High Resolution BPM

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Presented by Igor Syratchev

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A BPM for CLIC

Where	Main Beam, before Quadrupole
Bunch frequency	2 GHz
Meas. Frequency	2xn GHz
Q_L	<400
Wakefields	$W_L(s)$<46V/pC $W_T(s)$<13V/pC/mm
Requirements	Aperture >4 mm Precision 10μm Resolution 50nm
Available length	95mm/65mm

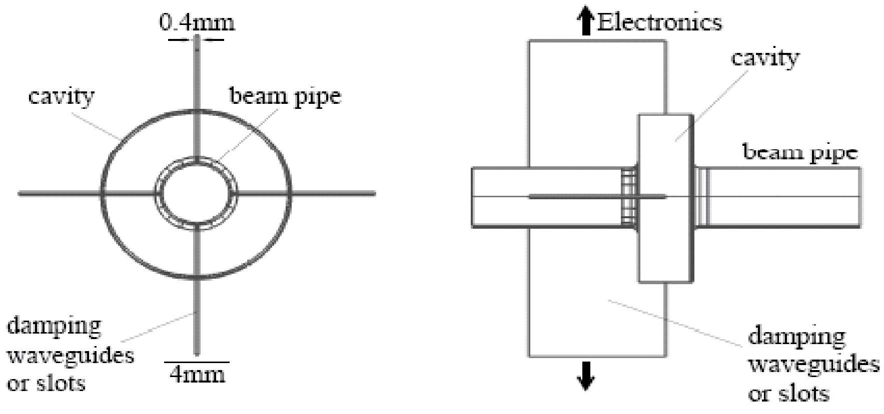


Figure 5.18: A "beam perspective" (left) and a side-view (right) of the BPM proposed for CLIC.

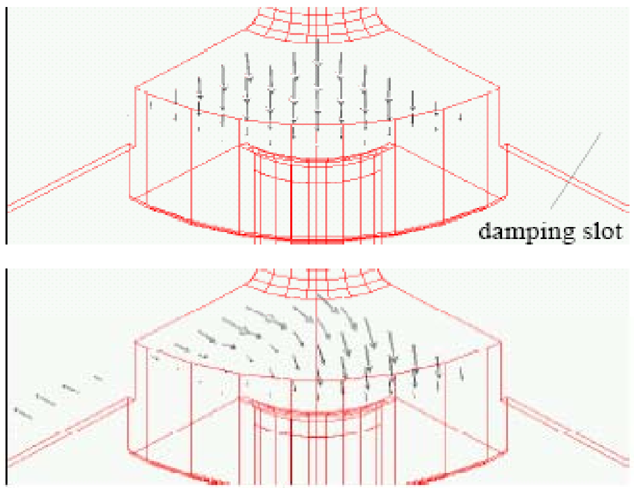


Figure 5.19: Electric fi eld vector of the TM_{01} (top) and TM_{11} (bottom) mode. Only a quarter geometry is displayed as the geometry has a fourfold symmetry. One can see that the dipole mode couples to the slots whereas the monopole mode does not.

The first study of the precision BPM for CLIC was done back in 2002.
At that time the idea was to use slotted TM 11 cylindrical cavity to increase the rejection of the common mode due to:
1. Natural symmetry
2. The cut-off properties of the waveguide.

To manipulate the impedance of the cavity, the tuning of the waveguide and the cavity mutual position was foreseen.

CERN-THESIS-2003-032

Beam Position Monitoring at CLIC

Prochnow, J ; Wuensch, Walter (dir.)
(RWTH Aachen)
Geneva : CERN, 2003. - 134 p.

PhD : RWTH Aachen : 2003

Slotted cavity BPM family

DESIGN OF A SUBMICRON RESOLUTION CAVITY BPM FOR THE ILC MAIN LINAC

A. Lunin, G. Romanov, N. Solyak, M. Wendt, FNAL, U.S.A.*

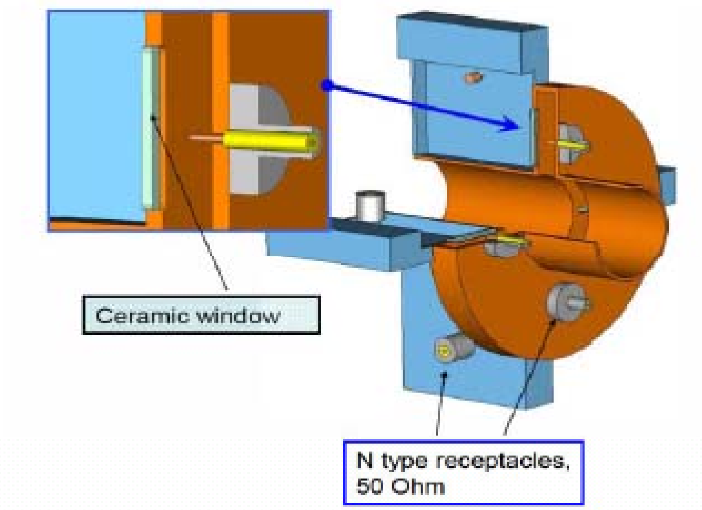


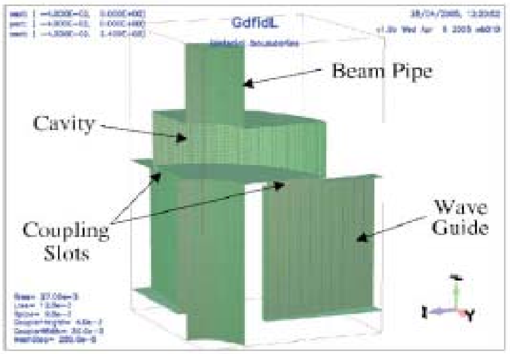
Figure 1: FNAL L-Band Cavity BPM.

