ACCEL Cryomodule Assembly Study I

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Introduction (1/3)

ACCEL was charged with the task of preparing an industrialization study report for the X-FEL cryomodules.

As the first step of this study ACCEL personnel was present at all assembly steps of module #6 at DESY and was able to observe in detail the string assembly and the assembly of the module outside the clean room

The first part of the report is a detailed description and summary of all individual working steps including an analysis of the time needed, possible improvements from an industrial point of view and a schedule analysis.

All assembly steps were analyzed in view of series production of 120 modules for the XFEL (efficiency, risk, costs).

The next steps in the study will be another participation in assembly of cryomodule #8. After that another assembly report as well a confidential financial report will be submitted.

Introduction 2/3

Based on the first observation of the module #6 assembly this presentation will focus on:

Recommendations/Conclusions

General remarks
QA-Plan
Infrastructure requirements
First summary on required time and staff

Specific topics

Module assembly with string under vacuum
Transport of X-FEL module

The detailed report on the assembly steps and sequence will not be presented here.

Introduction 3/3

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Boundary conditions:

The cavities entered the clean room under vacuum from the CHECHIA test. This means: HOM antennas, pick-up antennas and cold part of main couplers were already mounted. The beam tube flanges were blind-flanged on one side and on the other side a transition to CF 40 and all metal angular valve was mounted.

The BPM and the quadrupole used for module #6 differs from the XFEL module. It is expected, that the assembly of the XFEL quad/BPM will be easier.

The observation of the assembly for the industry ends before the module was transported to the module test stand

Recommendations/Conclusions:
General remarks

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- **The assembly times recorded for the individual steps are already close to time needed for the assembly of a series. This is true for work in the clean room as well as outside the clean room.**

- **The assembly procedures are clearly defined, well advanced and state of the art. There is only minor need to change procedures.**

- **Overall time saving can only be achieved by parallel work or better organization of the work packages. Some tooling might be improved.**

- **One shift assembly seems to be best for the series assembly of the 120 (or half of the 120) XFEL modules**

Recommendations/Conclusions:
General remarks for string assembly

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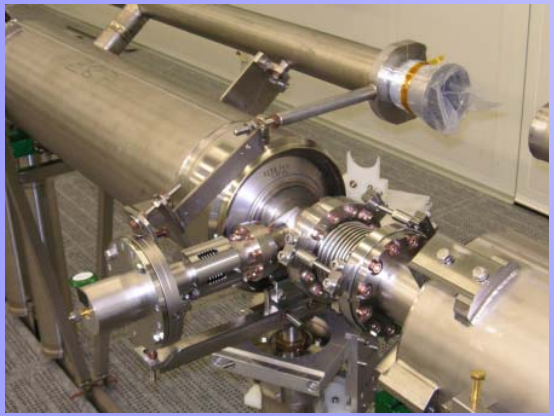
- New clean room design for series assembly necessary (see infrastructure requirements)
- Cleaning of nuts, bolts, gaskets and blank flanges must be separated from the assembly work in order to minimize the occupation time of the clean room.
- At least two pumping and assembly stations in the clean room necessary to allow work on two stations in parallel
- Venting of cavities with Nitrogen instead of Argon
- Review of alignment procedures for bellows assembly, use two non rotatable flanges on the bellows
- Goal to reduce the overall occupation time of the clean room by one string

Recommendations/Conclusions:
Alignment of cavities for bellows assembly:

The goal of this alignment must be to allow safe installation of the intermediate bellow. The flanges of the two cavities need to be aligned to each other. Eventually improved tooling can reduce alignment times.

