Cherenkov detectors for fast electron measurements: new diagnostics for Tore-Supra and other MCF

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Outline

- Introduction - Cherenkov Effect
- Multi-channel measurements within ISTTOK–tokamak
- Single-channel measurements within COMPASS–tokamak
- Preparation for measurements within:
  - FTU
  - Tore-Supra
- Conclusions

Association Euratom-IPPLM Council Meeting
Cracow March 15, 2013

Cherenkov Effect

- **Cherenkov radiation – emitted by charged particle moving through transparent medium with velocity higher than light velocity in this medium.**

  If charged particle penetrates transparent medium with velocity (v) higher than phase velocity of light in this medium, given by

  $u = c/n$ where n is refraction coefficient of material,

  condition for Cherenkov radiation can be written as:

  $v > c/n$ or $\beta * n > 1$ where $\beta = v/c$.

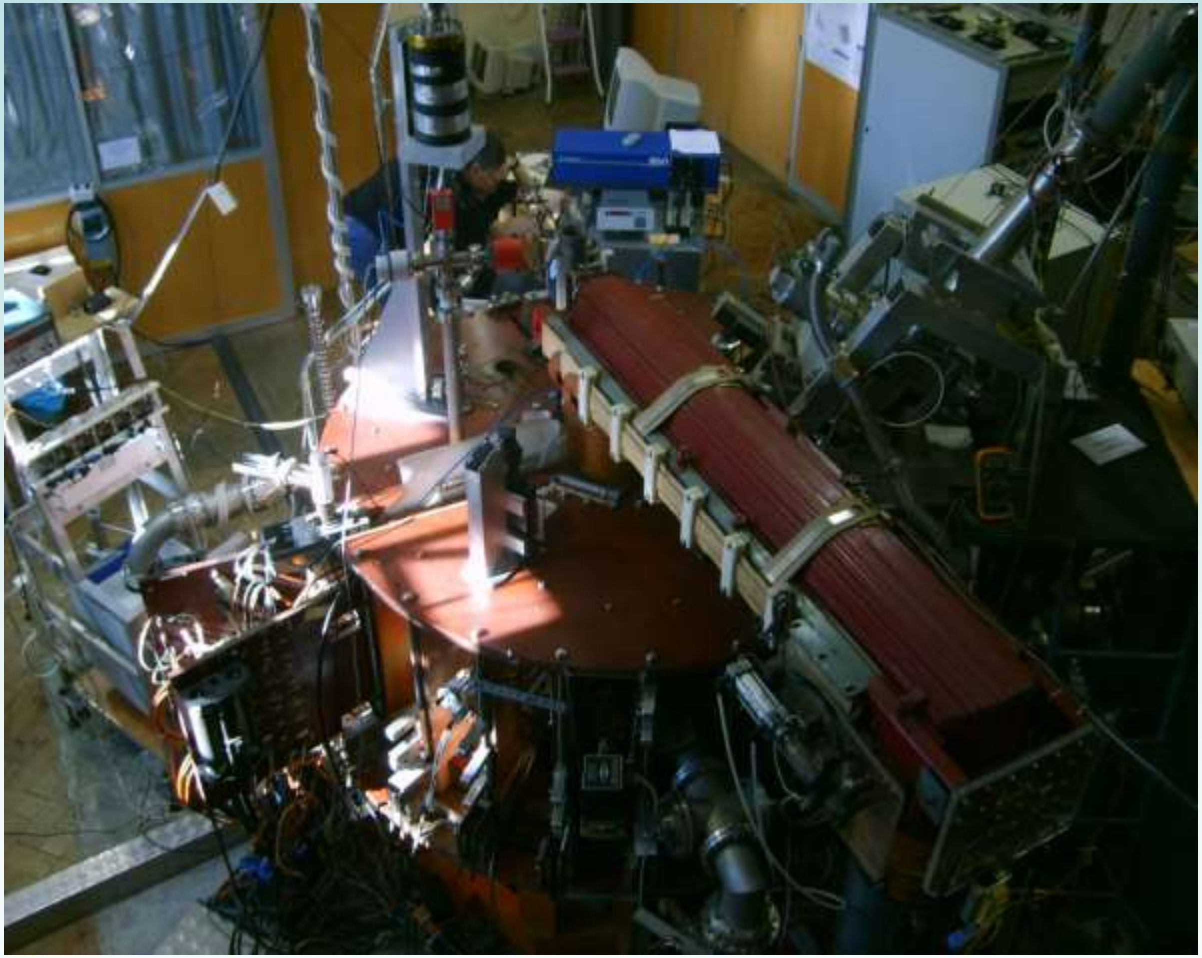
Materials for Cherenkov radiator

Material	Refraction index	Lower electron energy threshold [keV]	Thermal conductivity [W/cm K]
Glass	1.8	104	0.01
Aluminum-nitride	2.15	66	1.7
Diamond	2.42	51	20
Rutile (TiO_2)	2.9	33	0.12

Characteristic features of the Cherenkov radiation

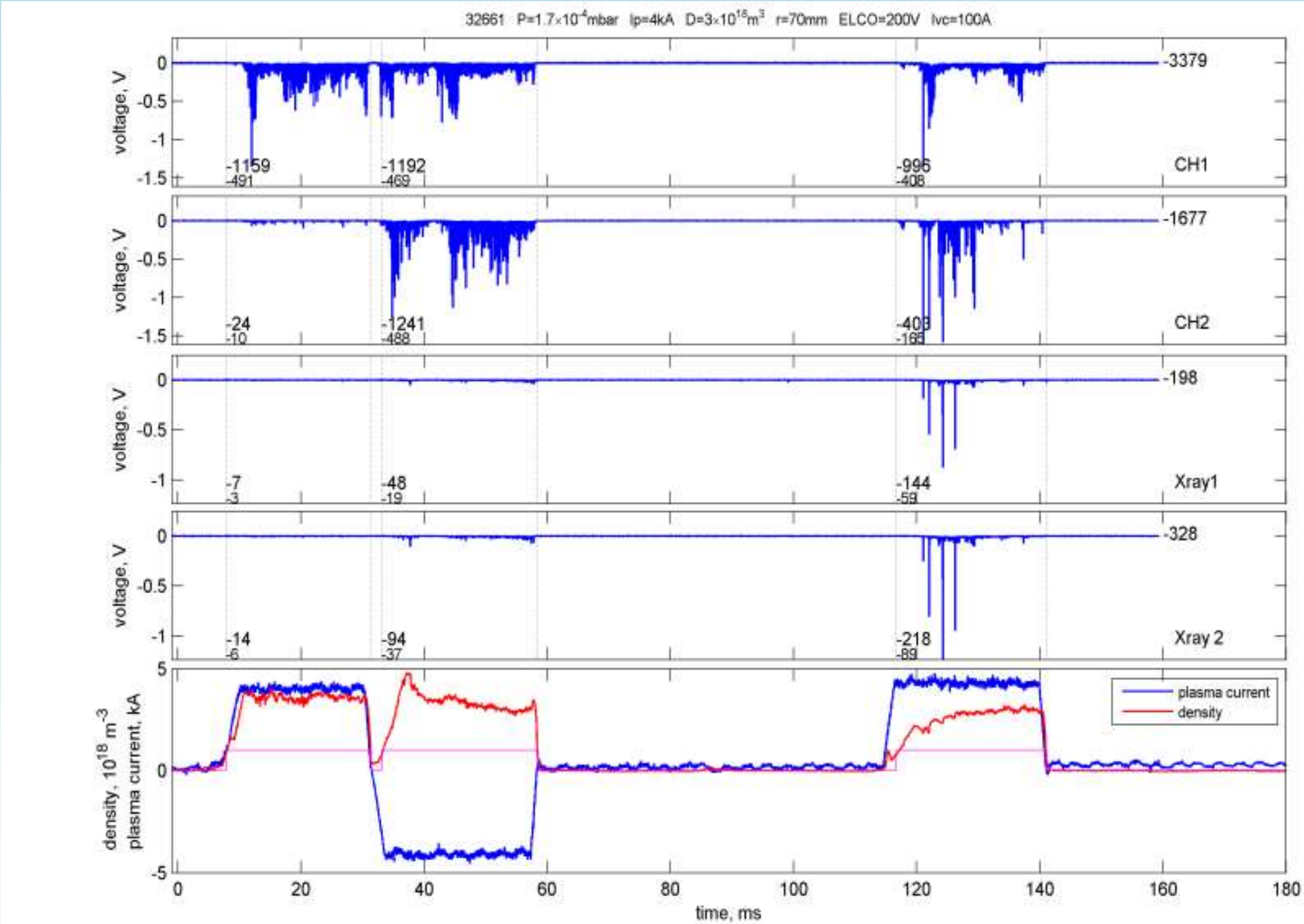
- Threshold, directional character and continuous spectrum
- Threshold energy is larger for medium with larger refraction coefficient. Thus to record beams of lower energy it is necessary to use diamond or rutile.
- Instantaneous character – radiation is emitted with delay of order of 10^{-10} s. Its intensity in comparison with typical Bremsstrahlung is about two orders higher. **Therefore, under reasonable experimental conditions the Bremsstrahlung emitted by charged particles (e.g. fast electrons) inside radiator may be neglected.**