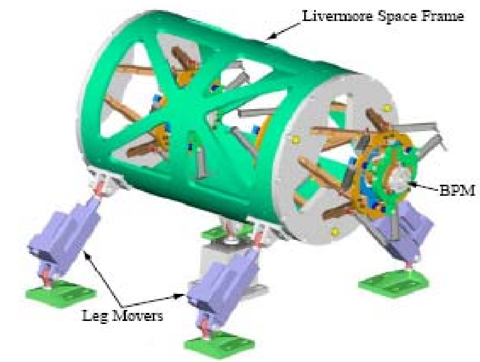
DIPAC 2007

TUPCH105 Proceedings of EPAC 2006, Edinburgh, Scotland

PERFORMANCE OF A NANOMETER RESOLUTION BPM SYSTEM *

S. Walston, † C. Chung, P. Fitsos, J. Gronberg, LLNL, Livermore, California, USA
R. Meller, Cornell University, Ithaca, New York, USA
V. Vogel, DESY, Hamburg, Germany
H. Hayano, Y. Honda, N. Terunuma, J. Urakawa, KEK, Tsukuba-shi, Ibaraki-ken, Japan
Y. Kolomensky, T. Orimoto, LBNL, Berkeley, California, USA
S. Boogert, Royal Holloway, University of London, Egham, UK
J. Frisch, J. May, D. McCormick, M. Ross, S. Smith, T. Smith, SLAC, Menlo Park, California, USA
M. Slater, M. Thomson, D. Ward, University of Cambridge, Cambridge, UK
A. Lyapin, S. Malton, D. Miller, University College London, London, UK
G. White, University of Oxford, Oxford, UK and SLAC, Menlo Park, California, USA





We have achieved a resolution of 16.9 nm to date.

CAVITY BPM WITH DIPOLE-MODE-SELECTIVE COUPLER*

Zenghai Li, Ronald Johnson, Stephen R. Smith, SLAC, USA; Takashi Naito, KEK, Japan; Jeffrey Rifkin, Lyncean Technologies, USA

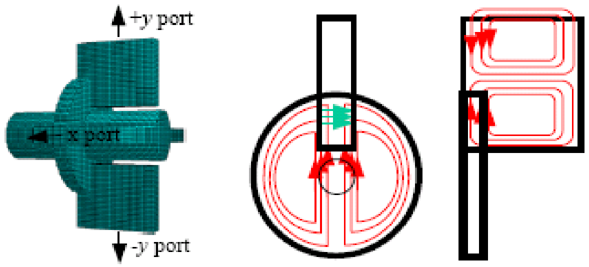
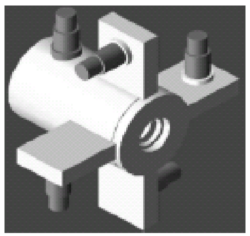


Figure 1 Cavity BPM with dipole mode selective coupler.

PAC 2003

PROTOTYPE FOR THE NLC

A prototype X-band cavity BPM for the NLC was designed and cold tested. A picture of the cold test model and the cavity BPM parameters are shown in Fig. 10. A resolution better than 100*nm* has been obtained. Detailed cold test setup and test results can be found in ref. [7,8].



Cavity gap	3*mm*
Beam pipe radius	6*mm*
Waveguide	3x18mm^2
r of coupling-slot	8*mm*
rms resolution	100*nm*

Figure 10 Cold test model of the NLC cavity BPM.

Another approach suggests to use the so called choke cavity. In this case the common and HOM are not rejected, but heavily damped.

*NANOMETER RESOLUTION BPM USING DAMPED SLOT RESONATOR**

S.C. Hartman
Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94309 USA
T. Shintake and, N. Akasaka
KEK, Naitonal Laboratory for High Energy Physics, 1-1 Oho, Tsukuba-shi, Ibaraki 305 JAPAN

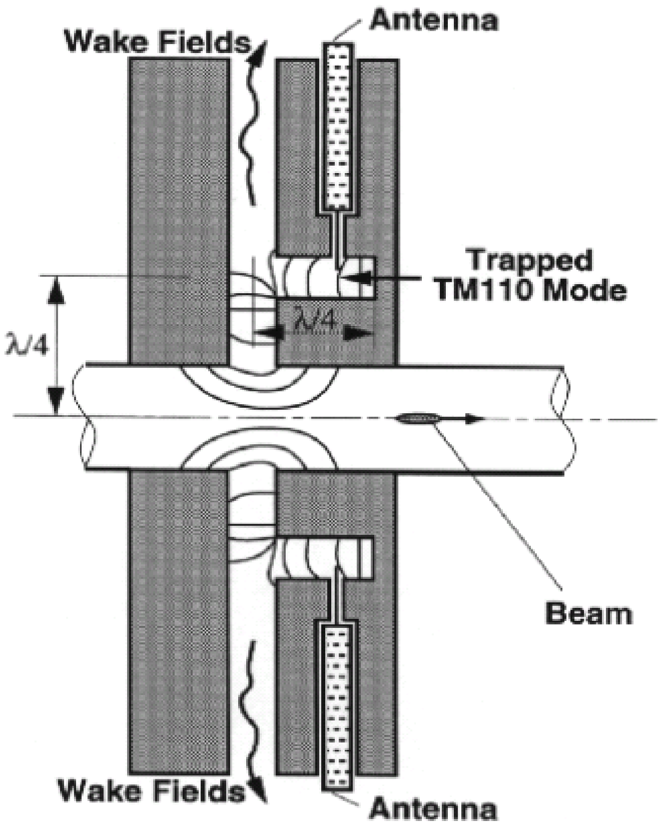


Figure 1. Damped Slot Resonator BPM.

