PETRA IV RF Cavity Tuner: Plunger Refurbishment

25th ESLS-RF Meeting 2021 - DESY

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Hamburg, 8th November 2021

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

Outline

- Motivation
- Experiences from PETRA III
  - PETRA III Cavity Tuning Principle
  - PETRA III Tuning Plunger
  - ṙ-events
- PETRA IV Plunger Refurbishment
- Plunger Testing & Investigations
- Conclusions & Outlook

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Motivation

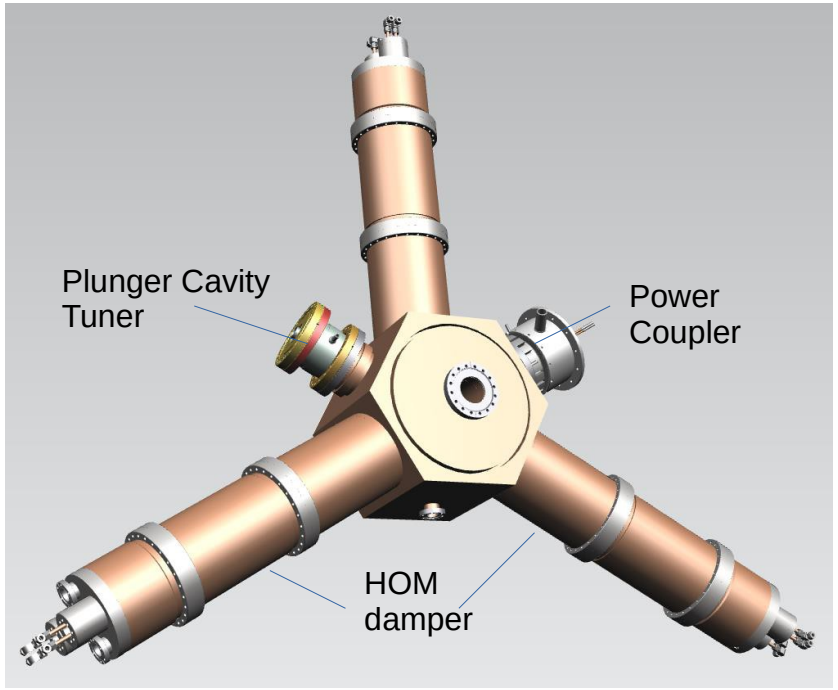
In PETRA IV a new RF system with 24 new 500 MHz EU HOM damped cavities will be installed (presentation by Stefan Wilke).

These cavities will be tuned by a piston plunger based on a design for PETRA cavities from the 1970s.

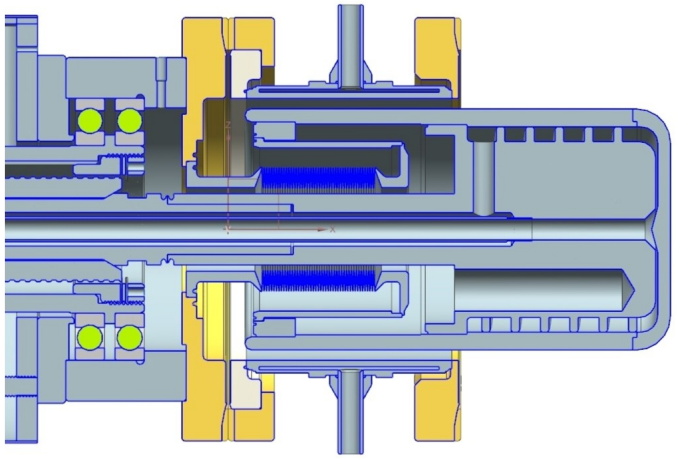
Plungers with such a design were used for cavity tuning by many institutes worldwide:

- At PETRA III cavity problems were observed which could be related to the tuning plunger.
- Other institutes use modified versions of these plunger successful.

These experiences and observations make it worthwhile to refurbish the tuning plunger for PETRA IV.



500 Mhz EU HOM damped Cavity



PETRA IV Plunger ReDESYgn

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Experiences from PETRA III

PETRA III Cavity Tuning

At PETRA III 12 7-cell 500 MHz Cavities are used for acceleration.

The cavities are tuned with two tuning methods:

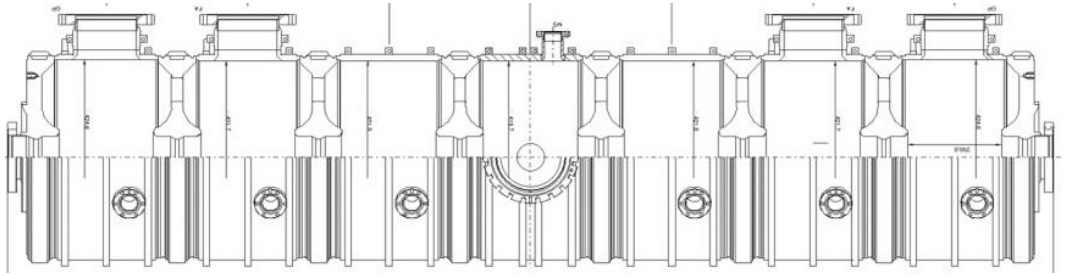
Coarse Tuning by cooling water flux:

- Keeping the cavity temperature constant to avoid thermal drifts by regulating the cooling water flux through the cavity (+/- 0.1°C).

