WA 10
Diagnostics

Alessandro Cianchi
On behalf of SPARC_LAB

Contribution from…

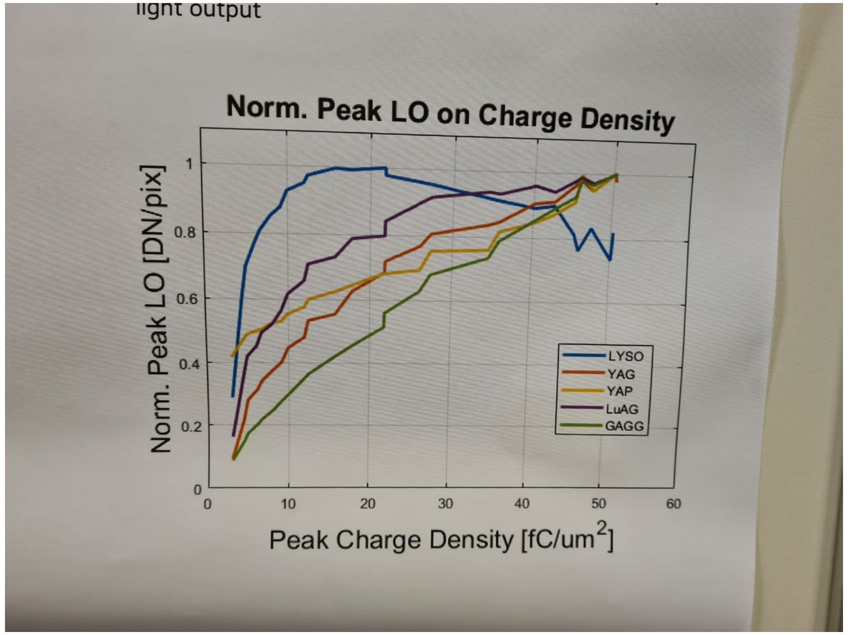
- Angelo Biagioni
- Angelo Stella
- David Alesini
- Fabio Villa
- Gianluca Di Raddo
- Giovanni Franzini
- Mario Galletti
- Stefano Pioli
- Valerio Lollo
- Vladimir Shpakov
- E. Chiadroni, G.Latini, V. Martinelli, A. Mostacci, S. Pioli, B. Serenellini, G. Silvi (Virtual Diagnostics)

The same history…the same people

- 6th May 1938
- Use of the same people every time

Beam size

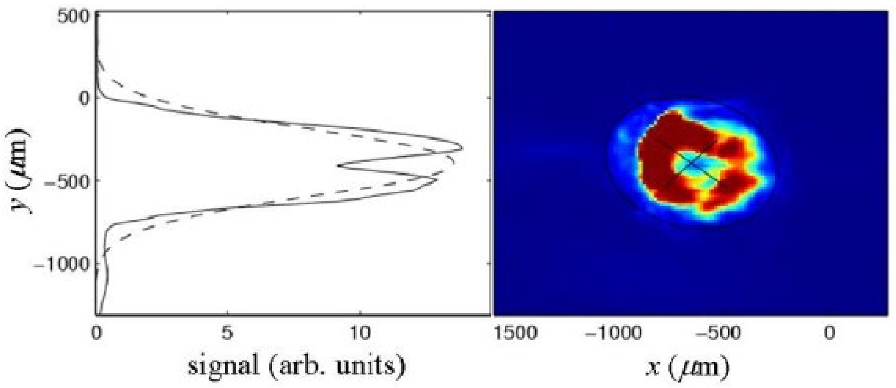
- For the measurement of the beam size, useful for envelope, emittance and longitudinal phase space we use fluorescent screens
- Actually we are using YAG:Ce
- We have just bought, and we'll test soon, GAGG:Ce that in recent test showed better uniformity, higher saturation level, more linearity and higher photons yield.