DEVELOPMENT OF NANOMETER RESOLUTION C-BAND RADIO FREQUENCY BEAM POSITION MONITORS IN THE FINAL FOCUS TEST BEAM*

T. Slaton and G. Mazaheri
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94309 USA

T. Shintake
KEK: National Laboratory for High Energy Physics, 1-1 Oho, Tsukuba-shi, Ibaraki 305 Japan

SLAC-PUB-7921
August 1998

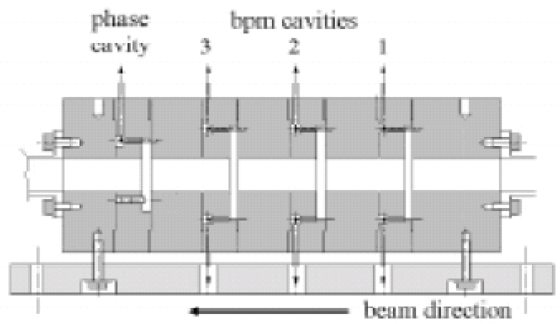


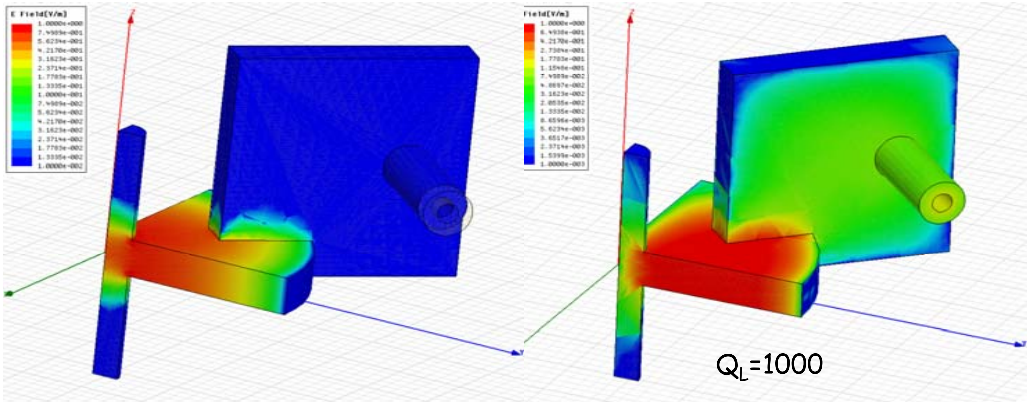
Figure 1. Mechanical drawing of the triplet RF-BPM set used for measuring the BPMs' resolutions.

5 DISCUSSION AND CONCLUSION

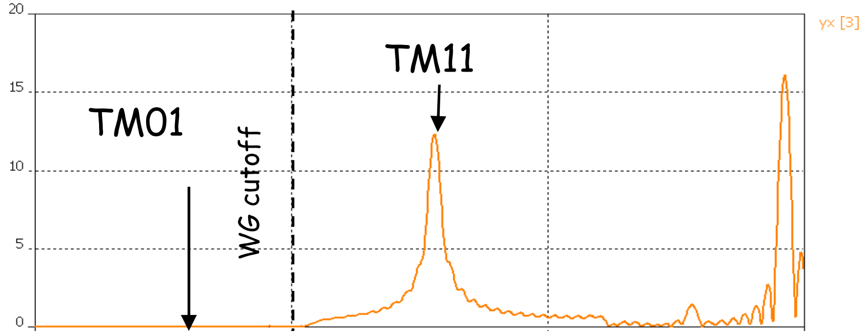
Although the resolution of approximately 25 nm was measured for the RF-BPMs from the triplet set, the measured resolution of the RF-BPM at the FFP was around 80 nm.

Some illustrations :Electric field patters in the cavities

TM01 TM11

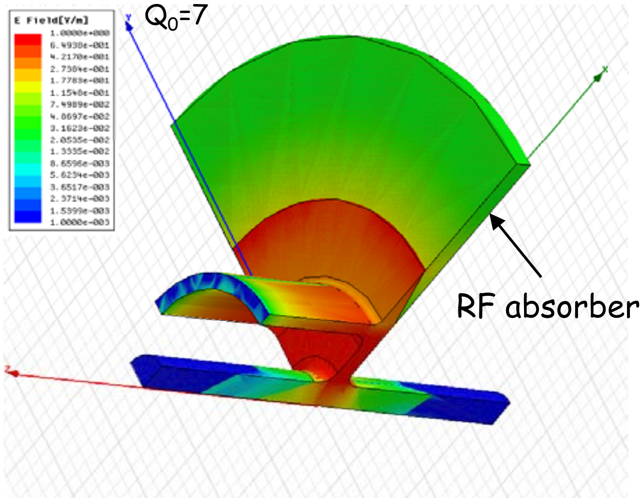


Spectrum of the port signal (single bunch)

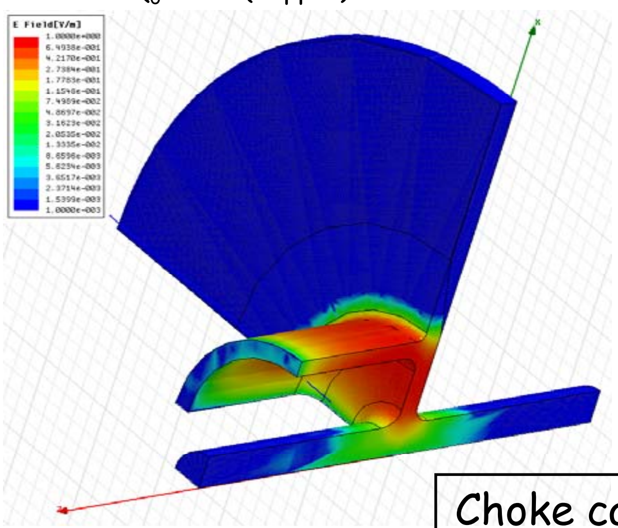


Slotted cavity

Monopole mode TM01
f=7.8GHz
Q_0=7



Dipole mode TM11
f=12GHz
Q_0=1600 (Copper)



Choke cavity

As we have seen there is a number of BPM's which have been developed in a paste decade that are capable to satisfy the CLIC requirements (resolution < 100 nm).

