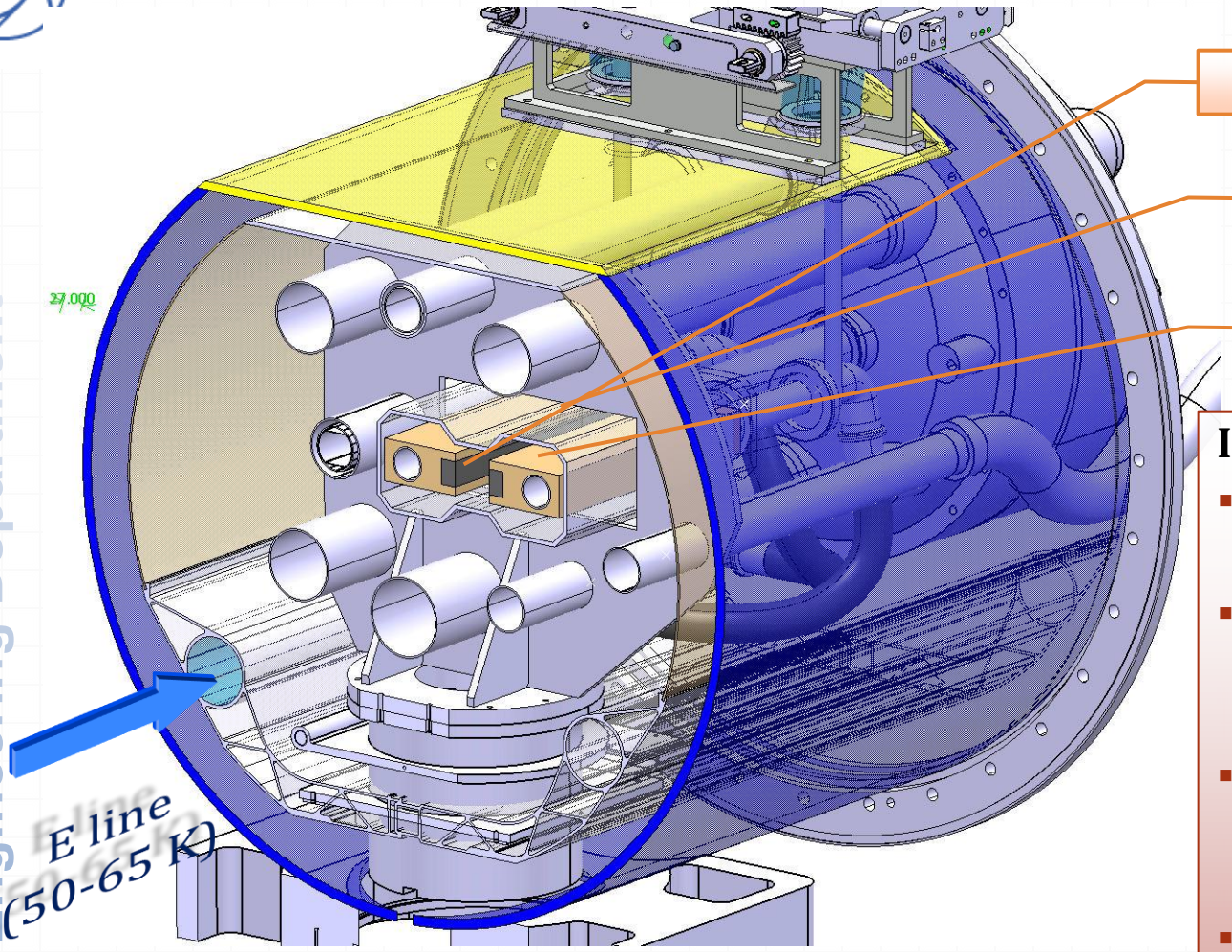
PRE-DESIGN 2: COLD COLLIMATOR



Features/Issues

- He by-pass flow to be minimized to reduce heating power.
- Bringing He from 50 to 80 K costs as much power as cooling the jaw.
- Active control necessary for He heaters ⇨ Reliability?
- Active flow regulation devices might be required ⇨ Complexity, Reliability?