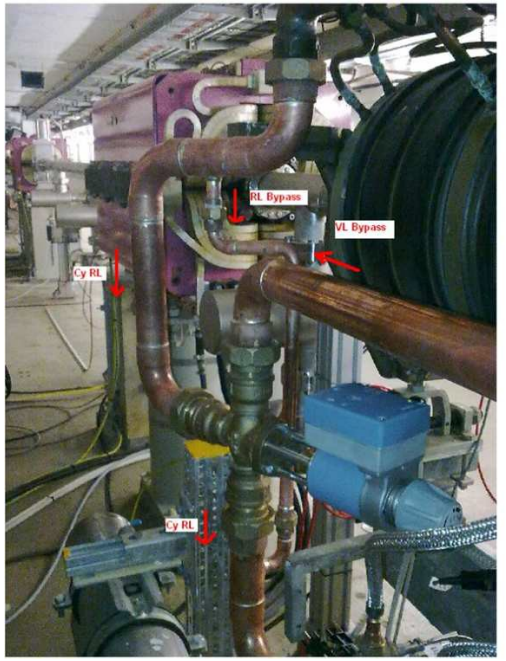
Fine Tuning by Piston Plunger (~800 kHz):

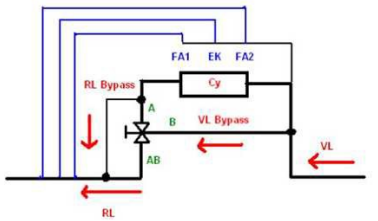
- Tuning the resonance frequency of the cavity by changing its volume by a moving piston plunger in the 2nd and 6th cell.
- Keeping the phase difference constant by PLC.

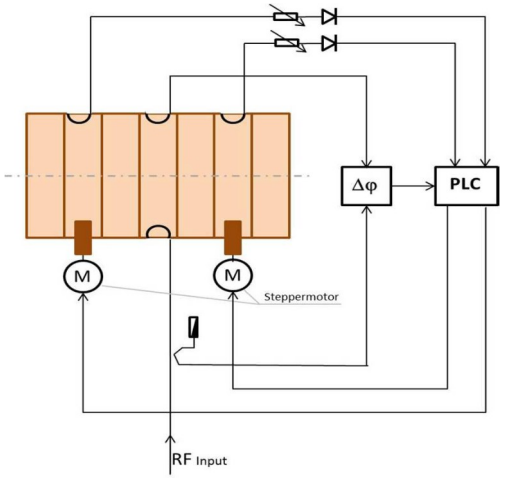
At PETRA IV cavities the same tuning principles will be used.



PETRA 7-cell 500 MHz cavity







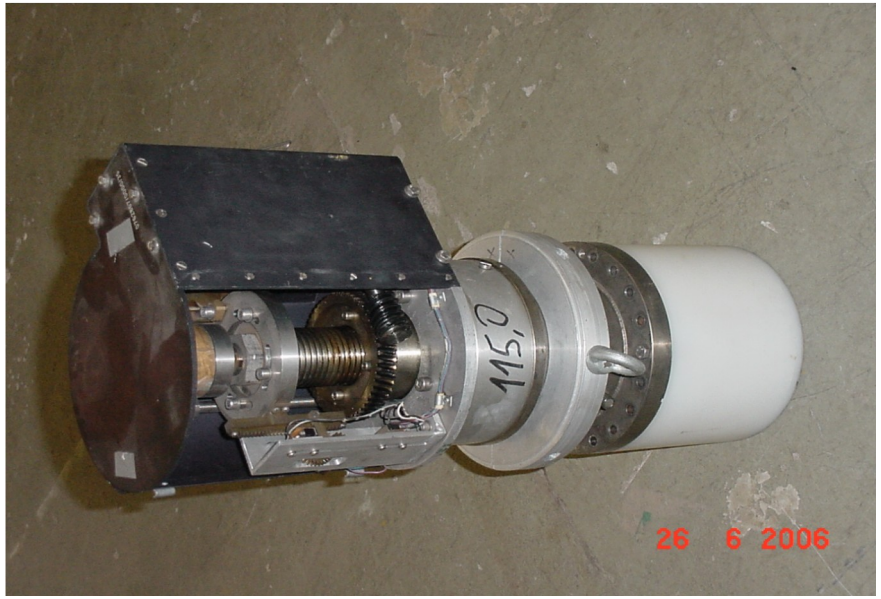
Tuning principles of PETRA cavities
R. Onken

Experiences from PETRA III

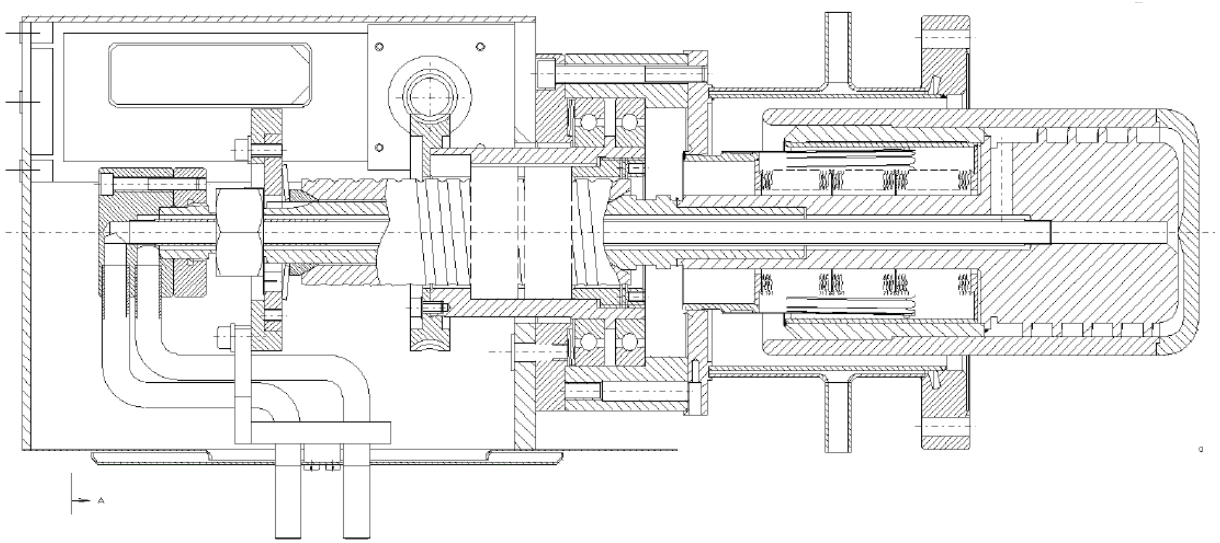
PETRA III Cavity Tuner Plunger

The Cavity Tuner was designed in 1976 for the PETRA cavities:

- Step Motor driven, water-cooled Piston Plunger
- flexible bellow as vacuum barrier
- Copper contact springs to protect bellow from RF currents
- Tuning Range (800 kHz): - 20 mm < x < 40 mm



PETRA Cavity Tuner, M.Ebert

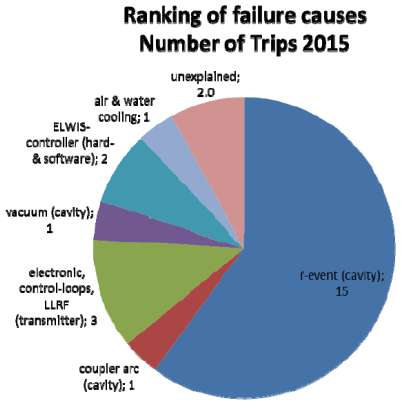


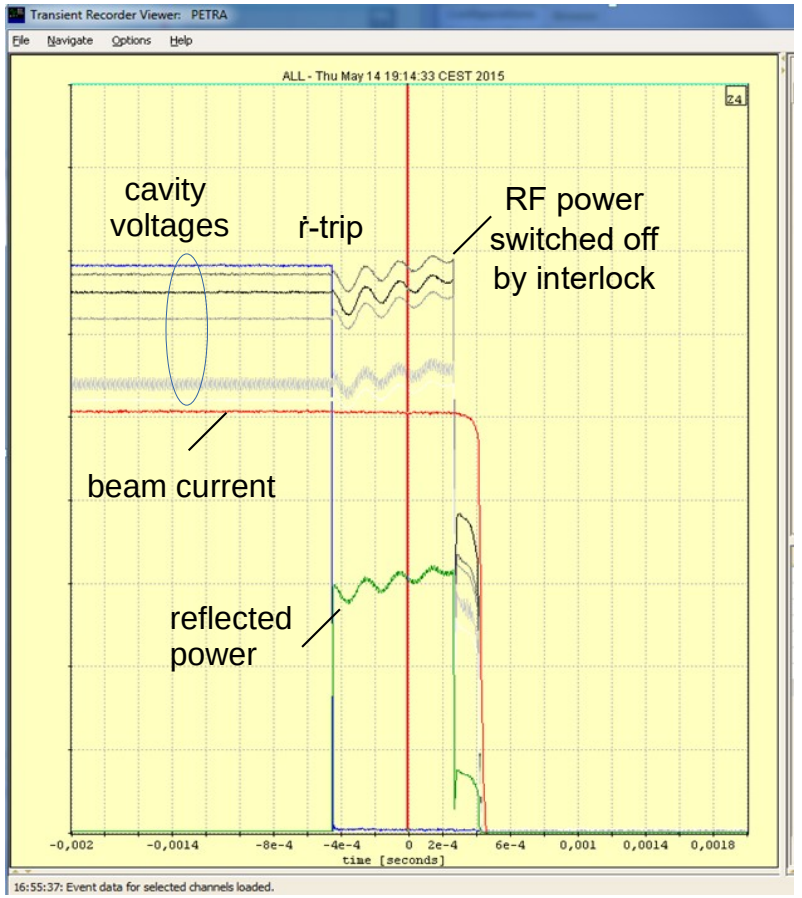
Technical Drawing PETRA Cavity Tuner

Experiences from PETRA III

ṙ-events:

- ṙ=dr/dt: differential reflected power
- ṙ-events were characterized by a sudden rise of reflected power in one cavity.
- ṙ-events were the main reason for cavity trips until 2015.
- Some cavites have more ṙ-events then others.
- Cavity Plunger are always suspected as reason for this events.
- Extensive Investigations were initiated to find the reason for the ṙ-events.





Typical signature of an ṙ-event

Experiences from PETRA III

ṙ-events:

In 2014 findings of old bead-pull-measurements from 1982/1983 bear out the suspicion that the plunger could be one reason for the ṙ-events.

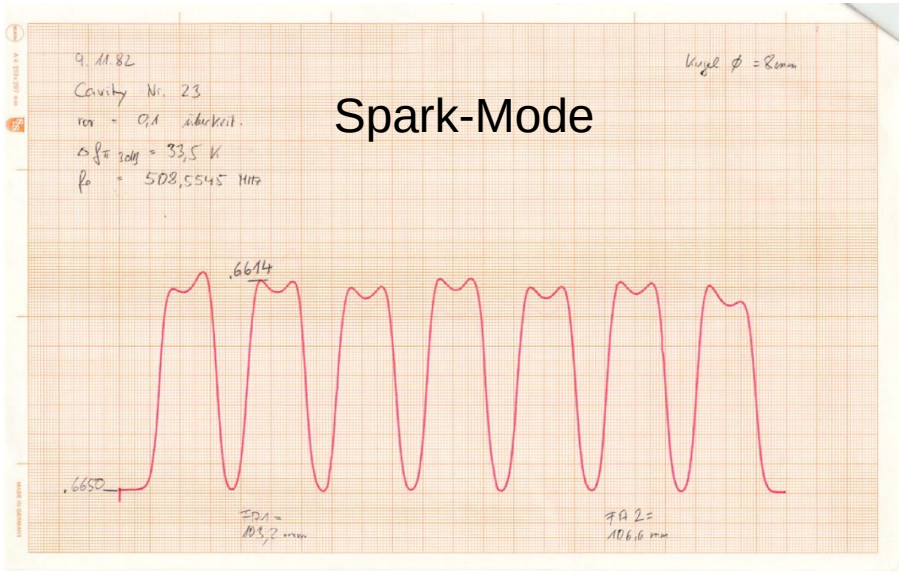
The cavities with most ṙ-events have a balanced fiels distribution (Spark-Mode).