So why should we bother to develop "yet another" BPM?

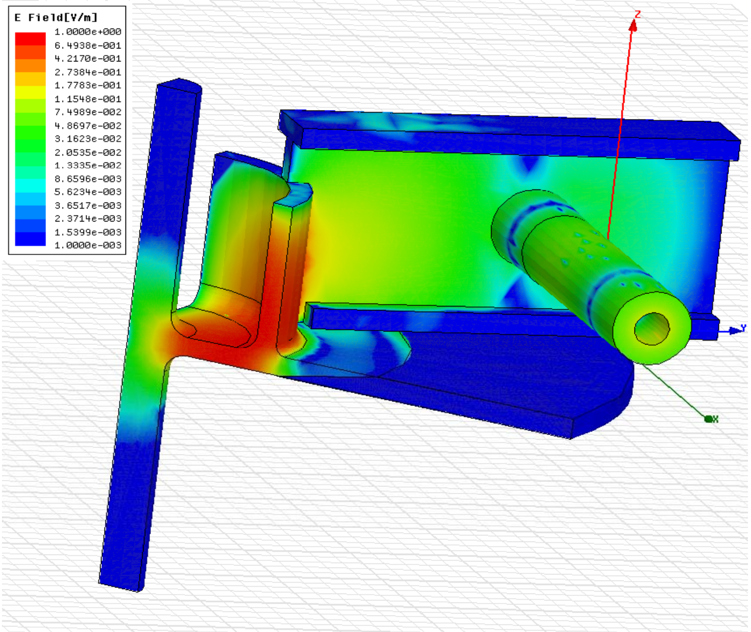
My personal points

- All the mentioned BPMs have been designed to deliver 1 nm range resolution. But none of them managed !
- For the initial machine tuning, the reduced peak current (charge/bunch or pulse length) will be used. Even pilot bunches. So we must foresee quite a margin for the BPM resolution (factor 10 better?) compared to the routine operation.
- Two thousands BPMs will be installed along the linac. Special care must be taken about their impedance. Both for the short and long range wakes.
- BPM now requires quite a sophisticated post processing and electronics, can we do it better?

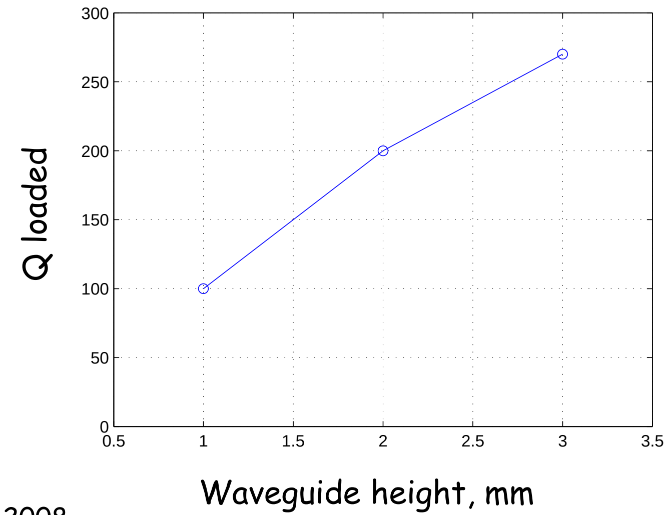
Our target was to try to develop the "single-mode" BPM with natural resolution < 10nm (without any post-processing)

Improving the Choke BPM #1

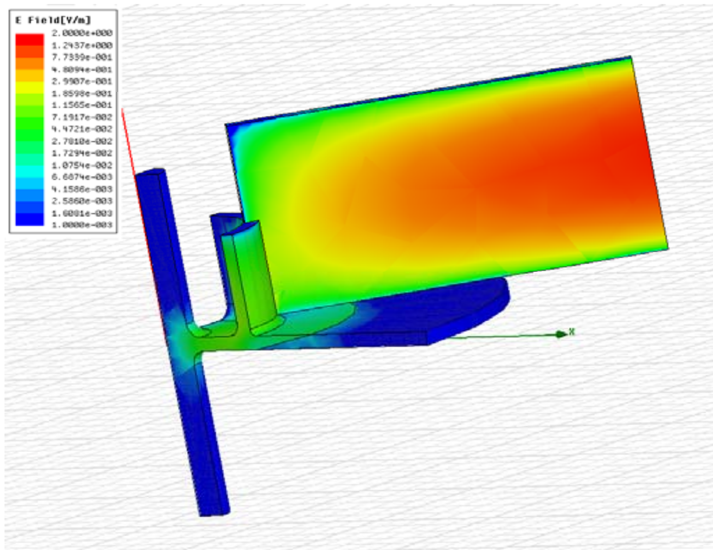
Coupling antenna substituted by the ridged waveguide → further rejection of the TM0n modes