In case the cavities are manufactured to drawing is will be possible to use a bellow with two non rotatable flanges has advantages:

- **Alignment tooling and therefore alignment simpler**
- **Assembly of gasket during assembly simpler and with less risk**
- **Assembly of flange to counter-flange simpler / no tilting, cant over of rotatable flange**



Quality Assurance/QA plan

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- **A detailed QA-plan should be used, where all assembly steps are listed and in which working steps are signed off by operators after they are done**

- **Templates and test procedures are part of the QA plan. Test results can be then documented within the QA-plan. A copy of the signed off and filled out QA-plan is part of the documentation. The QA plan will be the only document where all assembly steps and test results are documented.**

- **The traceability of all assembly steps is given**

- **Consider wearing of gloves during the assembly, minimum at assembly with superinsulation to avoid contamination**

QA / Final leak checks

- **Currently no final leak check of the insulation vacuum done at the end of the module assembly. Needed for series production to clarify responsibilities. End caps for the big vacuum vessel flanges need to be designed and produced.**

- **Currently no final integral leak check of the helium vessel system and cryogenic piping after final assembly. Recommended for series production. Can be done during leak checking of the insulation vacuum by pumping and purging vessels and lines with helium and observation of the background (should be below 1E-9 mbar l/s). In parallel the leak tightness to the cavity vacuum is possible.**

- **Integral leak check of the cavity vacuum to the insulation vacuum not so easy. Purging the insulation vacuum with helium produces high helium background for further leak checks of the insulation vacuum (helium is captured between superinsulation and might permeate into the wire insulation material). Eventually better to purge the insulation vacuum with nitrogen and observe with a mass spectrometer the partial pressure of nitrogen in the cavity vacuum. Better sensitivity than 1E-9 mbar l/s difficult with this method.**

- **All leak checks necessary at the end of the assembly just before shipment.**

First summary on required time and staff:
Goal for XFEL series assembly

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Time needed currently:

clean room assembly:	10 working days
assembly on rail system:	6 WD
assembly under cold mass:	8 WD
assembly at cantilever:	3 WD
assembly with vacuum vessel:	8 WD
Sum:	**35 WD**

goal:
app. 1000 cavities → 125 Modules in 2 years → app. 1 Module each week

- reduce time in clean room (easier alignment, cleaning of parts separately from clean room assembly) will speed up throughput
- reducing the time of other assembly steps seems possible
- at this time of the study/analysis the assembly in single shift operation is sufficient
- time reduction to in total 6 weeks (including final leak checks)

Infrastructure Requirements:
Optimized assembly hall (6 weeks assembly)
1 module every week