Coherent radiation

$$I_{tot}(\omega)=I_{sp}(\omega)[N+N^*(N-1)\ F(\omega)]$$

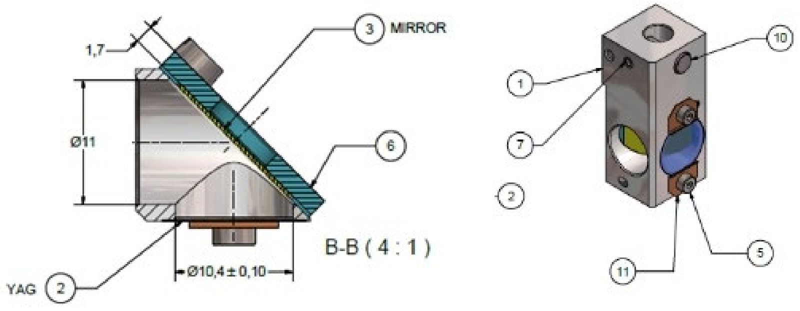
- COTR (Coherent Optical Transition Radiation) can be emitted if a microbunching is present inside the bunch with modulation shorter than this wavelength
- The image on a scintillator screen can vary shot by shot, due to the instability nature of the microbunching
- The transverse image of the coherent radiation is not useful to retrieve the beam dimensions.

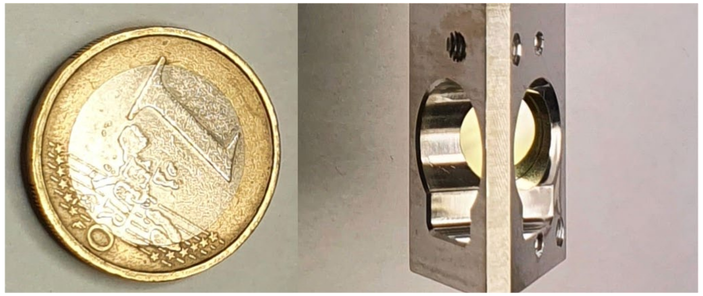


Akre, R., et al. "Commissioning the linac coherent light source injector." *Physical Review Special Topics-Accelerators and Beams* 11.3 (2008): 030703.

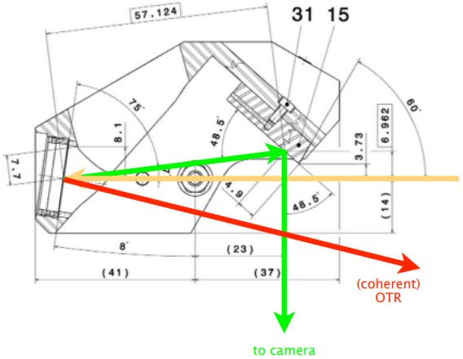
COTR prob

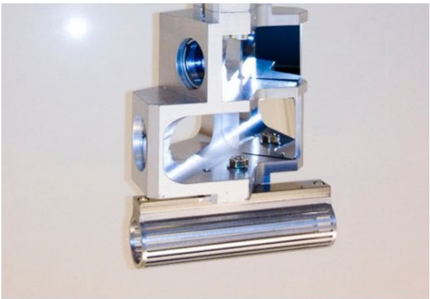
- COTR can be a detrimental effect for the scintillating screens