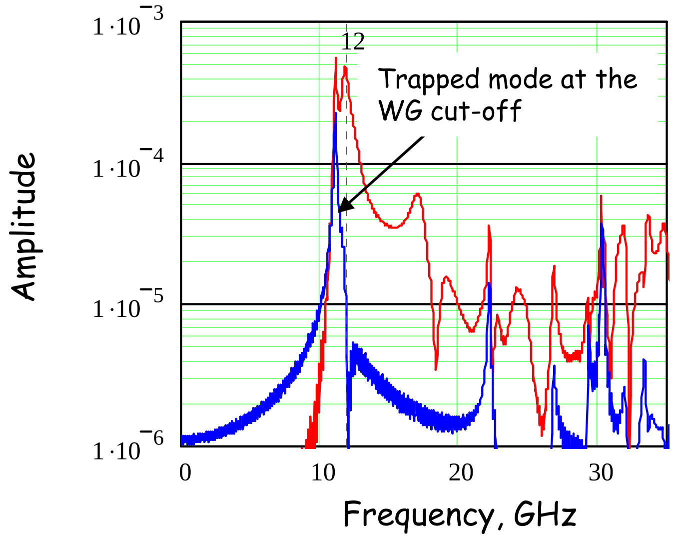


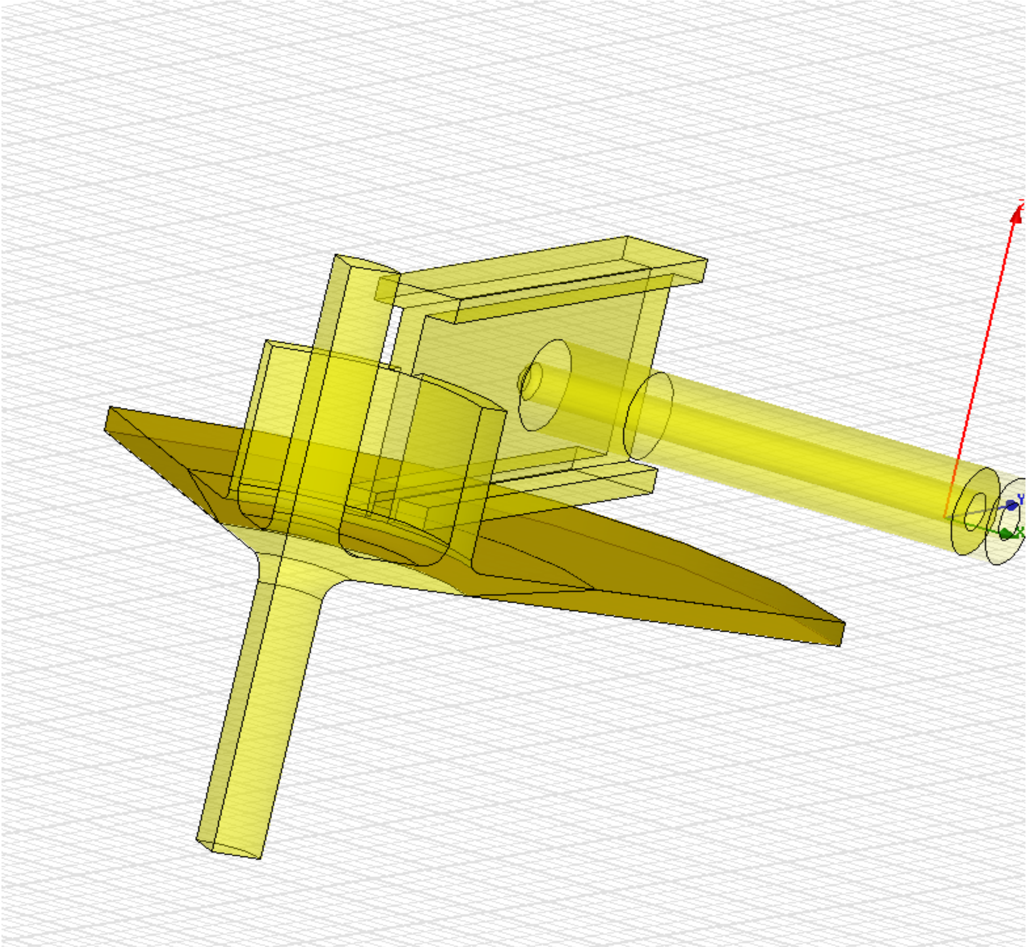
WG shape & position controls the Q loaded (coupling).



As well, the ridged WG avoids resonance at WG cutoff that appears for the rectangular one:





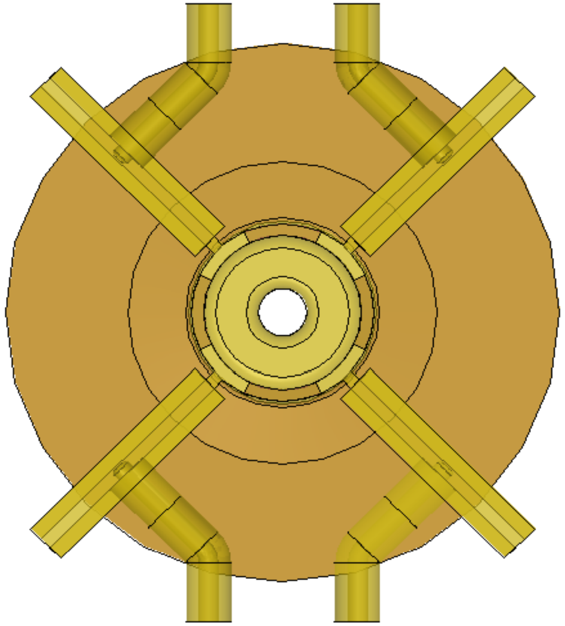


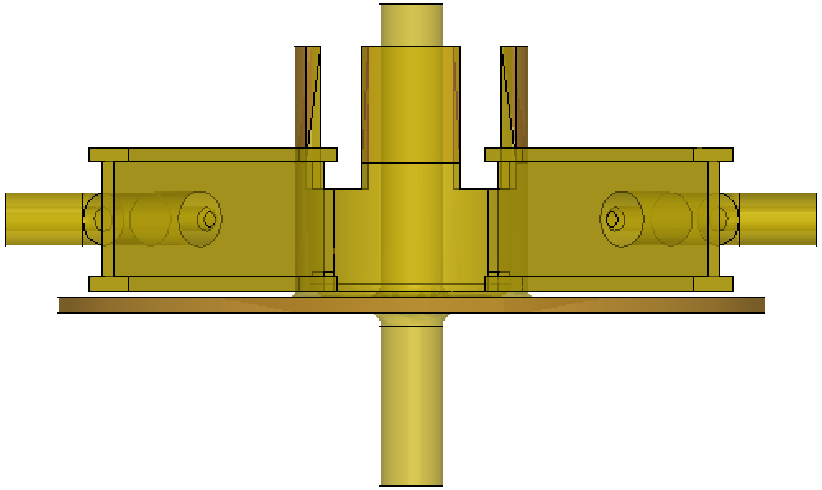
Still a few HOM's are trapped in the choke