PRE-DESIGN 2: COLD COLLIMATOR

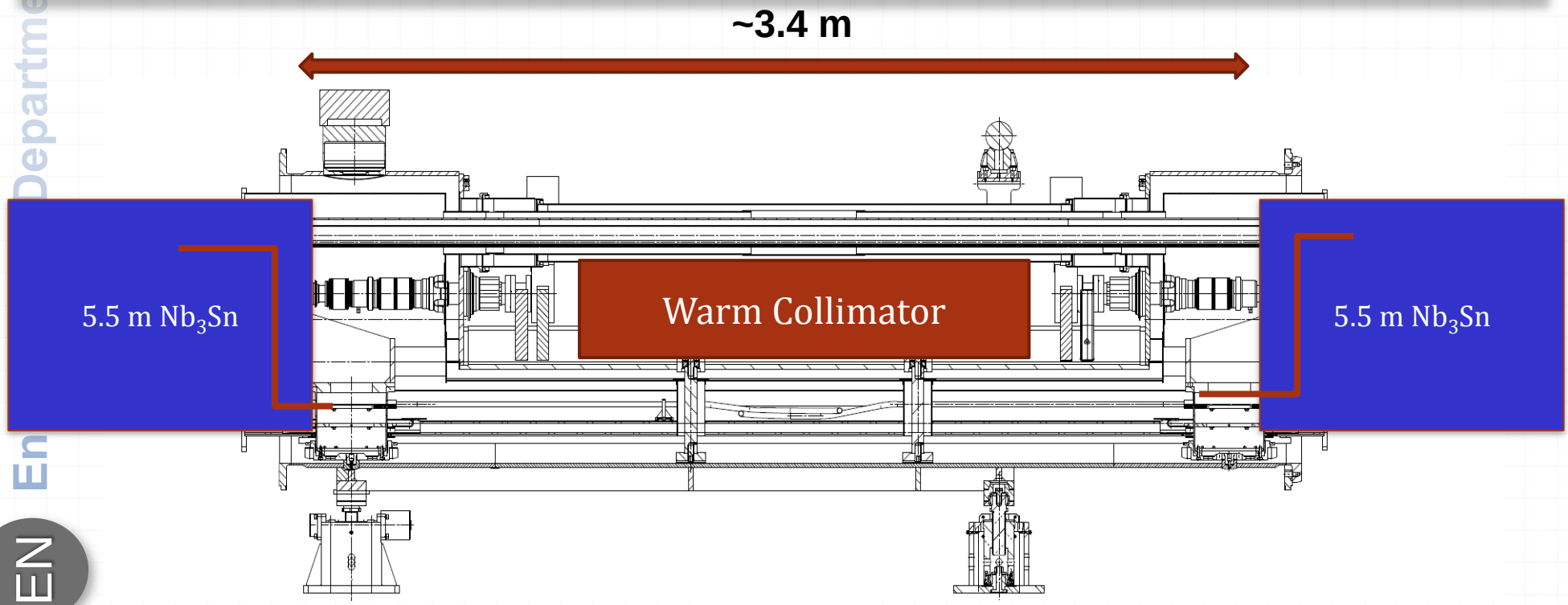


Issues

- Jaw operating temperature 100 ÷130 K
- Tungsten becomes very brittle at low temperatures ⇨ can it be replaced by Cu? Others?
- Cryo-pumping surface at ~3K plus 80 K screen required around jaws. Design issue?
- Design of RF sliding contacts at 100 K?
- Additional RF-induced heat loads?

ALTERNATIVE PROPOSALS

- Can one replace the small cold masses of the Cryogenic by-pass by 2 Nb3Sn Magnets?
- Are alternative bus-bar routings possible (e.g. everything on top of cold collimators)?



POTENTIAL SHOWSTOPPERS FOR COLD SOLUTION

- Beam vacuum operation at 100K.
- Tungsten brittleness at low temperature.
- Reliability of active devices for by-pass cooling circuit operating in cold and UHV (Heaters and valves).
- Possible additional heating from RF impedance.
- Issues with moving or sliding parts in cryogenic environment (e.g. RF contacts).

SUMMARY

- Preliminary study of a cold collimator was carried out in May-June 2010. It was based on assumptions and schedule no longer applicable.
- This development was abandoned at a very early stage. Many critical issues are still to be solved.
- Total length of the pre-design is 3.1 m. Jaw operating temperature is 100-130 K. Heating He from E-line above 80 K is necessary.
- Design optimizations are possible in particular if 11 T Magnets integrate collimator requirements such as bus-bar lyras and routing.
- Some pending issues may potentially constitute showstoppers for the cold design.
- Experience gathered by GSI may help in tackling some of the issues, namely operation at ~ 100 K.
- Jaw entirely made up of copper may reduce risks related to Tungsten brittleness.
- Alternative solutions like warm collimator with an optimized magnet interface could still be considered.