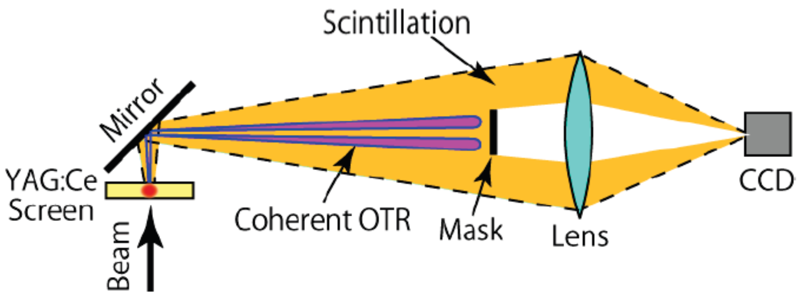


- Actual design very compact





- PSI

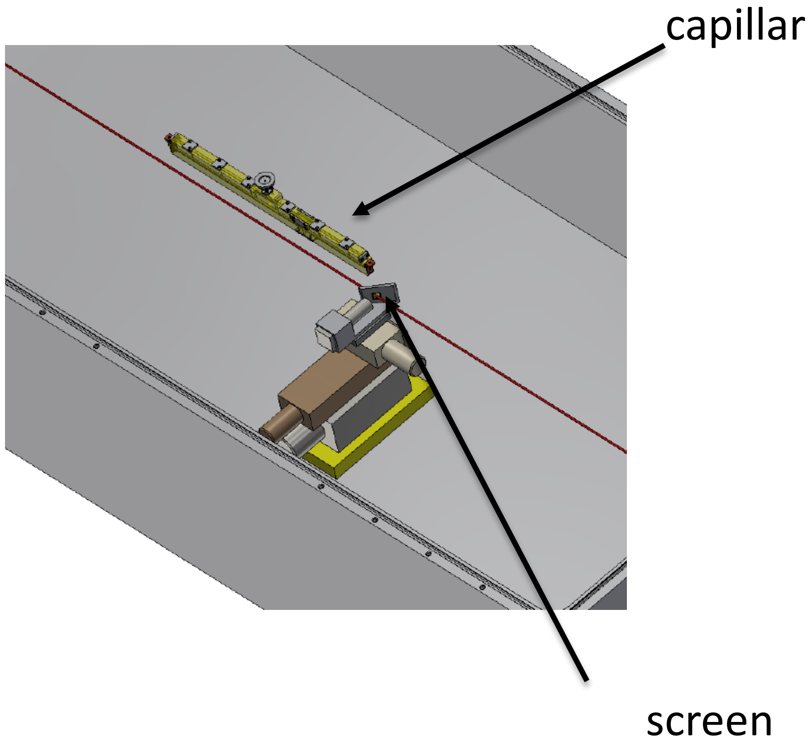


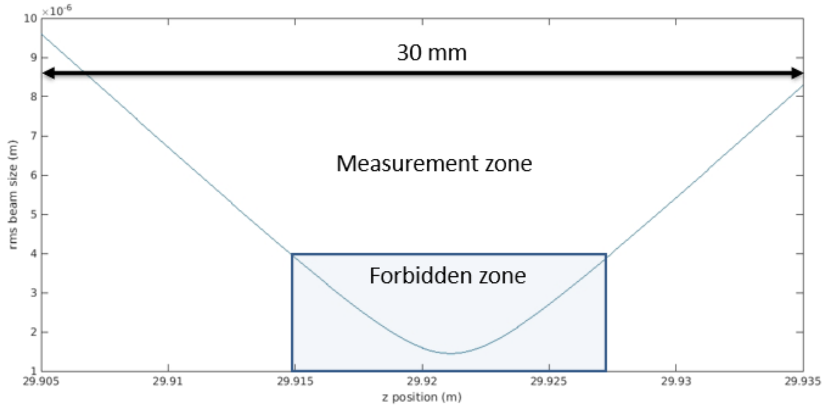
- Sacla

- Additional possibility is to separate in time COTR and scintillating light.
- COTR is emitted practically prompt when the beam hit the screens, while scintillator light is emitted for much longer time.
- However, a ICCD is very expensive device, and this solution can be considered only for a very limited number of positions.

Beam size measurement @plasma entrance

- First choice: microemittance meter, a device that can measure the beam size in a range of few cm and reconstruct the beam size with the envelope.