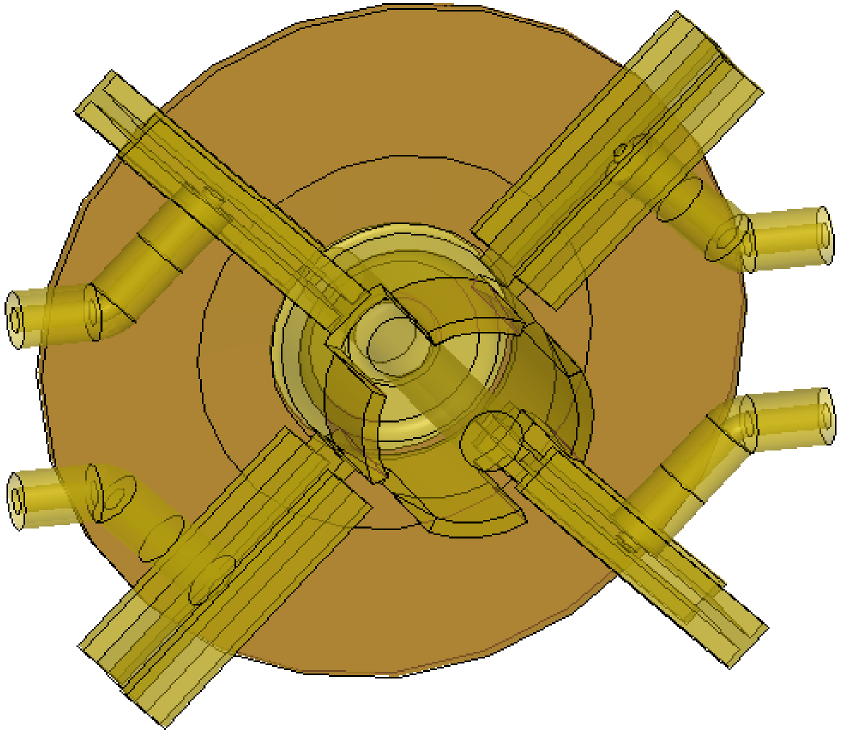
Next we introduced the damping sectors:

- Respect the TM11 (cut-off frequency)
- Absorb HOM's not damped in the choke absorber