ISTTOK Tokamak (IPFN, Lisbon)

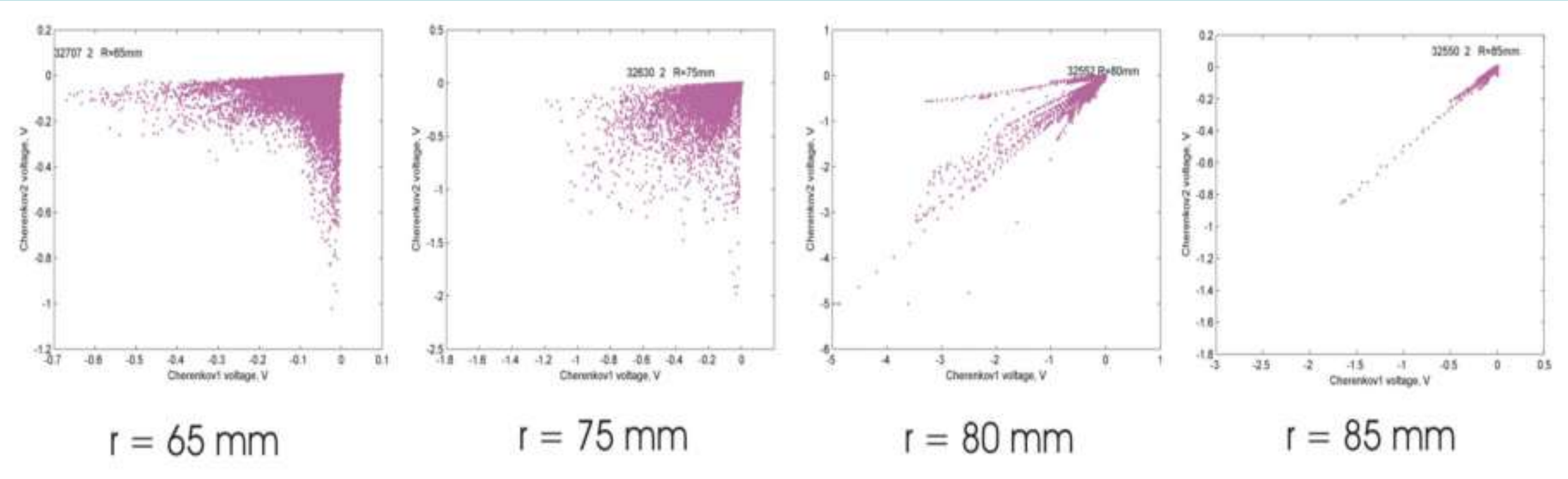


Major radius	46 cm
Minor radius	8.5 cm
Plasma current	~7 kA
Max. magn. Field	0,5 Tesla