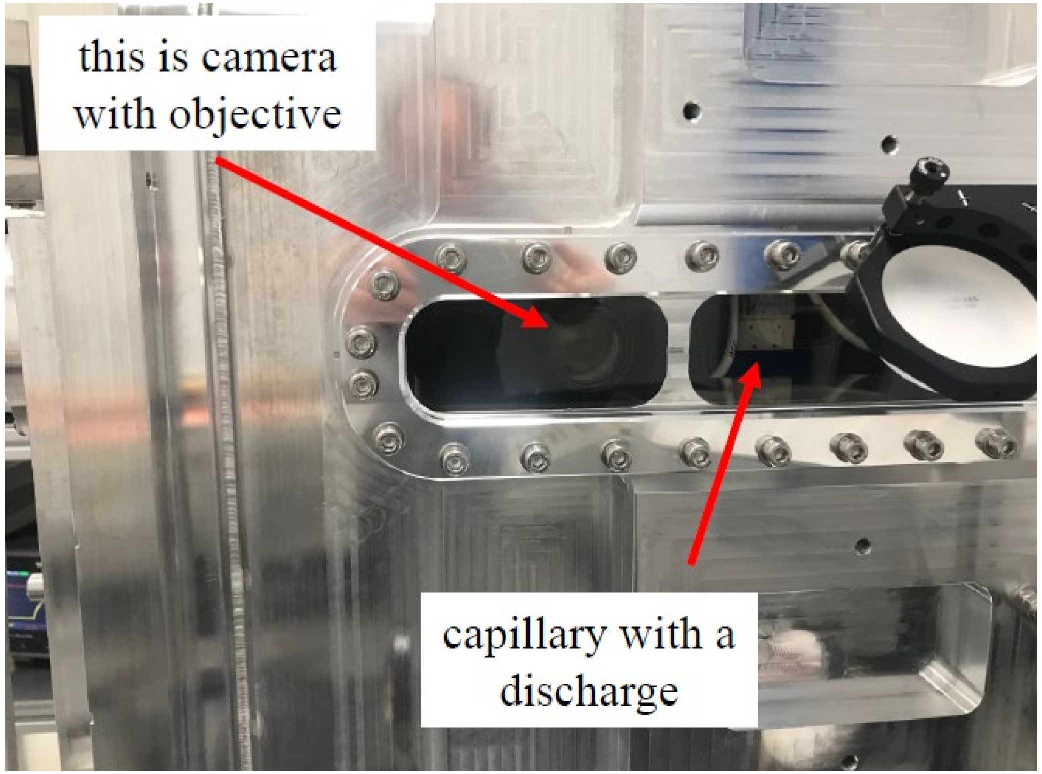
With 5% error in the beam size in the measurement zone (10 points every side) the error in the minimum is around 20%
With 10% error is about 33%
It gives also an emittance measurement about with the same error

Expected problems:
Heating of the CCD in the vacuum
Effect of the discharge when the system is not used.

Question from RC

- The ”small size zone” emittance measurement technique still needs to be reviewed. The RC understands that due to delays in delivery of cameras, other options to measure small beam sizes are considered.

Test results



- V. Shpakov, A. Biagioni

- Available camera Basler Scout which was used inside the bunker tested
- Camera was located inside the vacuum, level of ~10^{-6} mbar
- Discharge was used in the direct vicinity from the camera
- Distance between the camera and the discharge capillary was 120-150 mm
- Camera was tested with and without external trigger

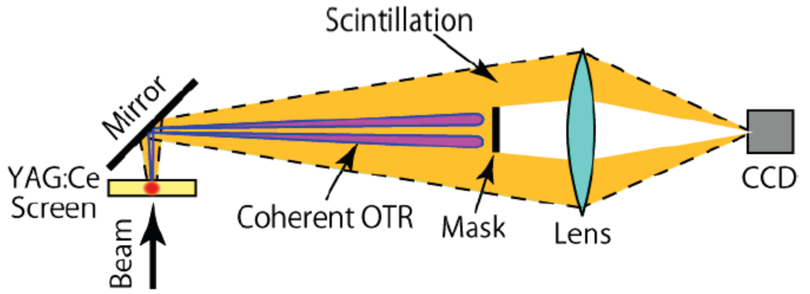
Conclusions:

- Camera can work inside the vacuum without problems with the temperature
- Discharge does not create problems with the camera or the trigger

Diagnostic into plasma chamber

- Diagnostics around the plasma source still need to be studied in more details. Layout, functionality, and requirements are certainly different than those in more standard diagnostics in the electron beamline. An example would be that coherent OTR (COTR) is hard or impossible to suppress close to the plasma chamber – when standard OTR screens are used.

We can talk about diagnostics integration once that the plasma chamber has been defined.
Yes, there is no way to suppress COTR in case of using OTR screen. With other screen we can use SACLA-type optics.
An incremental commissioning of the machine can help in this context.