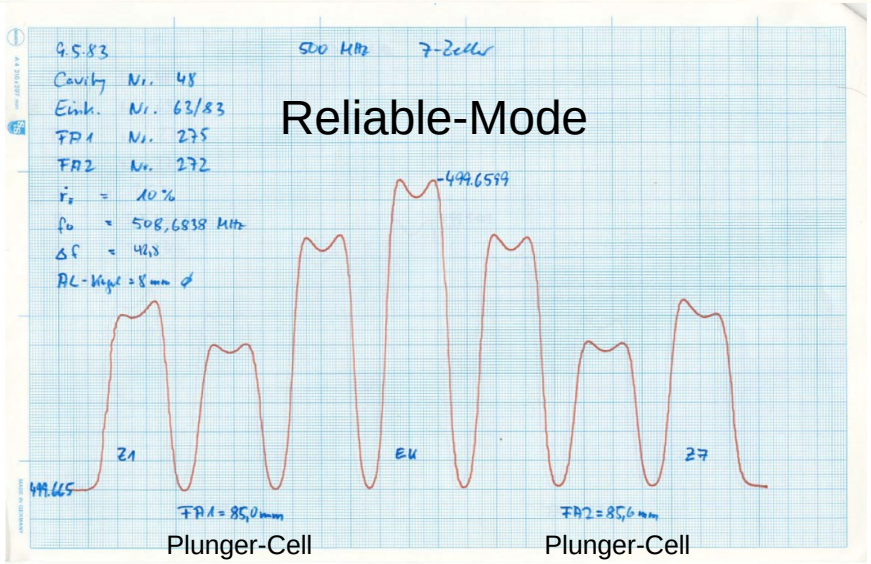
The cavities with less ṙ-events have reduced fields in the plunger cells (Reliable-Mode).

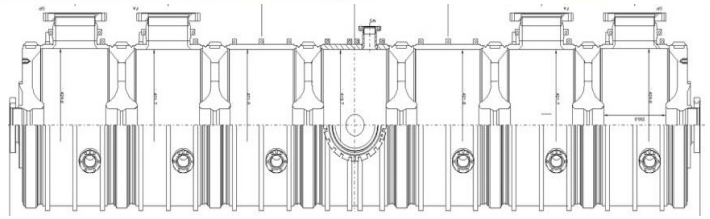
By heating up the unreliable cavities up to 70 °C the field pattern of the unreliable cavities could be turned to that of the reliable cavities.

This method reduced the number of ṙ-events significantly.

At PETRA IV:
single-cell cavities → This method is not usable!!







Experiences from PETRA III

ṙ-events: Plunger Inspections

Due to the plunger design (bellow welded on flange) inspection of most plunger parts is only possible by destroying the plunger.

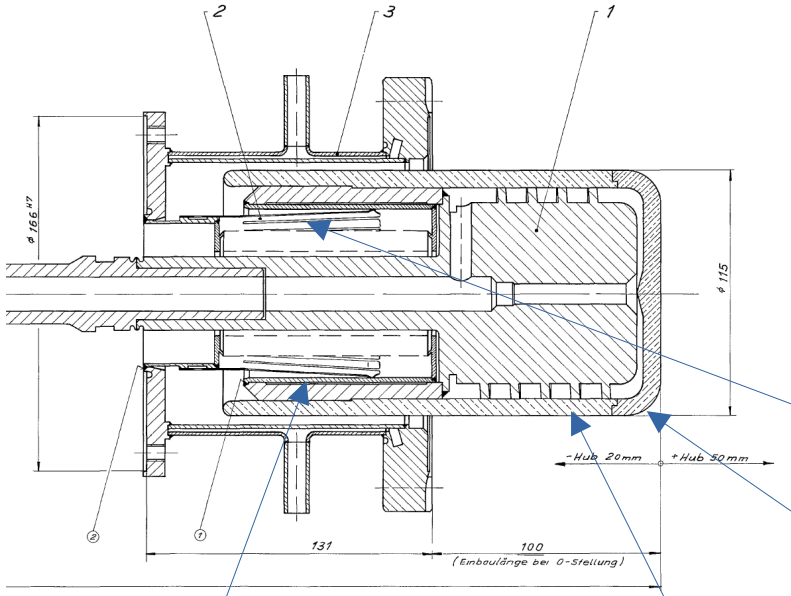
Plunger Head:

- areas (extensive, circular) with electrical stress marks

RF Contact Fingers:

- scratch marks on inner contact ring
- burned copper on inner contact ring
- circular traces of arching between fingers

Many of these traces are already seen on PETRA and HERA plungers.



M.Ebert

M.Ebert

M.Ebert

M.Ebert

Experiences from PETRA III

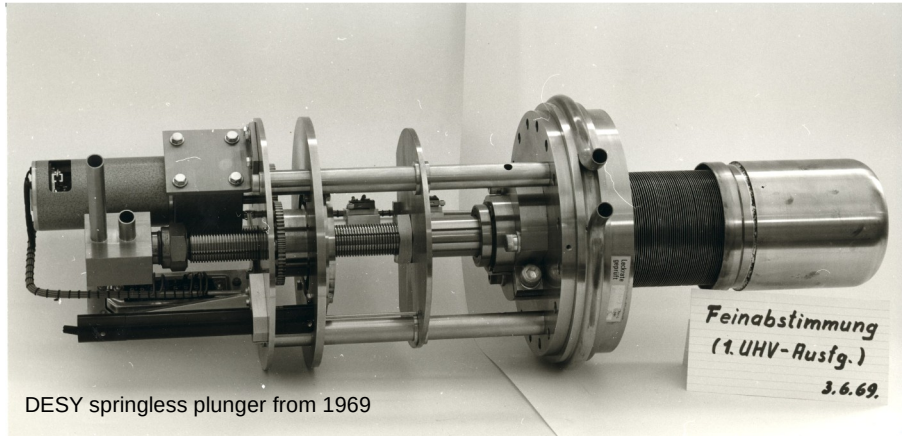
ṙ-events: Plunger RF Contact Fingers

The first plunger with such a design at DESY were build without contact springs.