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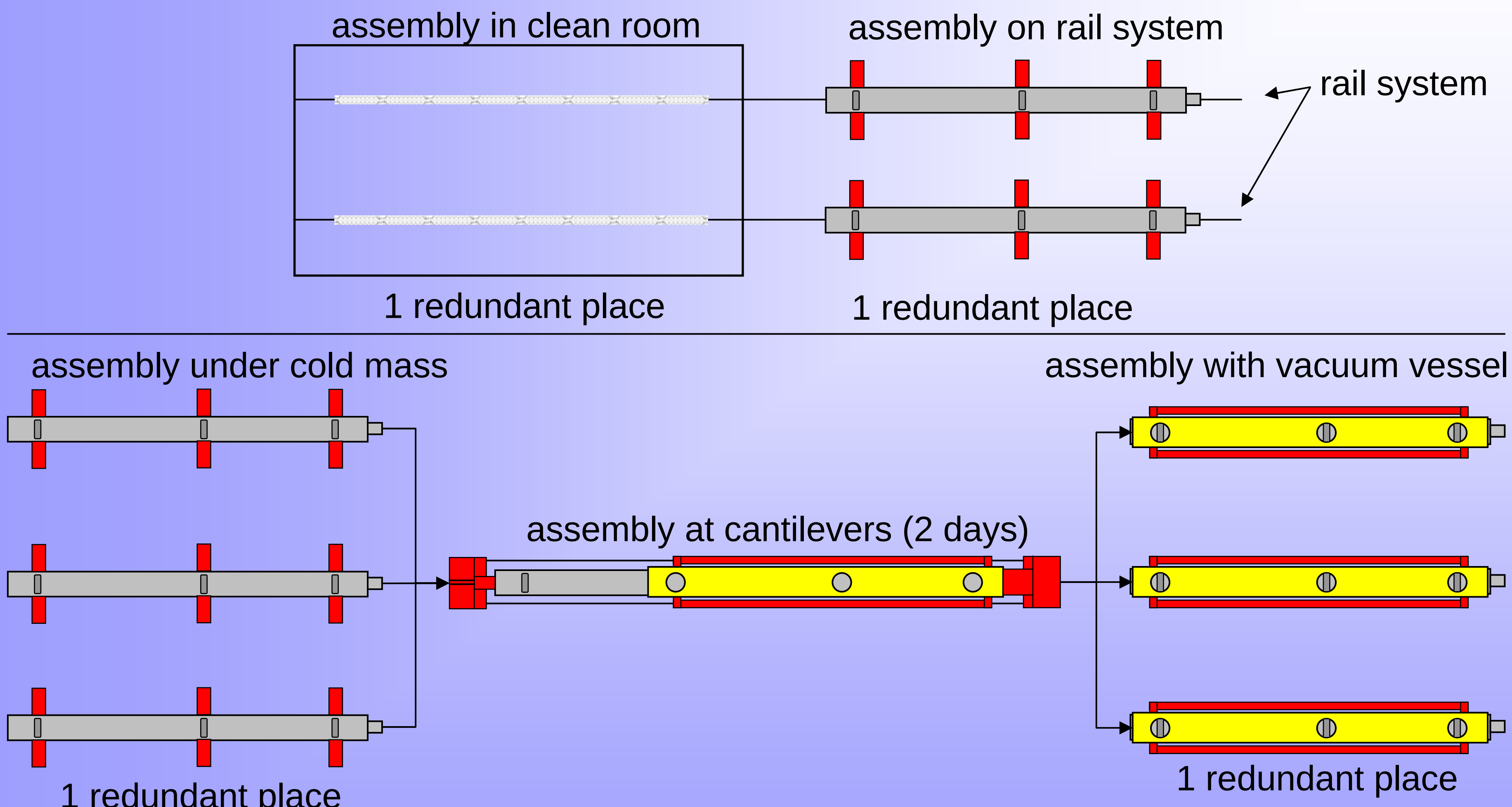

In case of technical problems, the module can be parked on redundant place.
working on other modules continues without interference

First summary on required time and staff

- Engineering / Organization
  - Assembly team A → clean room, assembly on rail system
  - Assembly team B → assembly under cold mass
  - Assembly team C → assembly at cantilever
  - Assembly team D → assembly with vacuum vessel
  - Electrician → all stations
  - Welder → all station
  - RF test, Leak check → all stations
  - Infrastructure maintenance → all stations
- QM / documentation