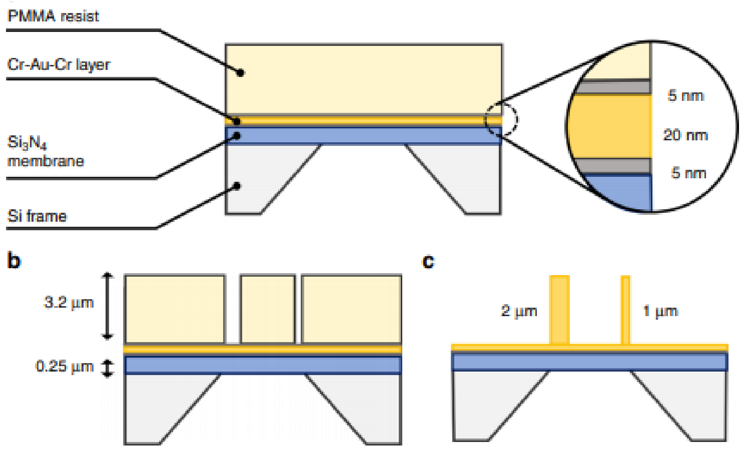


We have plan to study Mylar with aluminum coating to shield the plasma light, if it is needed.

Next steps and alternatives

- The next step will be integrating the device into the vacuum chamber design.
- We should also consider realizing this device's prototype and testing it at SPARC or other facilities.
- The decision is not independent of the results of the betatron source because using part of this beam for an electron diagnostics test is a possibility that we are now evaluating.

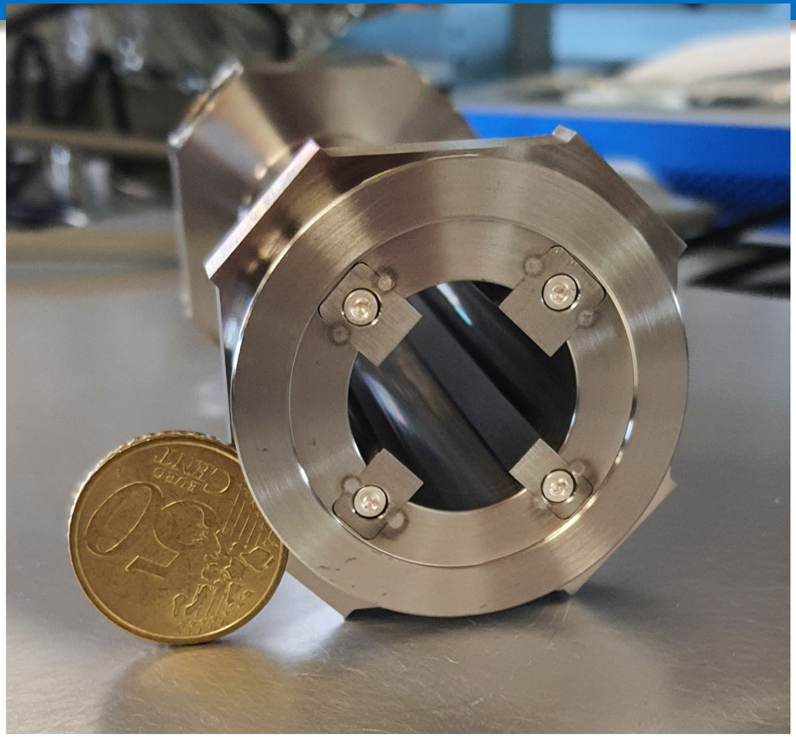
- The microwire scanner developed at PSI and Fermi is the most feasible alternative.
- It is a 1-D diagnostic, multi-shot for its nature as a wire scanner.
- Tested so far up to 200 pC
- Laser wire scanner is another device that is in developing and could be also another alternative.



Borrelli, Simona, et al. "Generation and measurement of sub-micrometer relativistic electron beams." *Communications Physics* 1.1 (2018): 1-8.