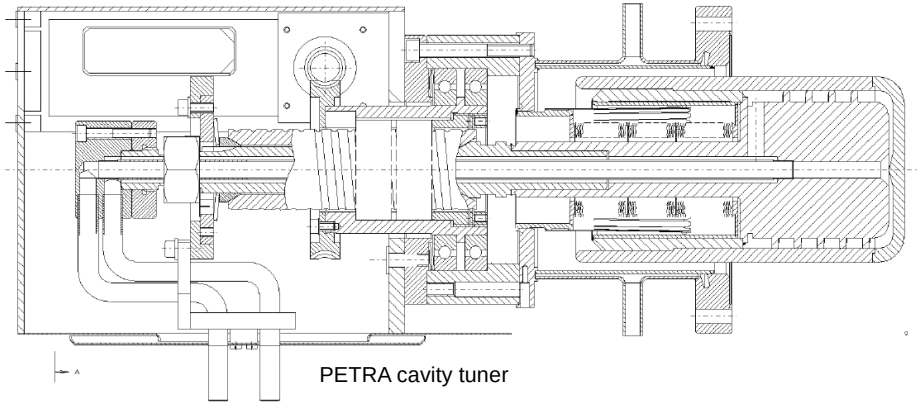
Technical Report PETRA Cavities (1977): Contact springs were introduced to protect the bellow from rf currents.

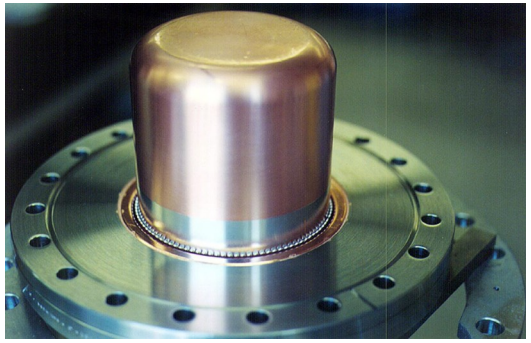
PEP-2 476 MHz cavity tuner: The contact springs were placed at a position, where the ¼ wavelength resonance is placed between the lowest two longitudinal cavity modes (750 MHz & 1300 MHz). [1].

Some institutes use plungers without contact fingers successfully.



DESY springless plunger from 1969


PETRA cavity tuner

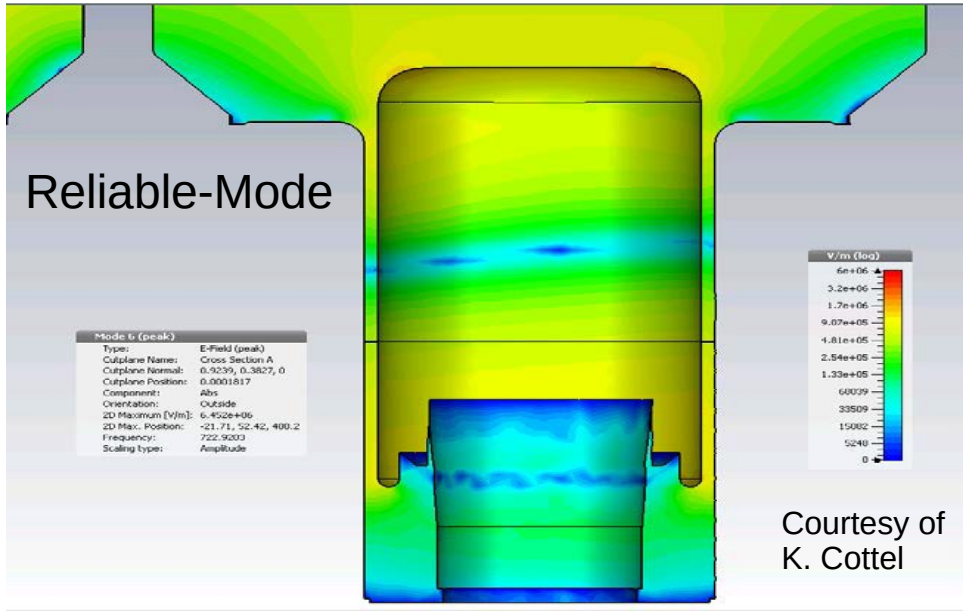

PEP-2 476 Mhz piston plunger cavity tuner [1]

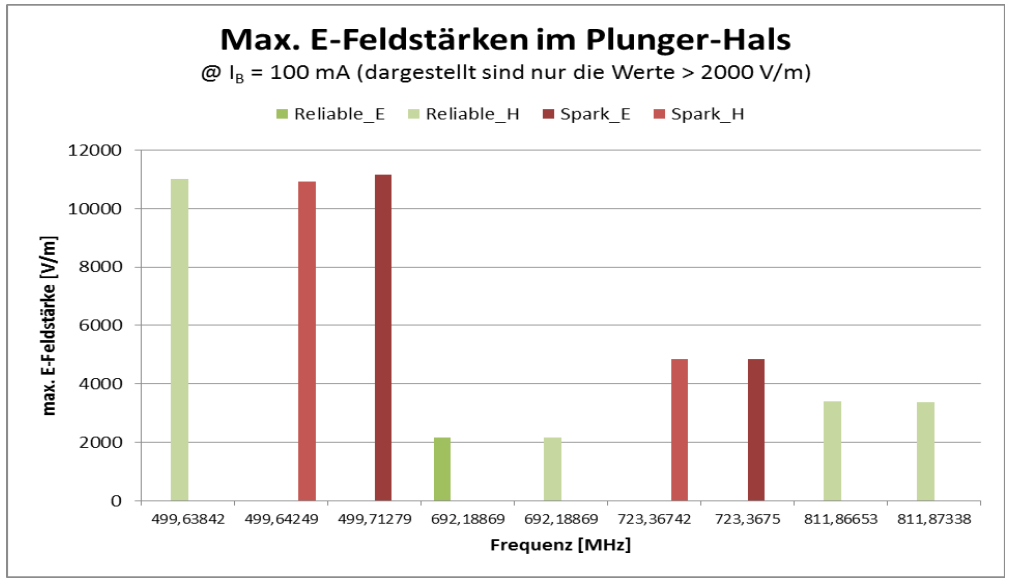
[1]: Development of a Movable Plunger Cavity Tuner for the High Power RF Cavity for the PEP-II Factory, Schwarz et al., PAC97 proceedings, pp. 3039