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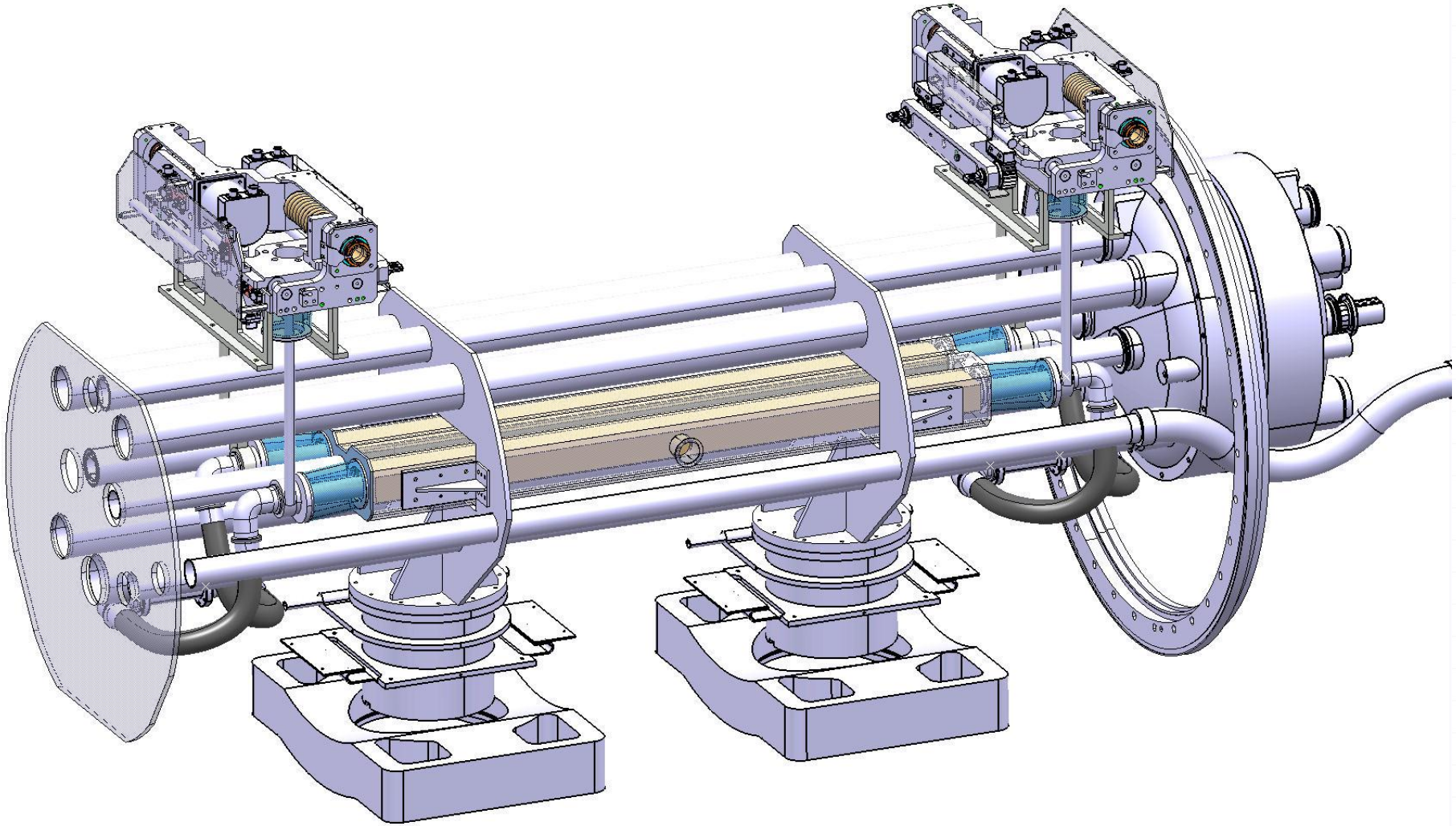