Trajectory

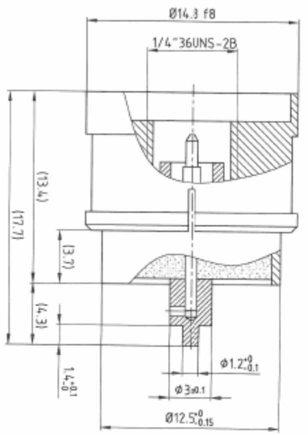
- Striplines bpms will be inside the quads to save space.
- Compact design realized @LNF
- WP14 Angelo Stella



Tender for mechanical realization in progress

Installation @ SPARC (before 03/23)

Beam Tests@ Sparc (before 09/23)



Cavity BPM selection

cBPM requirements for EuPRAXIA:
Resolution: < 1 µm
Observable Range : ± 1 mm
Bunch Charge: > 10 pC
Repetition Rate: 100 Hz
Length: as short as possible
Number of Units: < 10

	PSI CBPM5/8	FMB Oxford
Material	Stainless Steel (outside) – Copper (inside)	Stainless Steel
Length [mm]	100 mm	100 mm
Inner Aperture [mm]	5 / 8 mm	20 mm (custom)
Res. frequency	4.9266 GHz	6.474 GHz
Q_L	1000	610
Decay Constant	64.6 ns	30 ns
Charge Range	10-200 pC	10-100 pC
Typical Position Range	±1 mm	
Position Sensitivity (CBPM5)	4.5 V/mm/nC	1 V/mm/nC
Charge Sensitivity (CBPM5)	62.8 V/nC	

- Already Installed and functioning at SWISSFEL.
- Measurements show results compatible with our requirements.
- Designer (Fabio Marcellini) is willing to collaborate with us to adjust or create a new design.

THIS SEEMS THE BEST CHOICE

There are three possible solutions for the readout electronics:

1. To buy (or to develop together) read-out electronics from Instrumentation Technologies.
2. To buy and to test PSI readout Electronics.
3. To internally develop readout electronics

G. Franzini

Charge

- A dedicated toroid with a conventional one and a turbo toroid (Turbo+ICT), has been designed and realized for us by ‘Bergoz Instrumentation’ equipped with dedicated hardware/software acquisition system
- We are using right now in the injector
- But we have realized that need to know the beam charge at pC level also before and after the plasma module.
- Our plan is to use conventional toroid except in the gun and around the plasma module

RC intraondulator

- Each intersection between the undulators is equipped with a high-resolution beam position monitor and a screen to measure the transverse beam size. The RC would like to hear about more studies on the radiation load of undulator magnets due to radiation produced by screens. Thickness and type of screens should also be discussed. The RC wants to point out that an alternative to screens should be considered for the intersections.

- We are not ready for this discussion.
- We need an expert of GEANT4 to make simulation of radiation produced by screens
- At the beginning of next year, a person with such expertise will join our group
- If we'll see that there is incompatibility between screens and radiation production we can consider to change screen type and thickness.
- A possibility that we can consider is to have Silicon Nitride Membrane (1 um thickness) with aluminum coating.
- In this case we need dedicated R&D

Intraondulator

- The design of the intersections has started. A more detailed study on how to efficiently integrate diagnostics into the present intersection length, including the space required for a movable quadrupole, a phase shifter, and a vacuum connection is expected.

- From diagnostics point of view, we have already the prototype of the view screen. The cavity BPM can be assumed similar to other already existing with overall length of 100 mm.
- The diagnostics space occupancy is well defined.

Beam loss monitor

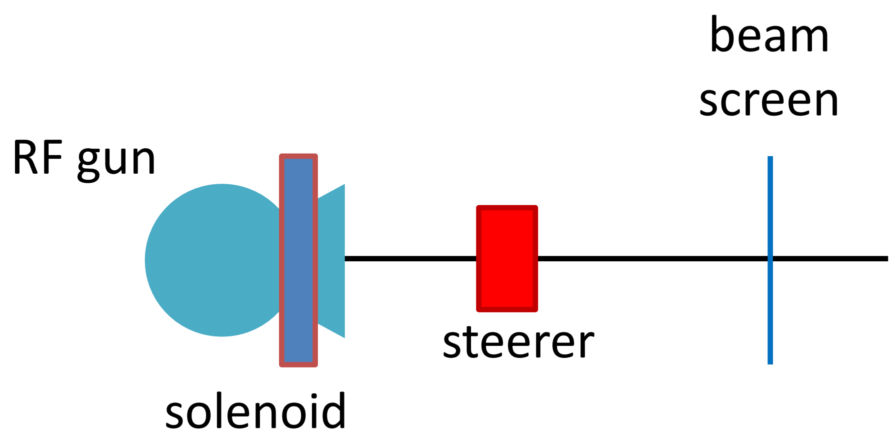
- Radiation monitors based on fibers and RADFETs installed along the beamline and the undulators have been chosen. They will be tested at TEX and SPARC LAB. The integration of the loss monitors into the protection system should be addressed at the next meeting.