Experiences from PETRA III

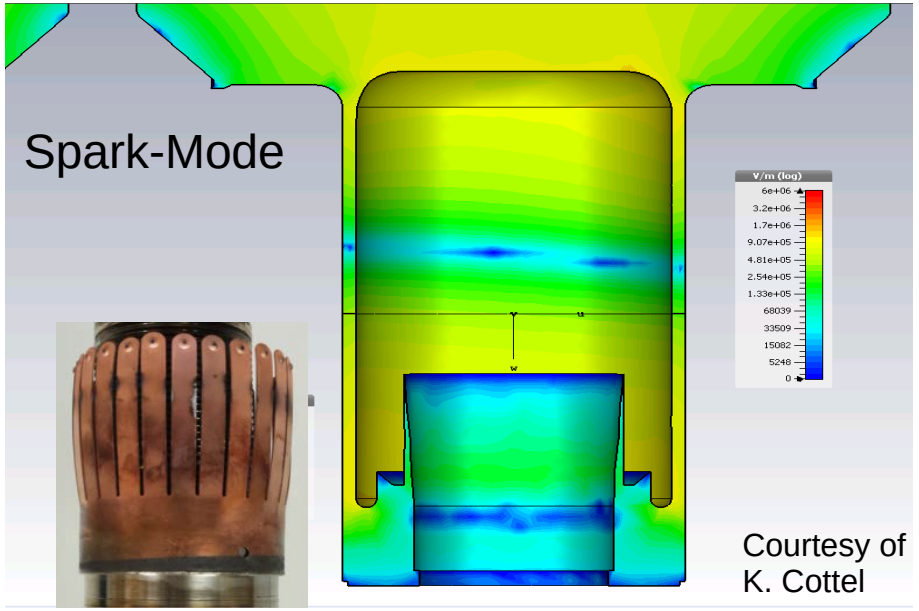
ṙ-events: RF Simulations

- Detailed CST MWS simulations were carried out by DESY (K. Cottel) and TU Darmstadt (TEMF institute).
- Eigenmode simulations of PETRA III Cavity showed that the TM011-Mode in the “spark”-mode is close to the 139th machine line at 723,47 MHz and can excite the 3/4-wavelength coaxial resonance in the plunger.





f_{HOM} / MHz	R_S / kΩ	Modell
722,92	2394	Reliable-E
722,92	2394	Reliable-H
723,35	2472	Spark-E
723,35	2472	Spark-H
723,47		139*fu*Nb



Simulation Results: Resonances close (<100 kHz) to the 40 bunch machine lines [Courtesy of W. Ackermann, TU Darmstadt, Institut für Theorie Elektromagnetischer Felder]

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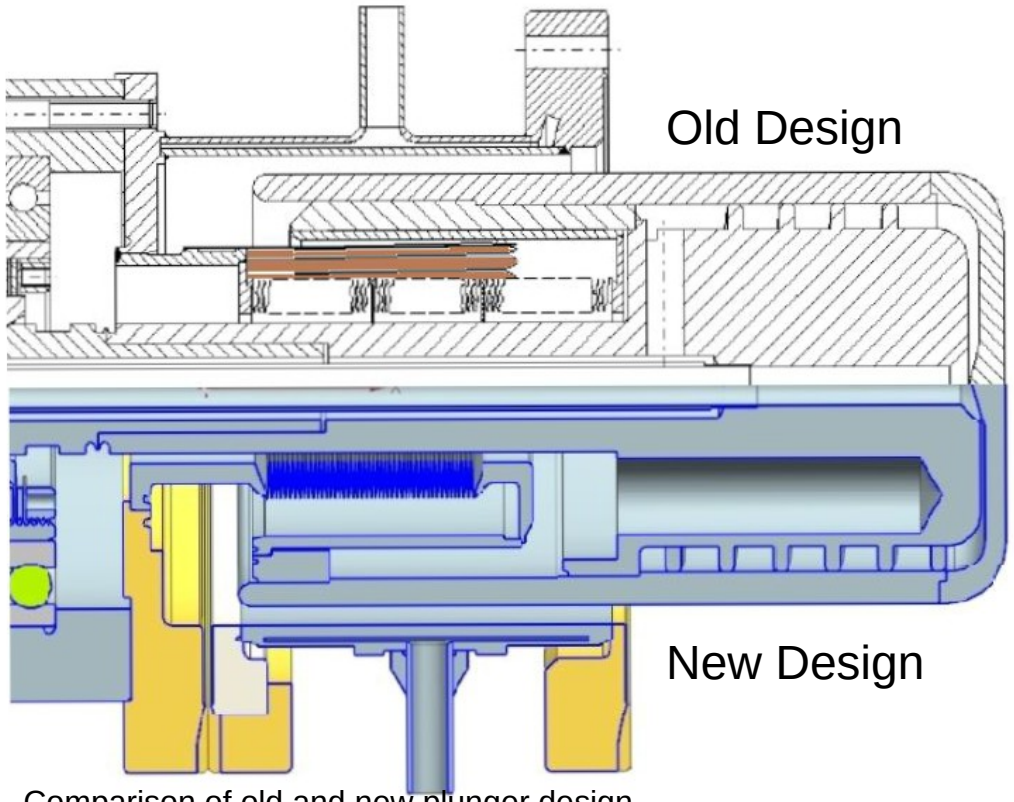
PETRA IV: Plunger Refurbishment

Plunger ReDESYgn for PETRA IV

Considering experiences from PETRA III and modifications of other institutes, a new plunger was designed:

- based on DESY design
- reuse most of the components like step motor driving unit, because more than 100 are available from HERA/PETRA
- Two major modifications:
  - Additional second flange:
    - Better diagnostic & inspection of inner/lower side of plunger.
  - Omitting rf contact springs:
    - Suspicion that contact springs are reason for ṙ-events.
    - No reported bad experience by other institutes.
    - But: Damage (Leakage) of vacuum bellow will lead to serious consequences for cavity & operation → Extensive Testing is required.