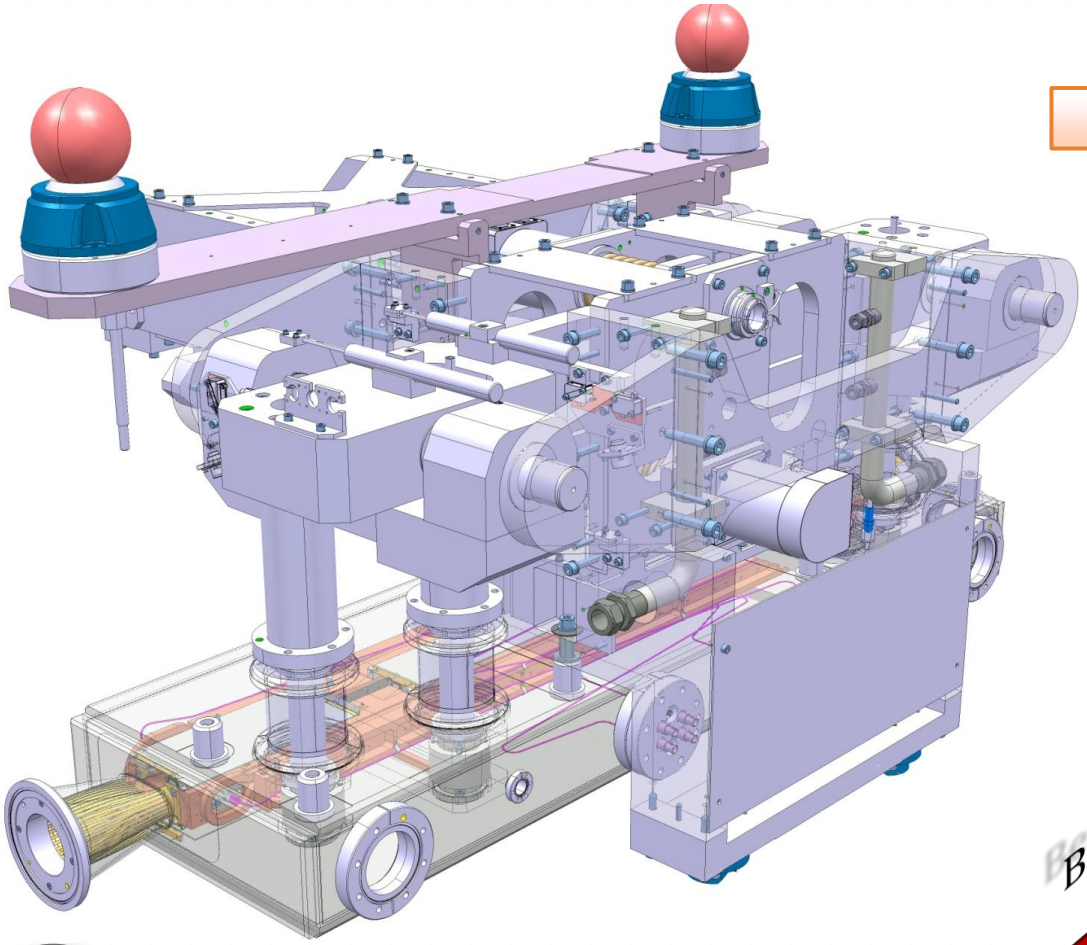
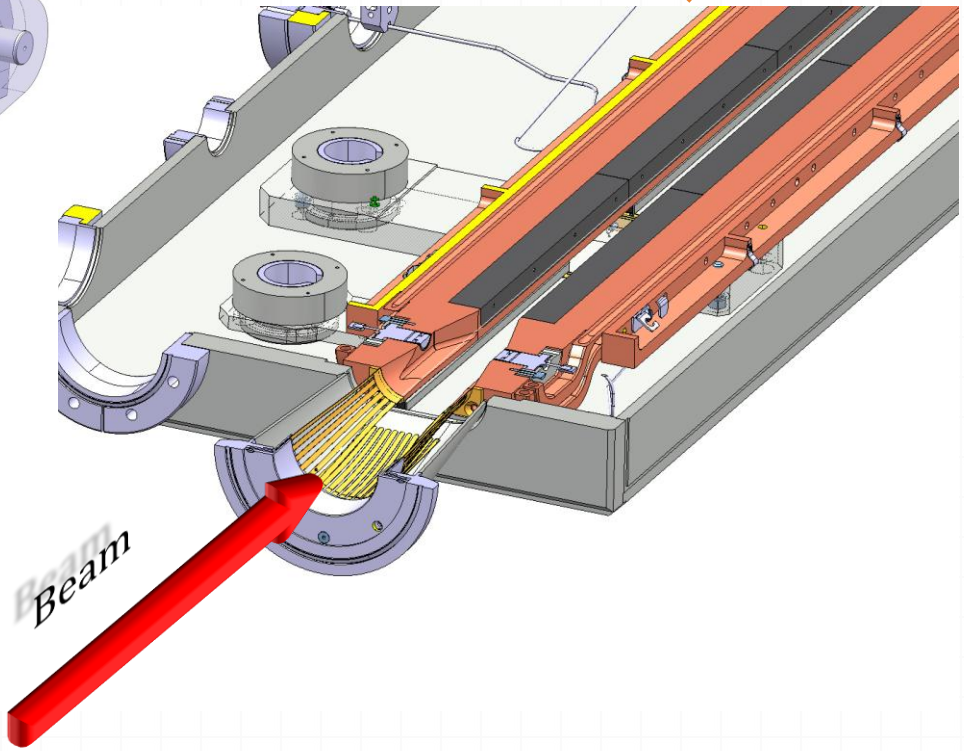
Thank you for your attention!