It is too early to talk about integration.
There is not yet a design of the machine protection system.
Maybe in one year…

Photon diagnostics in the beamlines

- The RC suggests that in a next step, all diagnostic items be addressed in more detail: from design, construction and prototyping, to realization. One should start with the key components and with those requiring a long development time. Measurements of the number of photons per pulse, of spectrum, of transverse pulse shape, including the wavefront are essential for start-up FEL operation. A specific effort needs to go into the design and production of all mirrors and focussing elements (especially the KB-optics).
- Another important point is to understand how all the diagnostics components presented could fit into the short beamline space available.
- The RC wants to point out that some important parameters, such as the monochromator transmission efficiency and general stability issues, have not yet been specified. The RC would like to hear about detailed specifications of key diagnostic elements in the next meetings.

- See talk F. Villa

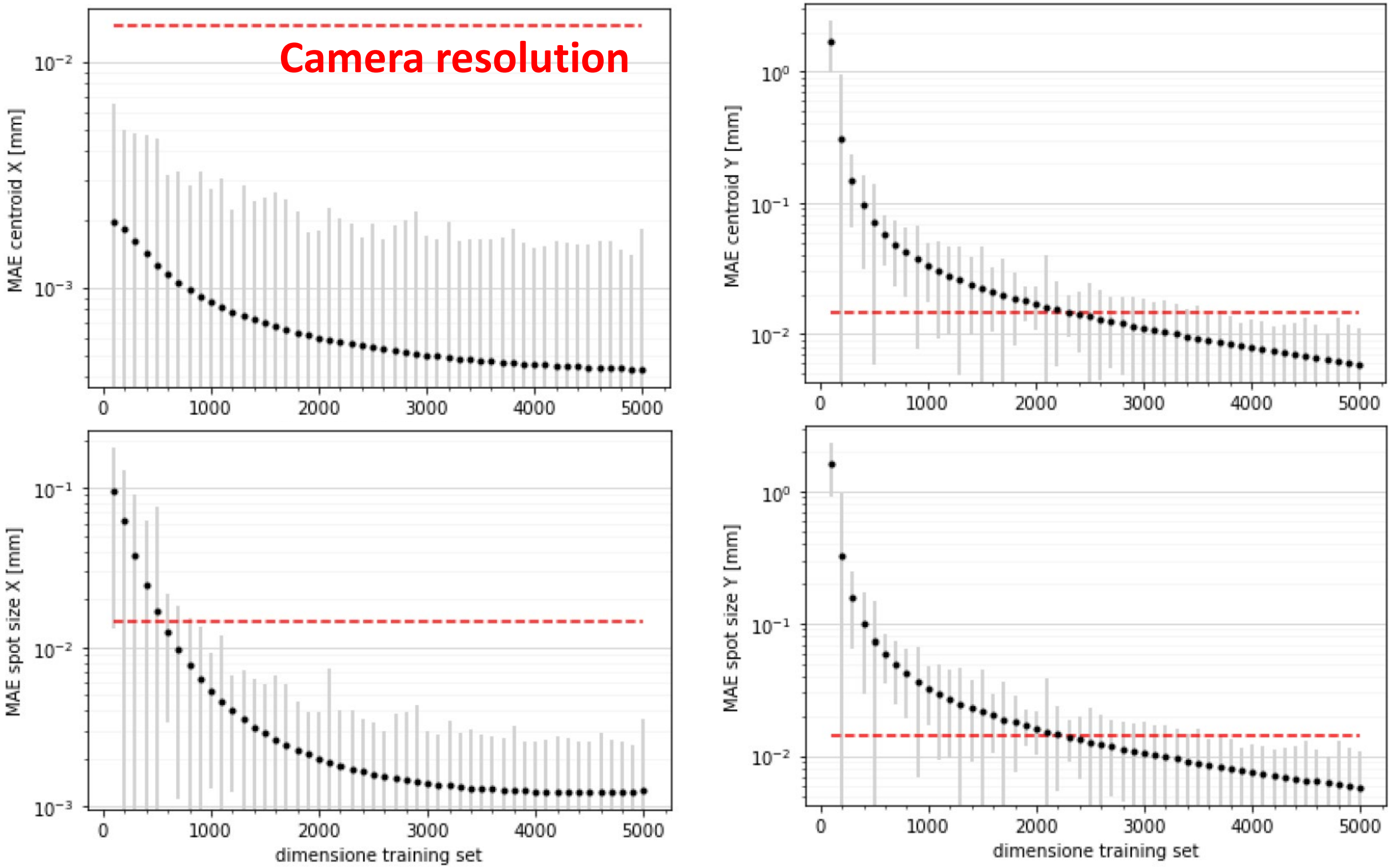


Neural Network training:

- Photo Cathode Laser pulse length
- Photo Cathode Laser spot size
- RF Gun phase
- RF Gun solenoid setpoint
- RF Gun steerer setpoint

→ ASTRA → Transverse spot images

VIRTUAL DIAGNOSTIC @ SPARC_LAB: Error reduction STUDIES



Error trends (Mean Absolute Error)
vs
Traning dataset size

- After 2k samples prediction error below camera resolution
- System suitable for both digital twin development
- Prediction elaboration suitable for 400 Hz operation (0,5 ms per predition)

WA 10

Alessandro Cianchi
30/11/2022

On going actions	Outcome closed actions & Decisions	To Do
Realization of the compact BPM stripline Definition of photon diagnostics for the photon beamlines	Test of CCD under vacuum and discharge for microemittance meter Decision to adopt PSI-like CBPM	Realization, test and installation of compact stripline Design of the plasma chamber with the microemittancemeter Discuss with PSI about cavity BPMs and related electronics Start the test of beam loss monitor in TEX Start to define at least 1-2 diagnostics devices for photons beamlines GEANT4 calculation for screens