Comparison of old and new plunger design

4 prototypes are build and now ready for testing.

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Plunger Testing & Investigations

Open Questions and Testing Tools

Before using the Plunger in PETRA IV cavities the following questions and challenges have to be solved:

- **Are the RF contact springs a reason for the ṙ-events in the PETRA III Cavity Tuning Plunger?**
- **Does the unprotected vacuum bellow resist the rf currents induced by Fundamental and Higher Order Modes?**
- **Where are potential arching spots in the plunger?**

Tools for Testing and Investigation:

- new developed Plunger Teststand
- Cavity Teststand CaTs
- PETRA III

Supplementary RF simulations are carried out by DESY and TU Darmstadt.

Plunger Testing & Investigations

Plunger Teststand

Based on the findings so far a Plunger Teststand was developed to excite the plunger as ¼ or ¾ wavelength coaxial resonator to:

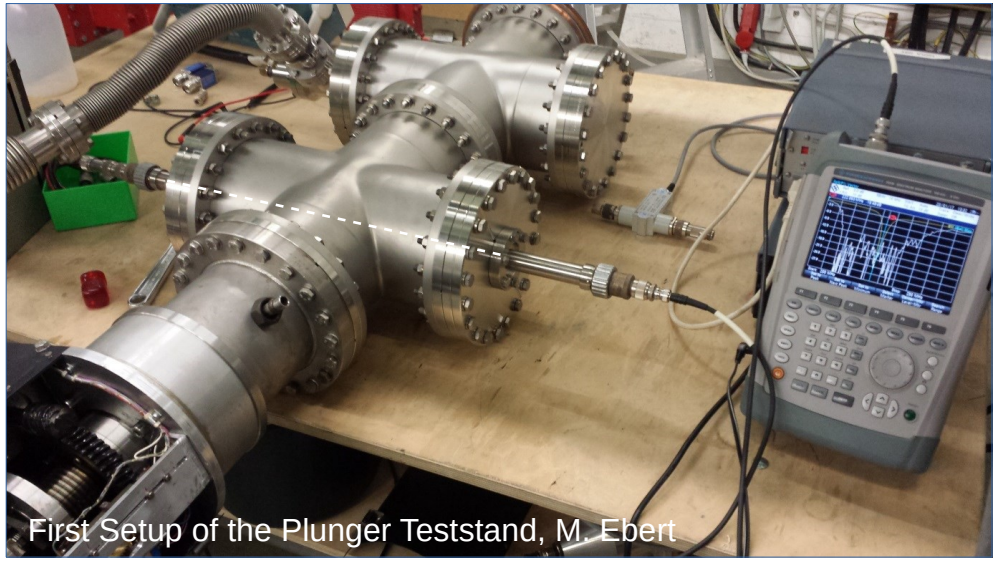
- initiate ṙ-events in plunger

- compare old and new plunger design

Setup with two standard CF vacuum crosses:

- ports for vacuum, diagnostics, rf windows,…
- 1kW SSA (200-1000 MHz)
- easy to modify and upgrade

CST MWS Simulations and Low Level Measurements shows possibility to excite the plunger as coaxial resonator.



First Setup of the Plunger Teststand, M. Ebert

Plunger Teststand in former DORIS RF Hall, R.Onken

Plunger Testing & Investigations

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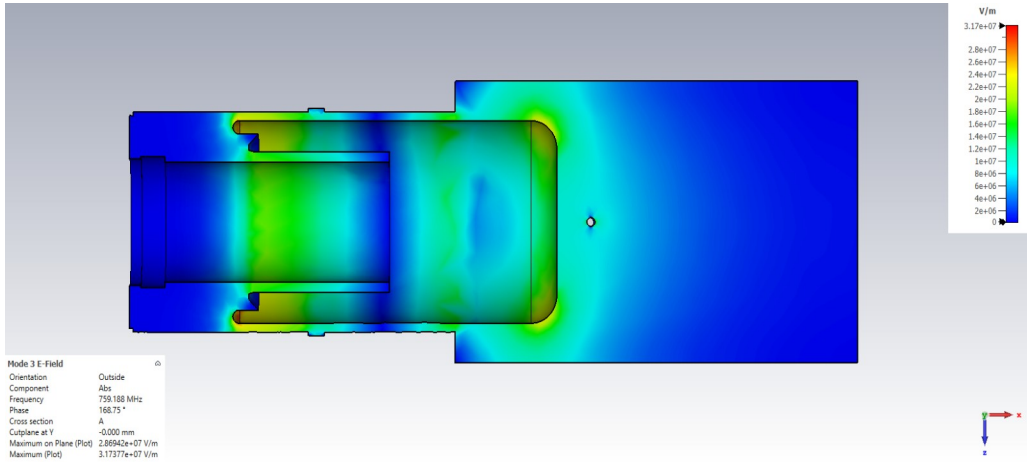


CST MWS Eigenmode Simulation of Plunger Test Stand

Plunger Testing & Investigations

Cavity Teststand (CaTs)