Technicians for clean room can work also outside clean room

Maximum work in clean room per day: 4 hours

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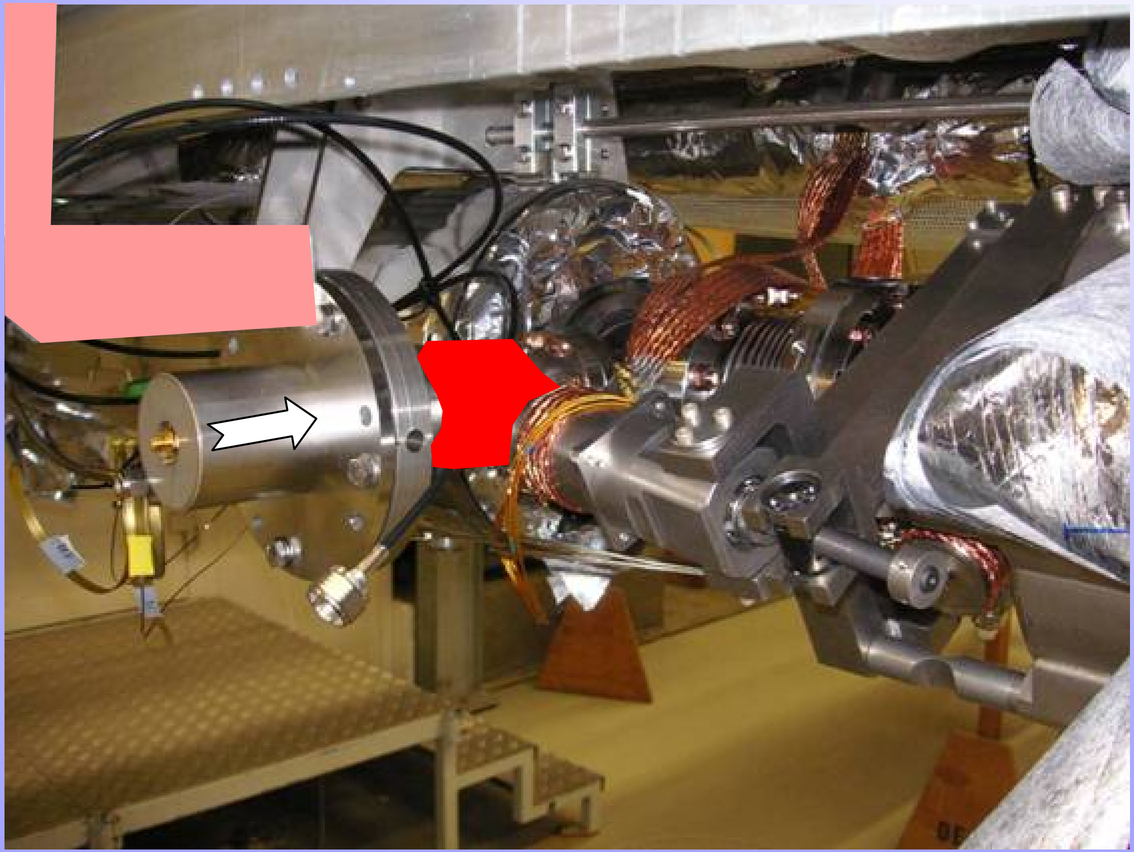
Specific Topics: Assembly of module with evacuated cavities

- There is a proposal to keep the cavity string under vacuum when it leaves the clean room for further assembly steps. We have found no good reasons to do this
- There is not a significant time saving. Basically, the cavities are purged and pumped down one times less. This may reduce the assembly time by one day, but the work load is not much reduced.
- Observing the total vacuum pressure or partial pressure with mass spectrometer will not detect a leak easily, because the desorption of the surfaces (10 m^2) is much bigger than a small leak
- Design changes on tooling especially at the coupler assembly necessary (see next slide)
- Alignment needs to be done under vacuum forces, different situation than later at operation
- Test assembly necessary

Assembly of module with evacuated cavities (cont)
Vacuum forces at the coupler

In case of evacuated string, the cold part of the coupler needs to be supported during the whole assembly against vacuum forces. This is currently not the case and new tooling needs to be developed and tested.



Specific Topics:
Transport of module with evacuated string to the module test at the XFEL site and into the tunnel

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- It should be considered to transport the modules with evacuated cavity string to the XFEL site for module testing. Then no additional pumpdown is necessary and responsibilities for eventual reduced cavity performance can not be linked to insufficient pumpdown of module at XFEL site.

- Transport of cavities to the tunnel and installation into the tunnel with evacuated cavities should be considered as well. This reduces the contamination of the module after module test, as no pumpdown of the string through intermediate vacuum sections assembled in the tunnel is needed.