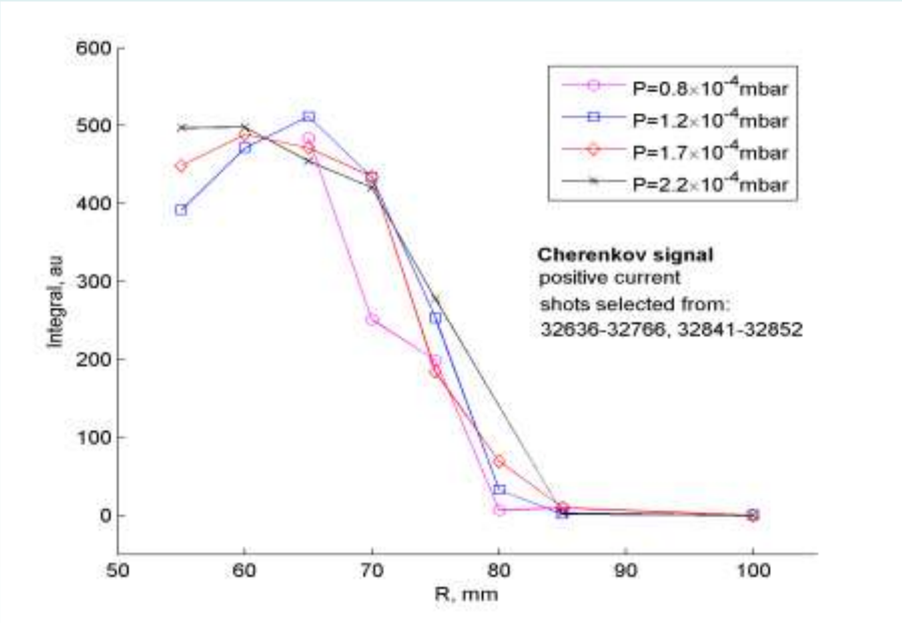
The view of the new, two-channel measuring head of the Cherenkov probe dedicated for measurements of electron beams within the ISTTOK experiment



Temporal changes of intensities of electron beams (traces CH1-CH2), and hard X-rays (traces Xray 1-2) in relation to the discharge current and plasma density (two bottom traces) for ISTTOK discharge



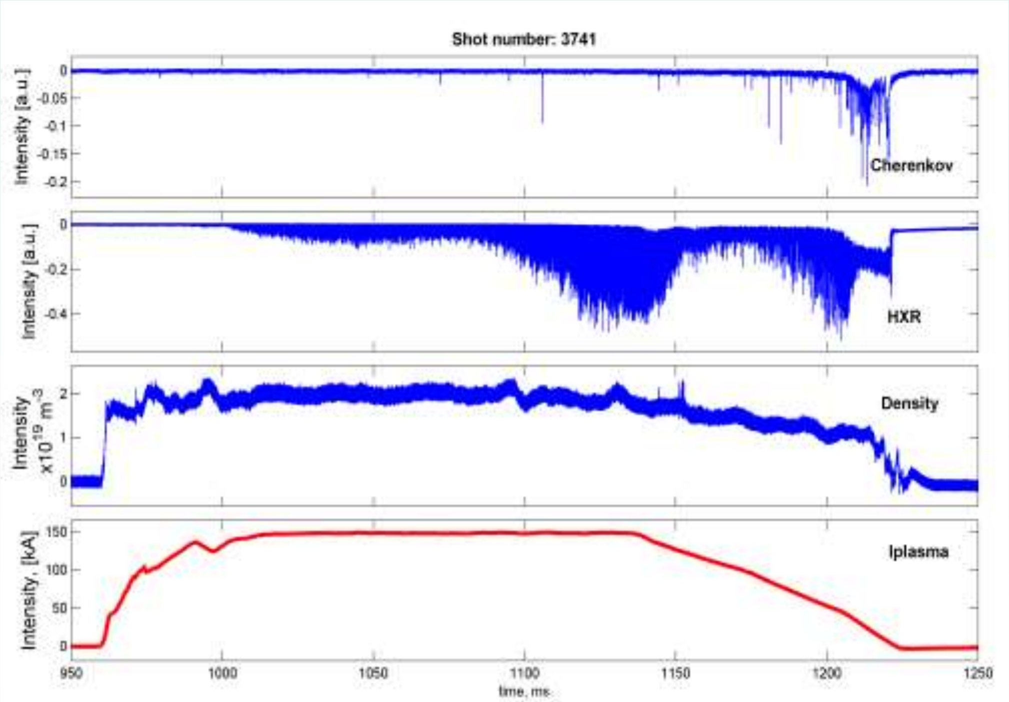
Dependence of correlation of intensities of electron signals CH1 and CH2 on measuring head position for series of ISTTOK plasma discharges