WA 10 –Diagnostics

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30/11/2022

Upcoming milestones

1. 30/01/2023 BLM prototyping

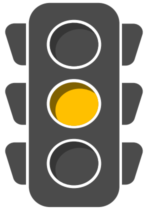
2. 31/05/2023 Design of micrometer resolution diagnostics

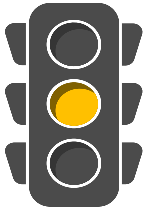
2. 30/06/24 Preliminary Technical Design of the photon diagnostics

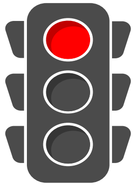
Potential risks

1. Manpower overlap with other projects
2. Availability of CAD designer, implementation with plasma chamber
3. Manpower

General Status







Timeline

WA.10	**DIAGNOSTICS**	**106,8 w**	**01/06/21**	**19/06/23**
WA10.0100	e-beam diagnostics design	10 mons	03/12/21	09/09/22
WA10.0101	High precision charge measurements	6 mons	03/12/21	20/05/22
WA10.0200	Compact diag. chamber design	12 mons	01/06/21	03/05/22
WA10.0201	Compact diag.chamber prototyping	10 mons	03/05/22	07/02/23
WA10.0300	BPM design	8 mons	01/09/21	13/04/22
WA10.0301	BPM prototyping	6 mons	13/04/22	28/09/22
WA10.0400	BLM design	8 mons	03/01/22	15/08/22
WA10.0401	BLM prototyping	6 mons	15/08/22	30/01/23
WA10.0501	ML data taking test	6 mons	02/01/23	19/06/23
WA10.0601	CCD Test in vacuum & under discharge	3 mons	10/10/22	30/12/22
WA10.0701	Design of micrometer resolution diagnostics	5 mons	12/01/23	31/05/23
M10.1	Diagnostic prototyping validation	0 w	24/04/23	24/04/23
M10.2	Final e-beam diagnostic design	0 w	09/10/23	09/10/23
M10.3	ML data taking final design	0 w	06/11/23	06/11/23

- It is worth mentioning that there are many other WAs that can impact on diagnostics, for instance machine layout, quadrupole development, plasma chamber and so on...
- From the point of view of diagnostics right now we are on schedule, but at some point we need to have integration and sooner is better.