Transport of XFEL modules

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- Module transport security: Use special designed end caps which allow securing the 300 mm helium gas return pipe relative to the flanges of the vacuum vessel. Lock posts.
- coupler needs transport security to protect the bellows from swinging of the big 70 K flange.
- Danger of vibration during transport. It has been observed, that nuts were un-tightened after transport due to vibration
- Danger from craning, loading and unloading, advisable to use a damped crane hook
- Use accelerometers to record the acceleration, impact time and impact value (integrated acceleration), critical value of 0.1 m/s impact value not to be exceeded
- Use special designed transport frame for module transport, like frame used for transport of 500 MHz modules (CESR type)

Example: Transport frame for 500 MHz modules

weight of module: 4.5 t

weight of frame: 1.5 t

transport frame consisting out of inner and outer frame

steel cable between inner and outer frame act as spring

500 MHz module assembled inside transport frame ready for shipment

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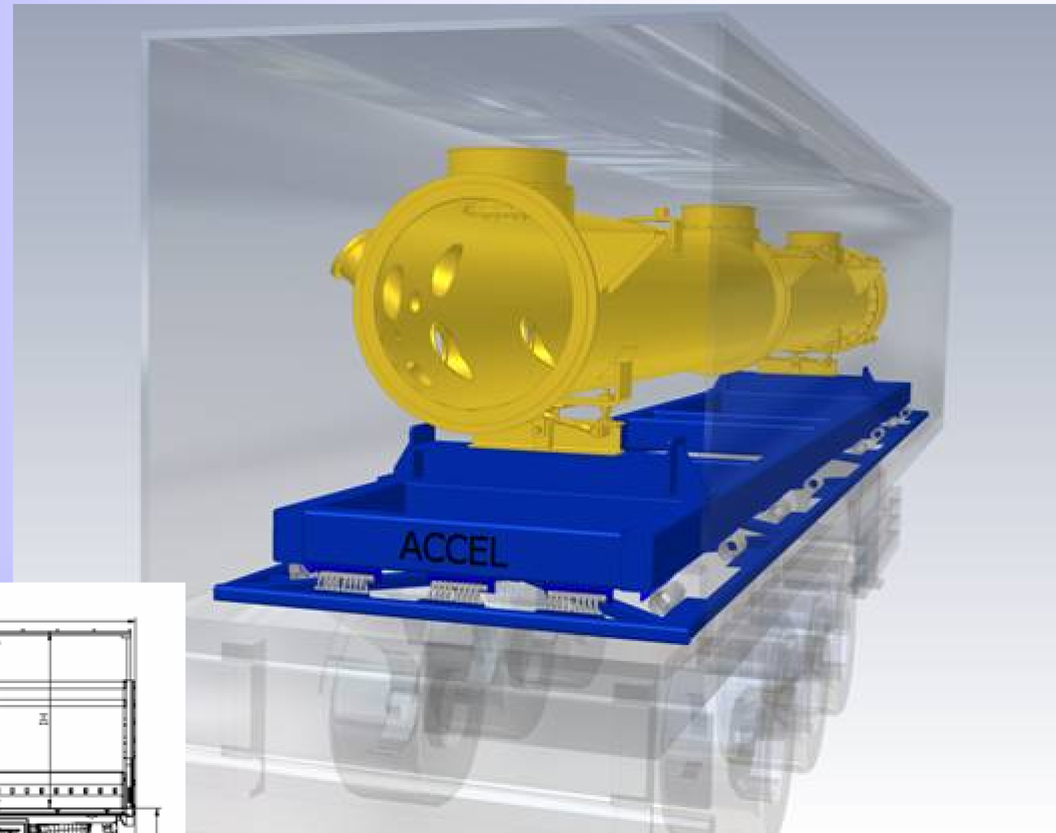
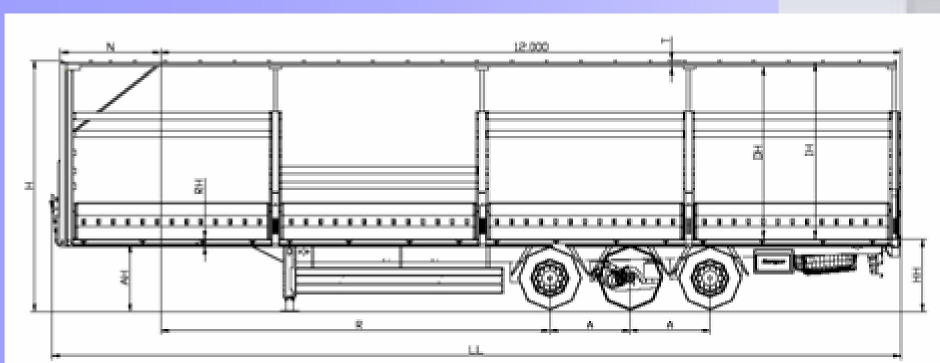
possible solution for XFEL module transports