Dependence of fluency of electron beams on measuring head position taken only for positive direction of plasma current at different working gas pressure, as measured for series of ISTTOK discharges

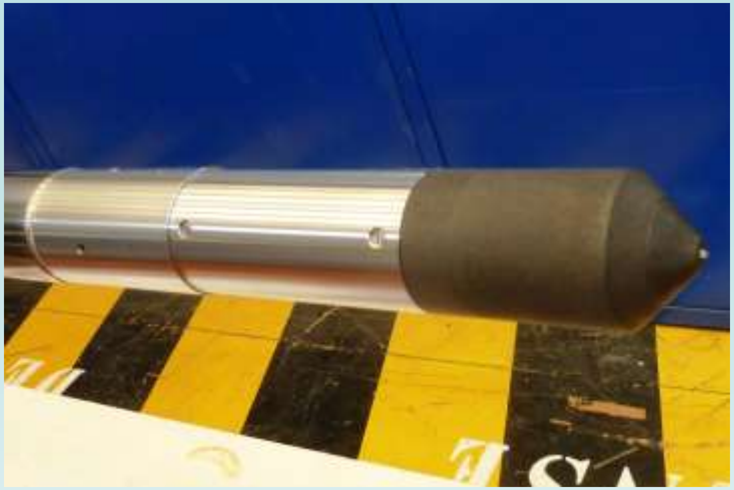
COMPASS Tokamak (IPP.CR, Prague)

The view of the prototype, single-channel Cherenkov detector for electron beams measurements within COMPASS



Time-resolved electron signals, as obtained by means of a prototype single-channel Cherenkov detector within the COMPASS tokamak (trace Cherenkov), in relation to the total hard X-rays emission (trace HXR), plasma density and discharge current (two bottom traces) for a typical COMPASS discharge

Tore-Supra (CEA, Cadarache)



Picture of the new measuring head of the Cherenkov detector (DENEPR-3) mounted on the TORE-SUPRA mobile shaft (Cadarache, July 2012).

Unfortunately, a very serious technical breakdown of the main supply transformer of the TORE-SUPRA facility occurred, and there were no chance for experimenting with plasma discharges in Cadarache in 2012.

FTU (ENEA, Frascati)

The construction of a single-channel measuring head for electron measurements in the FTU tokamak at the ENEA, Frascati, has been considered and prepared .

Summary and Conclusions

- Milestone concerning runaway measurements in the TORE-SUPRA facility, in spite of the manufacturing and installation of the new Cherenkov probe (DENEPR-3), was not achieved because of an electric network failure and a serious breakdown of the tokamak.
- Milestone, concerning a summary of fast electron measurements within the ISTTOK facility, was achieved . It was shown that outside the toroidal plasma column there can be detected fast run-away electrons, and the Cherenkov radiators (separated by a 5-mm distance) can record well correlated electron-induced signals.
- Milestone, concerning the construction of a prototype Cherenkov measuring-head for the COMPASS facility and the technical design of such a head for the FTU tokamak, was achieved. It was proved that electron-induced Cherenkov signals of a high intensity can be recorded in the COMPASS tokamak outside the LCFS.

Applications of solid-state nuclear track detectors (SSNTDs) for fast ion and fusion reaction product measurements in tokamaks (TEXTOR, MAST, ASDEX)