The New Choke BPM

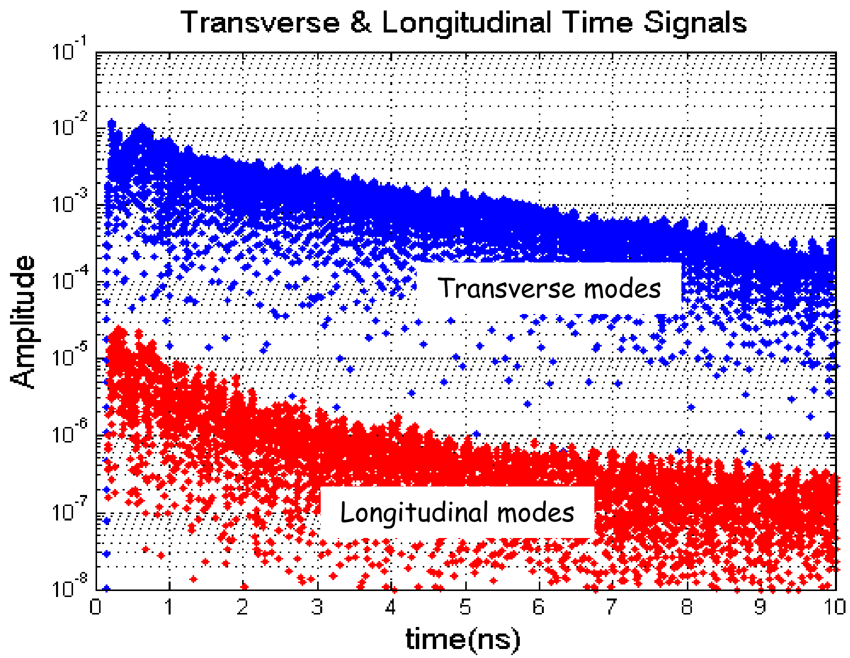




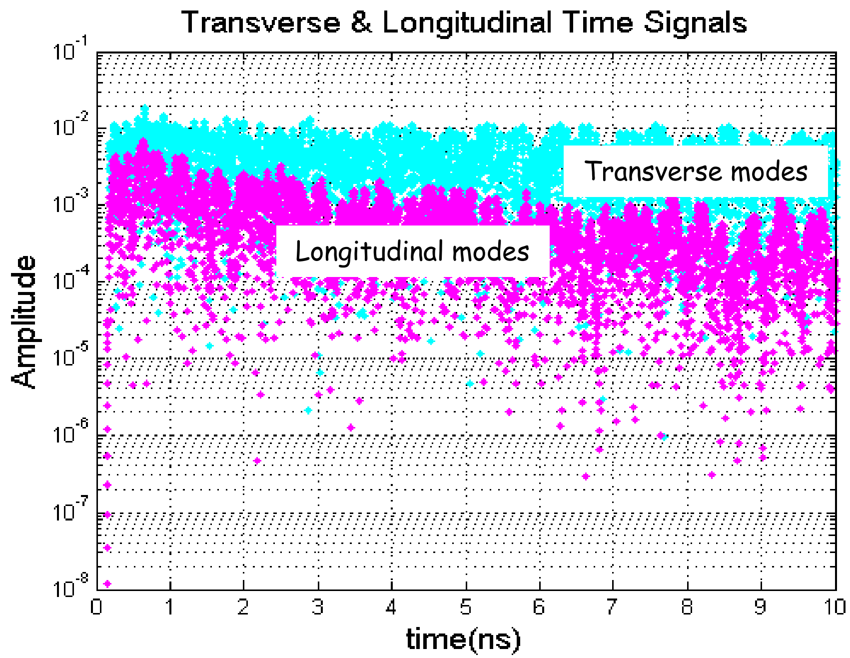


GDFIDL Simulation Results #1. Port signals

New choke BPM



Slotted cavity BPM



~ 1 micron ⇐ Internal single bunch resolution ⇒ 500 micron

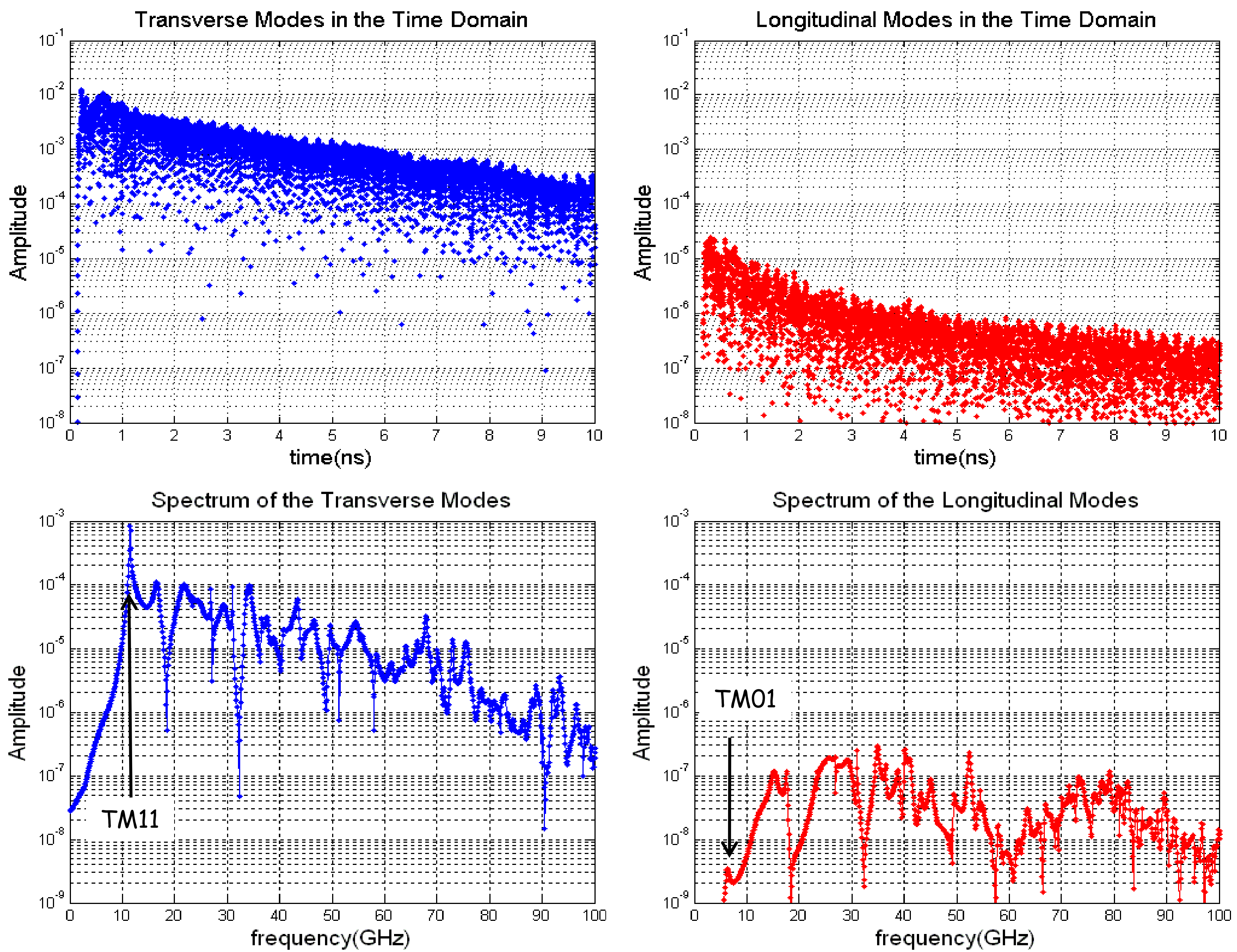
⇓

The two port pairs combination through the hybrid normally reduces the signals induced by the longitudinal modes by at least 20 dB