- transport frame is mounted on truck
- truck can be loaded with crane from top
- truck travels between assembly site and XFEL site
- available length: 13.6 m
- available width 2.5 m
- available height: 2.5 m
- allowable weight: 12 t





Caution: top loaded road semi trailer hard to find outside EU. In US only hard cover or flat bed trucks (weather impact) available.

Transport on airport / in airplane

Always use roller beds when moving the module.

Always be present and with own personnel to supervise transport when moving the module

Transport on airport / in airplane

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transport on roller bed in aircraft

fixation of transport pallet in aircraft

loading aircraft from the side and from the front

Data logger results (500 MHz module transport)

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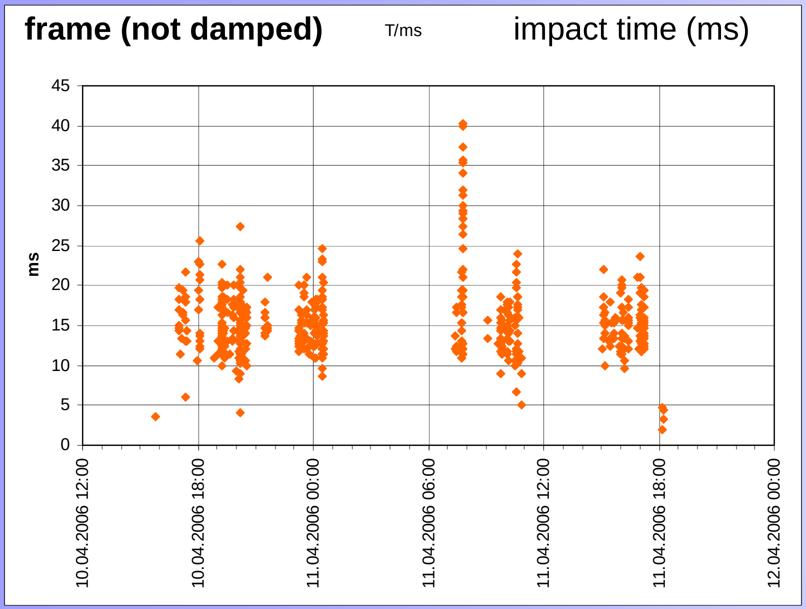