Bonus Slides!



PRE-DESIGN 1: WARM COLLIMATOR MODULE





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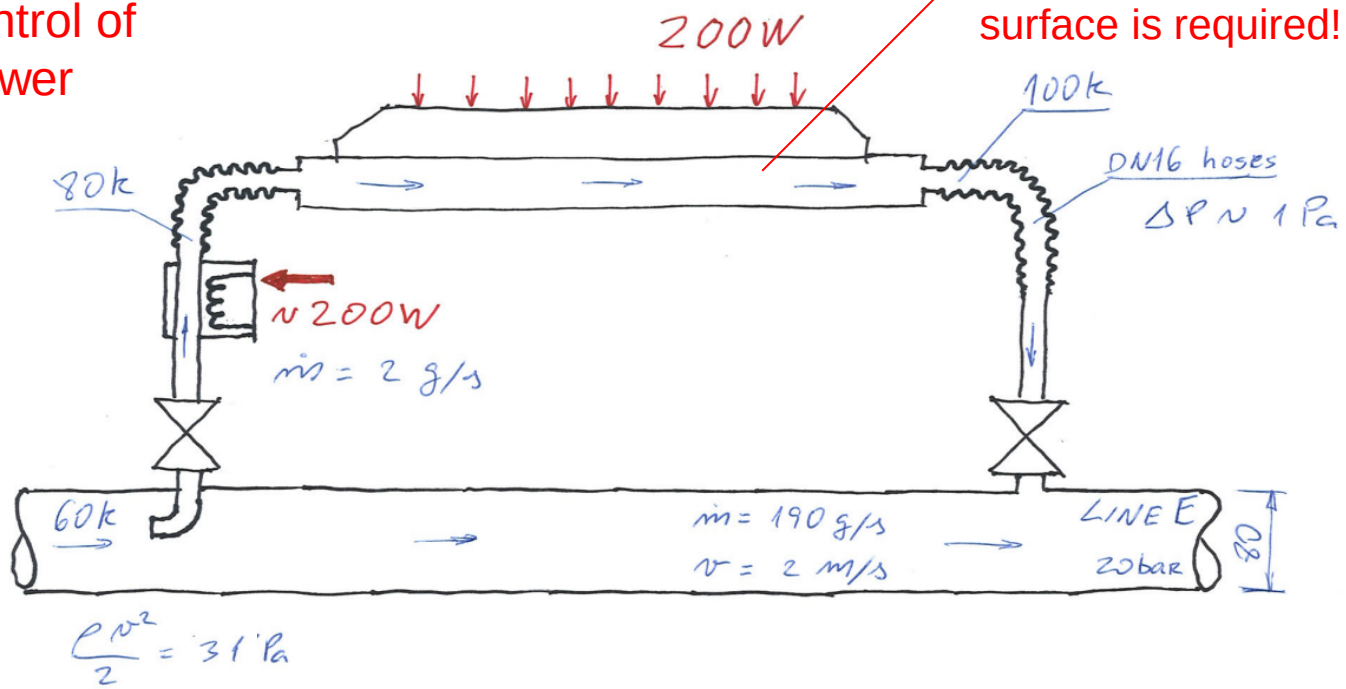
Cooling bypass design

- Heater to raise line E helium from 60 K to 80 K
- Minimum flow to extract 200 W keeping the outlet below 100 K
- Controlled flow or on/off valves (less efficiency)?

Active control of heater power

35 mm pipe would result in wall ΔT ~ 36 K (average). Larger surface is required!



Dynamic pressure is sufficiently high; no need to add a restriction in line E