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Outline

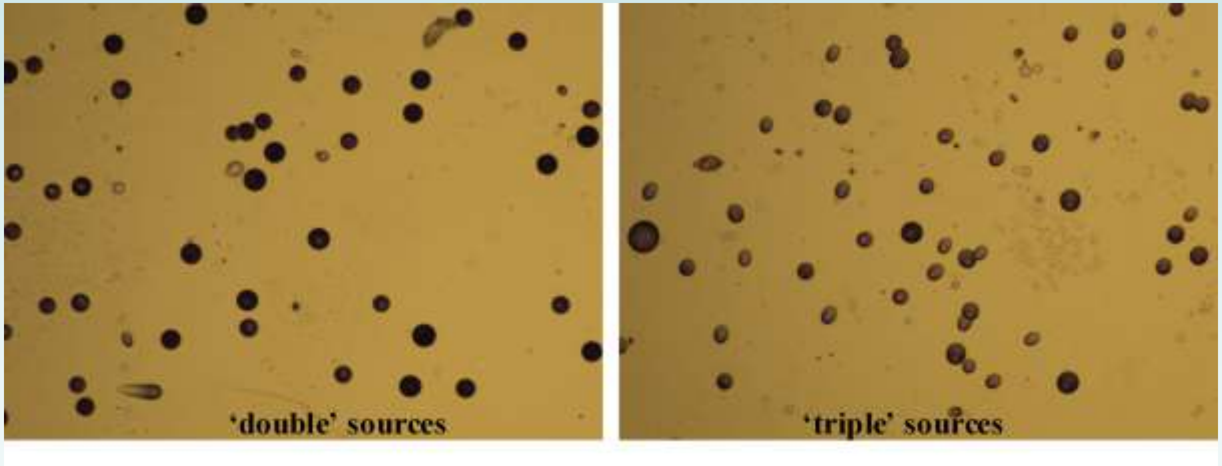
- **Calibration studies**
- **Measurements within COMPASS–tokamak**

Calibration studies

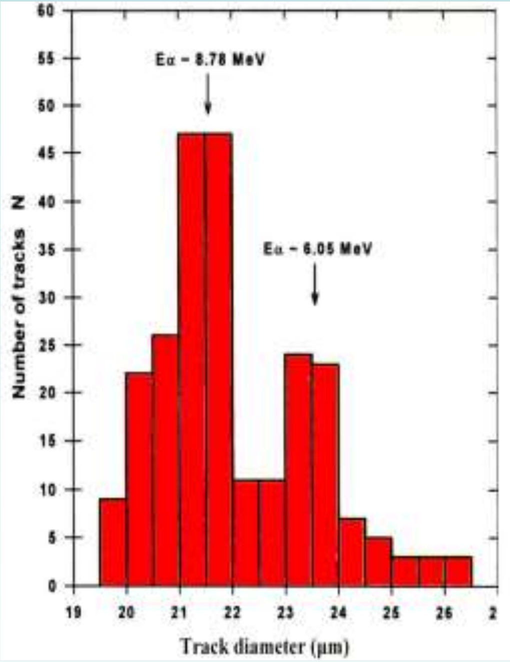
PM-355 spectroscopic properties especially for proton and α-particle detection were investigated in 2012.

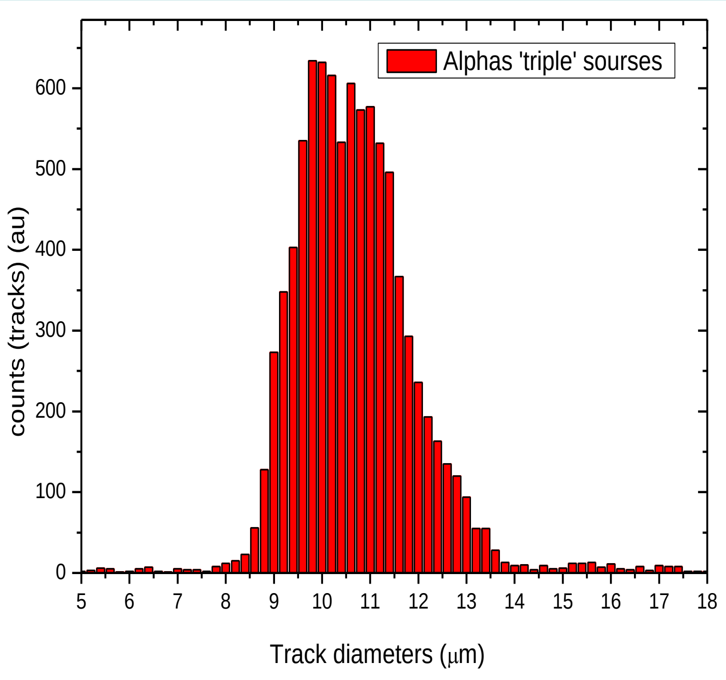
‘Double’ alfa-particle source: Polonium-212 and Bismuth-212 (of energies 6.05 MeV and 8.78 MeV, respectively, with intensity ratio ~ 0.5);

‘Triple’ radioactive alfa-particle source: Plutonium-239, Americium-241 and Curium-244 (emitting alphas of energies 5.15 MeV, 5.48 MeV and 5.8 MeV, with intensity ratio Pu/Am/Cm ~ 1)