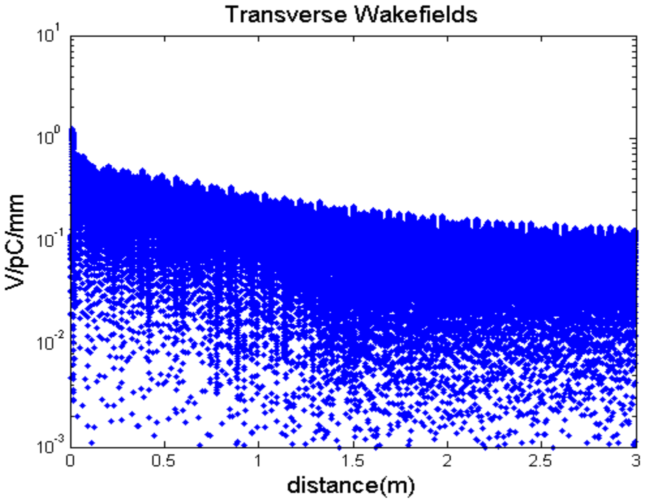
⇓

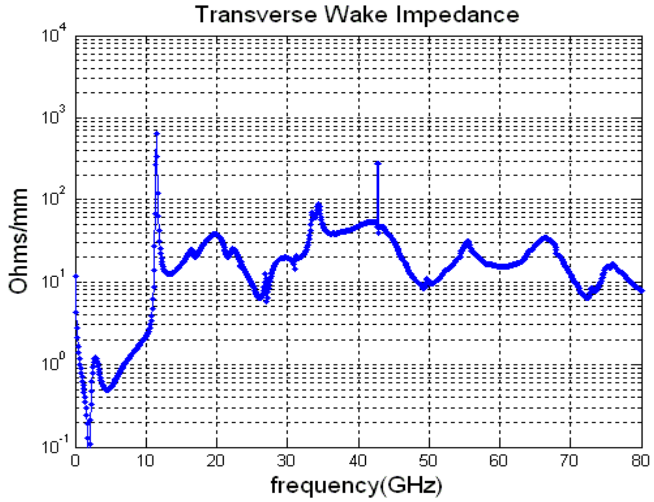
~ 10 nm ⇐ Single bunch resolution without post processing ⇒ 5 micron

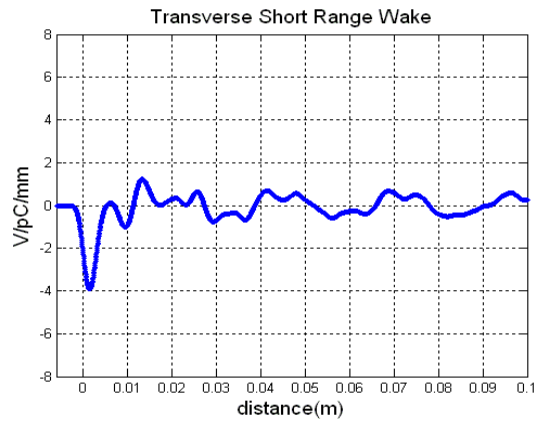
GDFIDL Simulation Results #2. Port signals and spectra



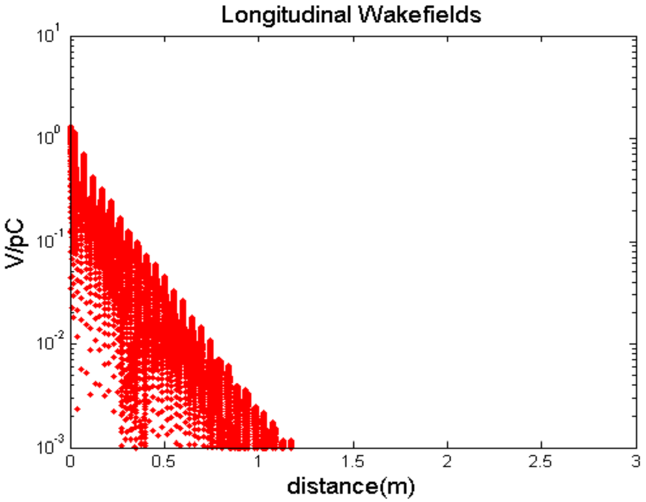
GDFIDL Simulation Results #3. Wakes

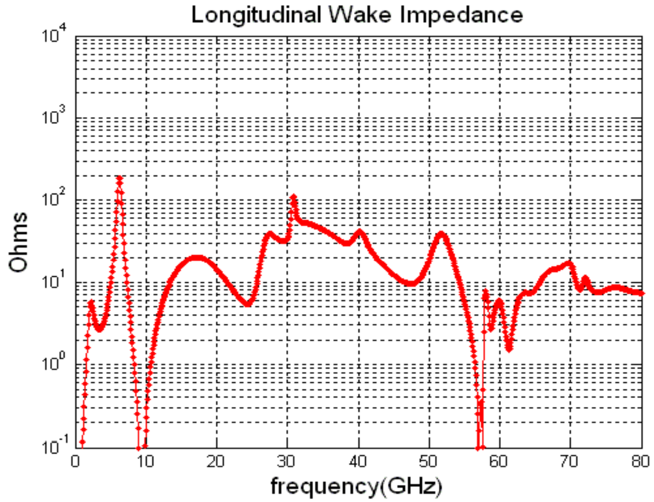


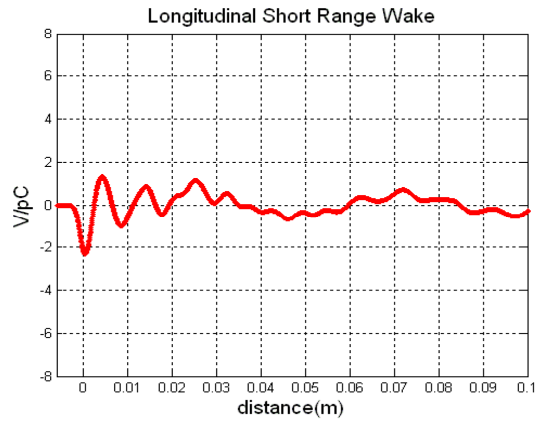




W_T<<13V/pC/mm







W_L<< <46V/pC

We have proposed the concept of the quasi "single moded" BPM with internal resolution in the nanometer range.

The further development is needed to bring the device design to the required specs:

- Optimization of the impedance and coupling factor for the particular machine needs: currents/charges beam time structure and beam position resolution requirements.
- Tolerances analysis including crosstalk and etc.
- Mechanical design.
- The required minimum of the post processing and electronics is needed to be defined.
- Testing of the device.

We are encouraging and inviting everybody to join our efforts in the development, fabrication and testing of the high precision PBM for Linear Collider!