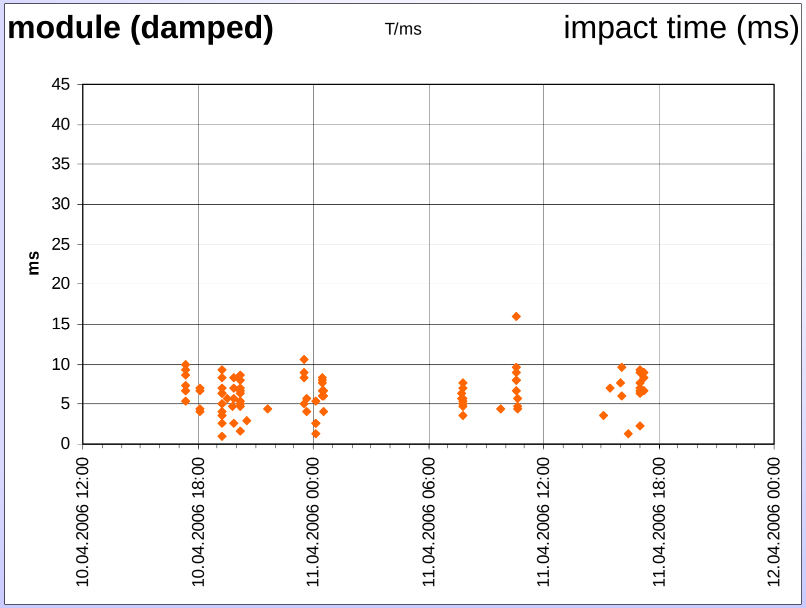

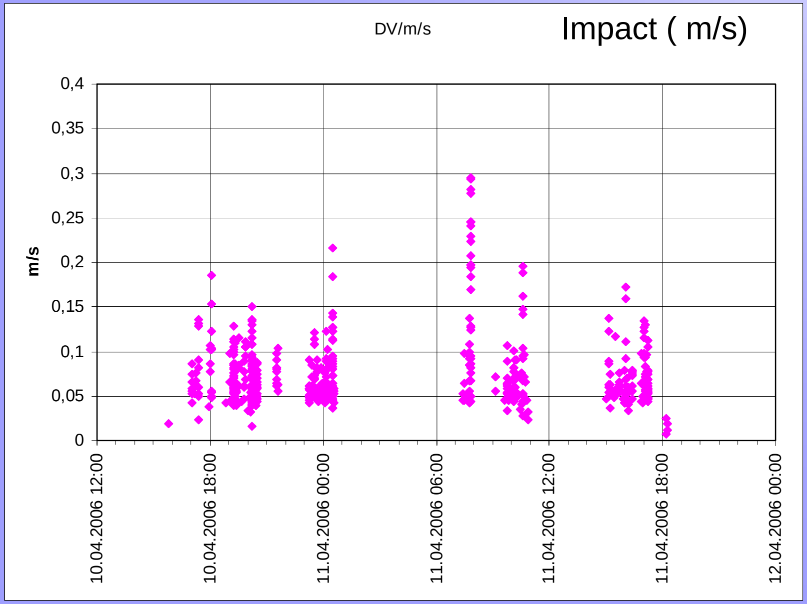

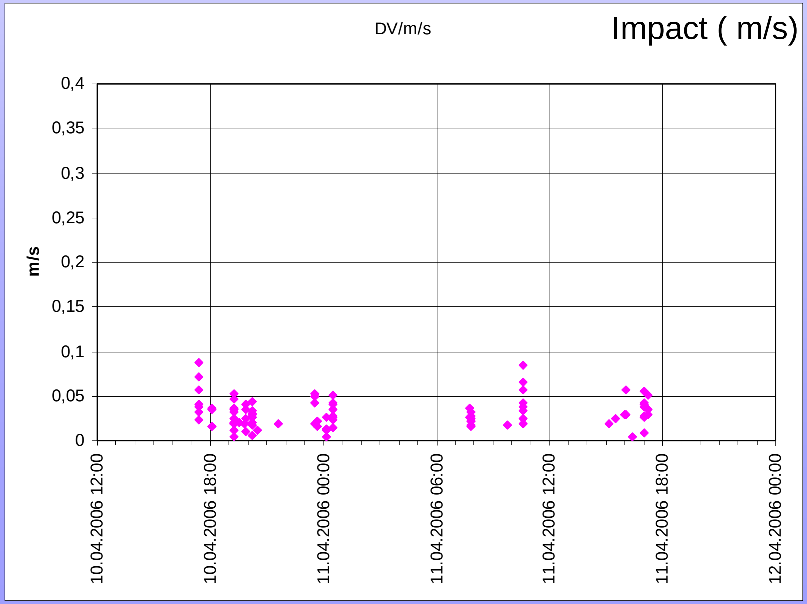

recorded acceleration during transport (500 MHz module)