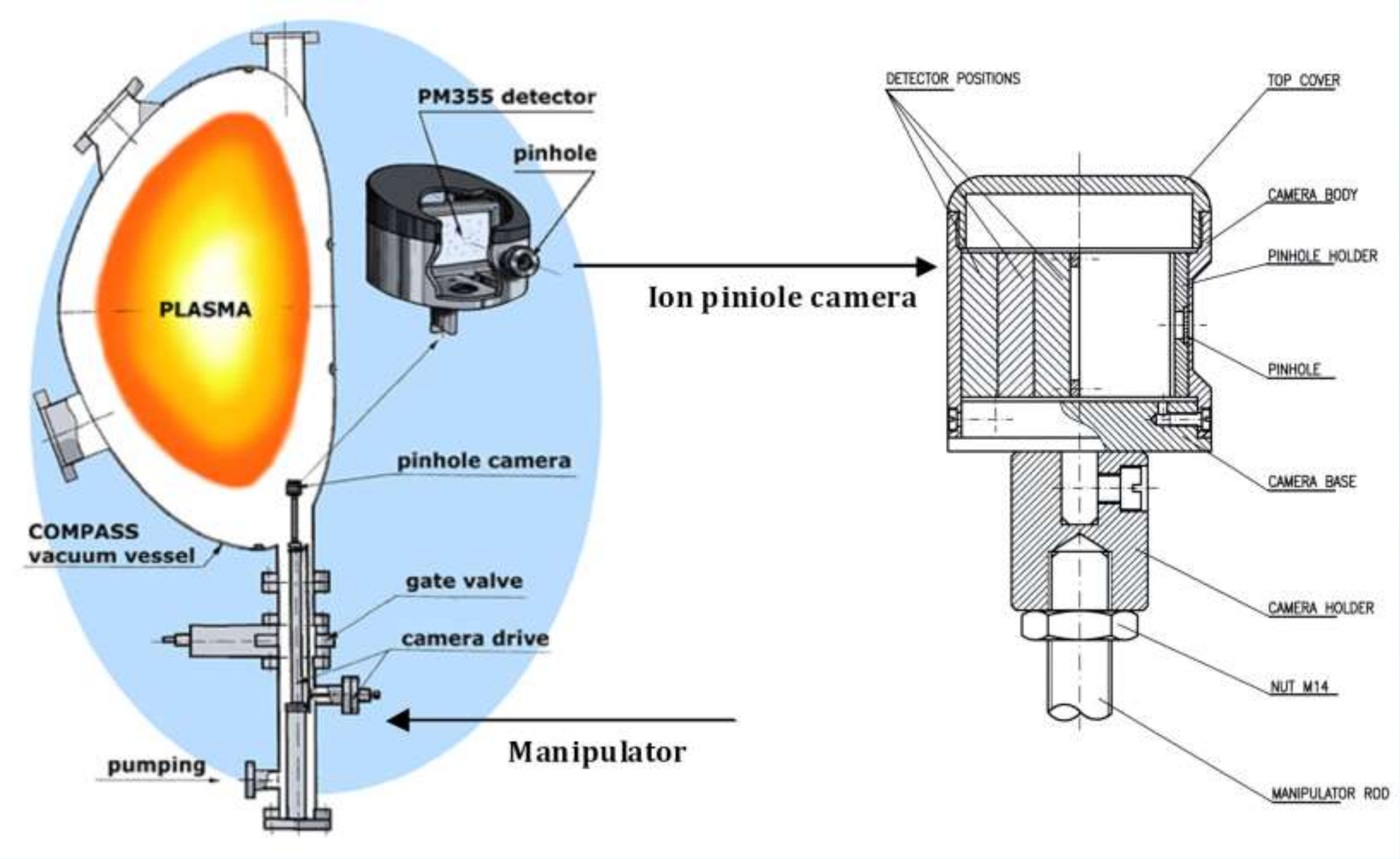
Exemplary pictures of the tracks produced by alfa-particles in the PM-355 detectors





Track diameter distributions of the alfa-particles emitted by ‘double’ and ‘triple’ alfa-sources

COMPASS Tokamak



Experiment planned for COMPASS