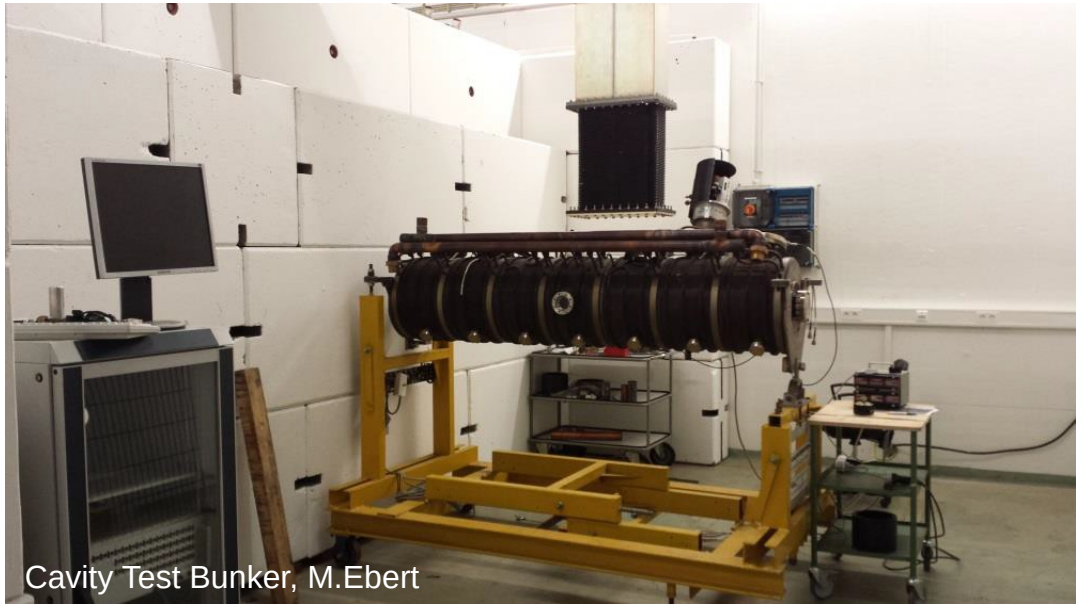
In 2016 a former DORIS transmitter was turned into a new cavity and klystron teststand.

CaTs is now used for:

- cavity conditioning
- high power tests of cavities.

For the new PETRA IV Plunger the resistance of the unprotected vacuum bellow to the fundamental mode rf currents at full cavity power can be tested at CaTs.

Former DORIS transmitter, M.Ebert



Cavity Test Bunker, M.Ebert

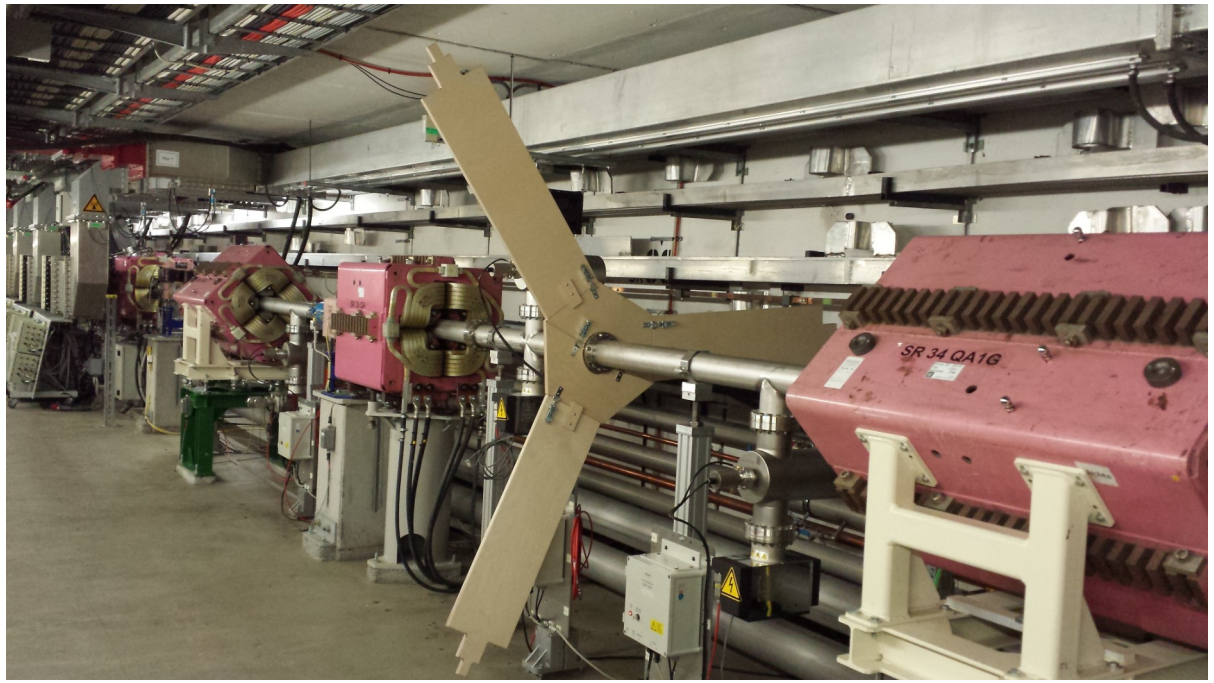
Plunger Testing & Investigations

PETRA III

In the Summer Shutdown 2022 or Winter Shutdown 2022/2023 a new HOM damped 500 MHz cavity will be installed in the PETRA III ring.

This gives the possibility to study:

- beam induced HOMs in the plunger
- influence of the plunger-caused field asymmetries to the beam.



PETRA IV cavity dummy in the PETRA III ring, M.Ebert

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Conclusions

The Cavity Tuning Plunger at PETRA III is identified as highly suspicious reason for cavity trips caused by ṙ-events.

A modified plunger was designed and build with a second flange for inspection and without RF contact fingers. Four prototypes are now ready for testing.

Before using this plunger in PETRA IV cavities extensive testings and investigations are required and the following questions needs still to be clarified:

- Are the contact fingers a reason for ṙ-events?
- Does the vacuum bellow resist rf currents (induced by Fundamental & HOMs)?
- Where are potential arching spots in the plunger?

For testing a new Plunger Teststand was developed.

Further investigation will be caried out using the Cavity Teststand CaTs before installing a new HOM damped cavity with the refurbished plunger in the PETRA III ring.

Thank you for your attention!

How are your plunger experiences?

Contact

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