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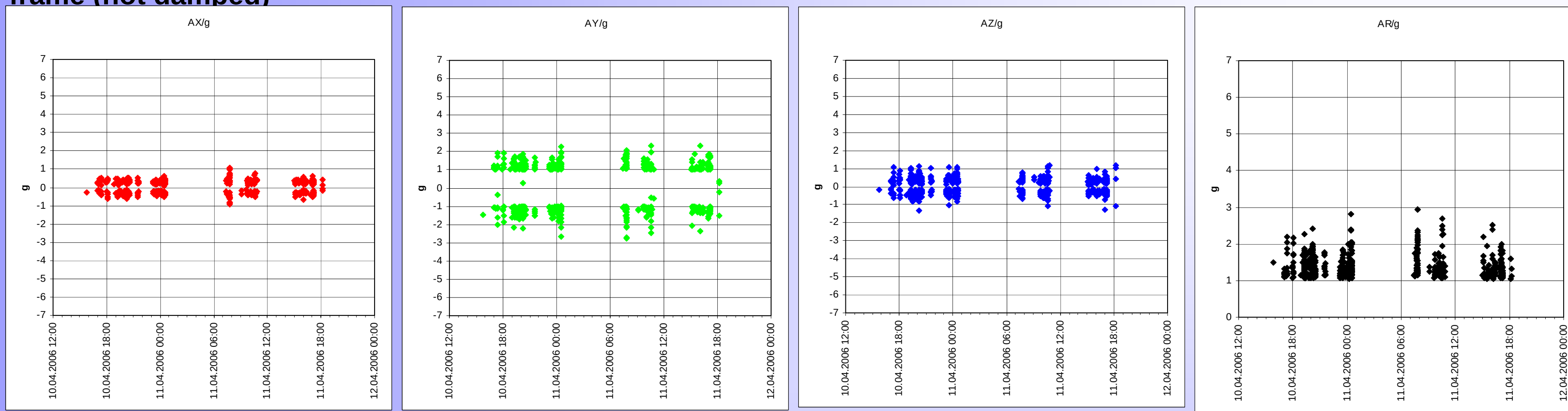
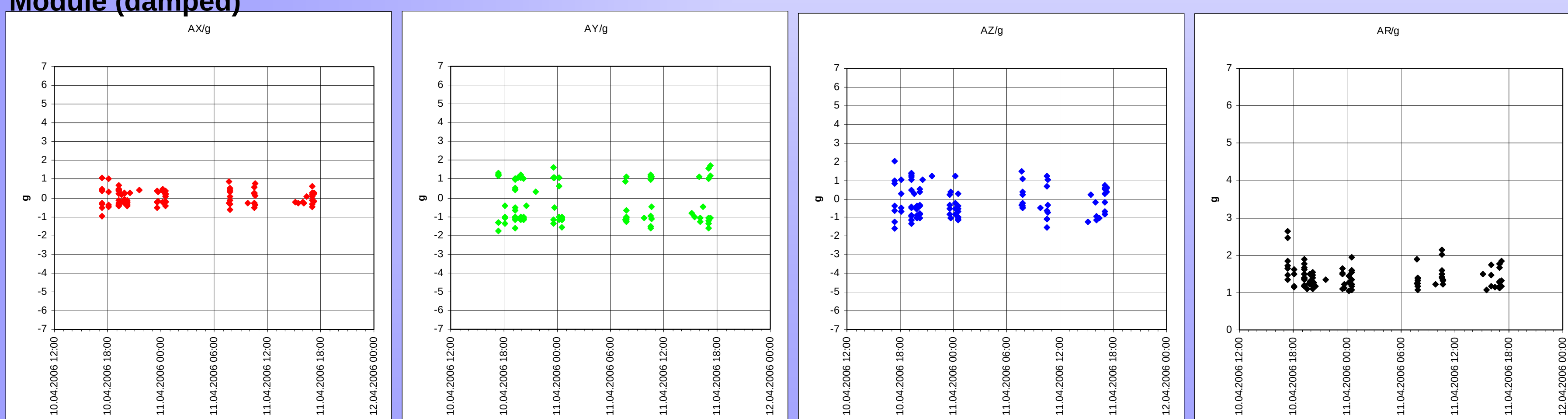
frame (not damped)



Module (damped)



X-direction **Y-direction** **Z-direction** **total amount**