# Demet Tanısı

## (Beam Diagnostics)

Dr. Salim OĞUR

Accelerator Physicist at Applications of Detectors
and Accelerators to Medicine (A.D.A.M.)

# Demeti Tanısı: Görünmeyeni Görmek


INDEPENDENT

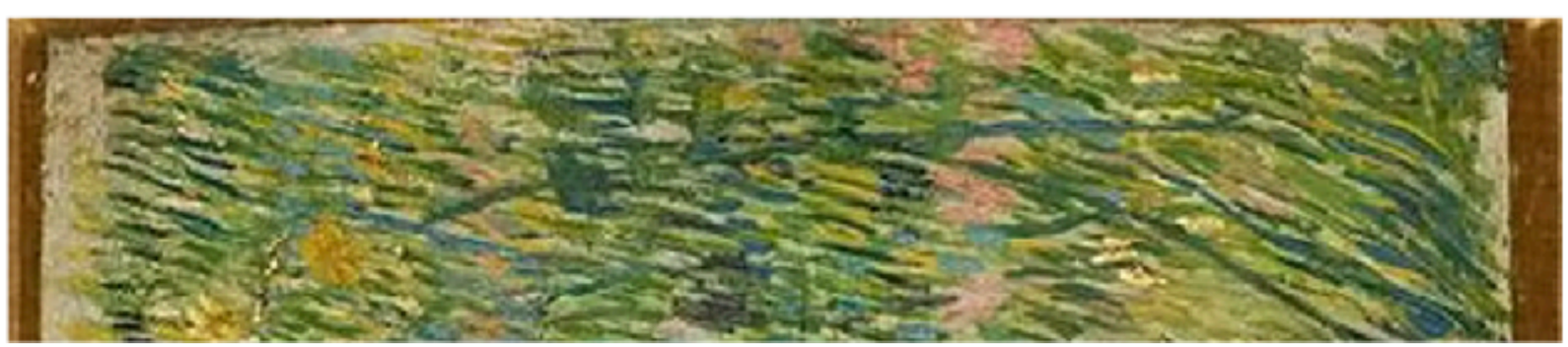
NEWS INDEPENDENT TV CLIMATE SPORT VOICES CULTURE TRAVEL INDY/LIFE PREMIUM INDYBEST INDY100 VOUCHERS COMPARE

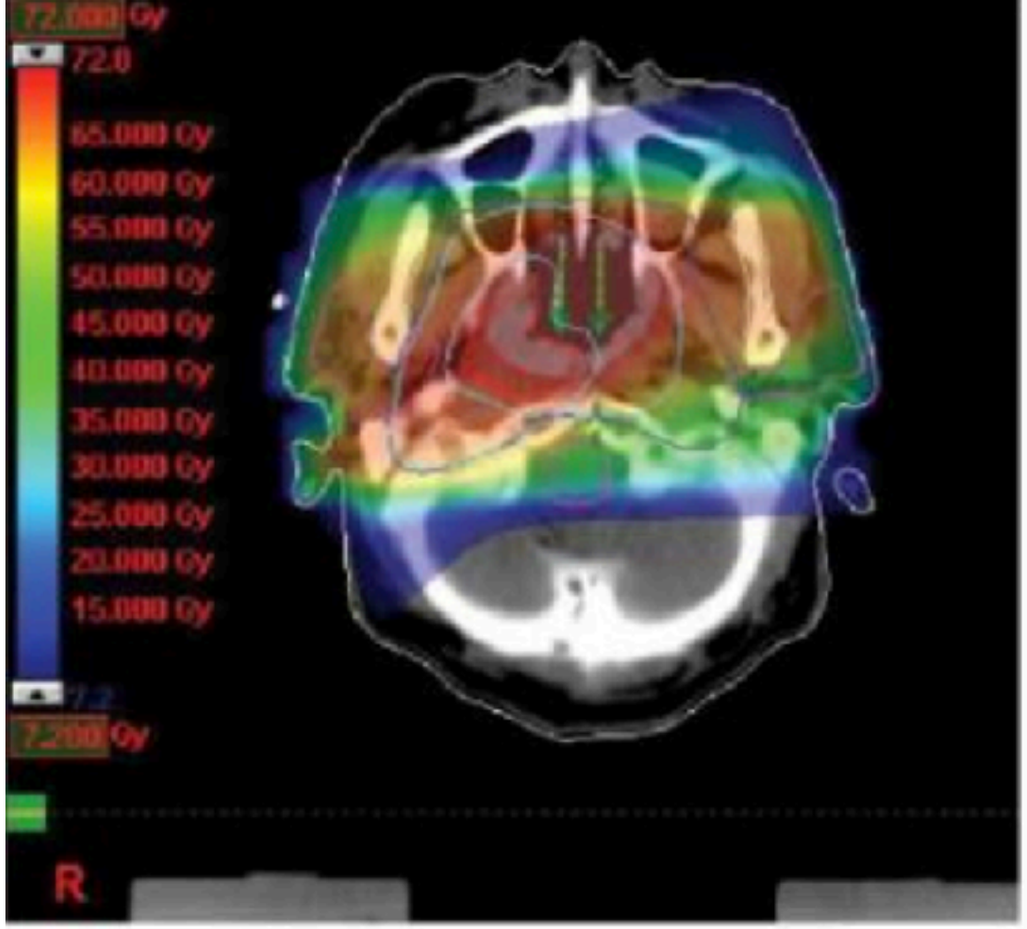
http://www.independent.co.uk/arts-entertainment/art/news/the-portrait-that-van-gogh-did-not-want-the-world-to-see-881393.html

Culture > Art > News

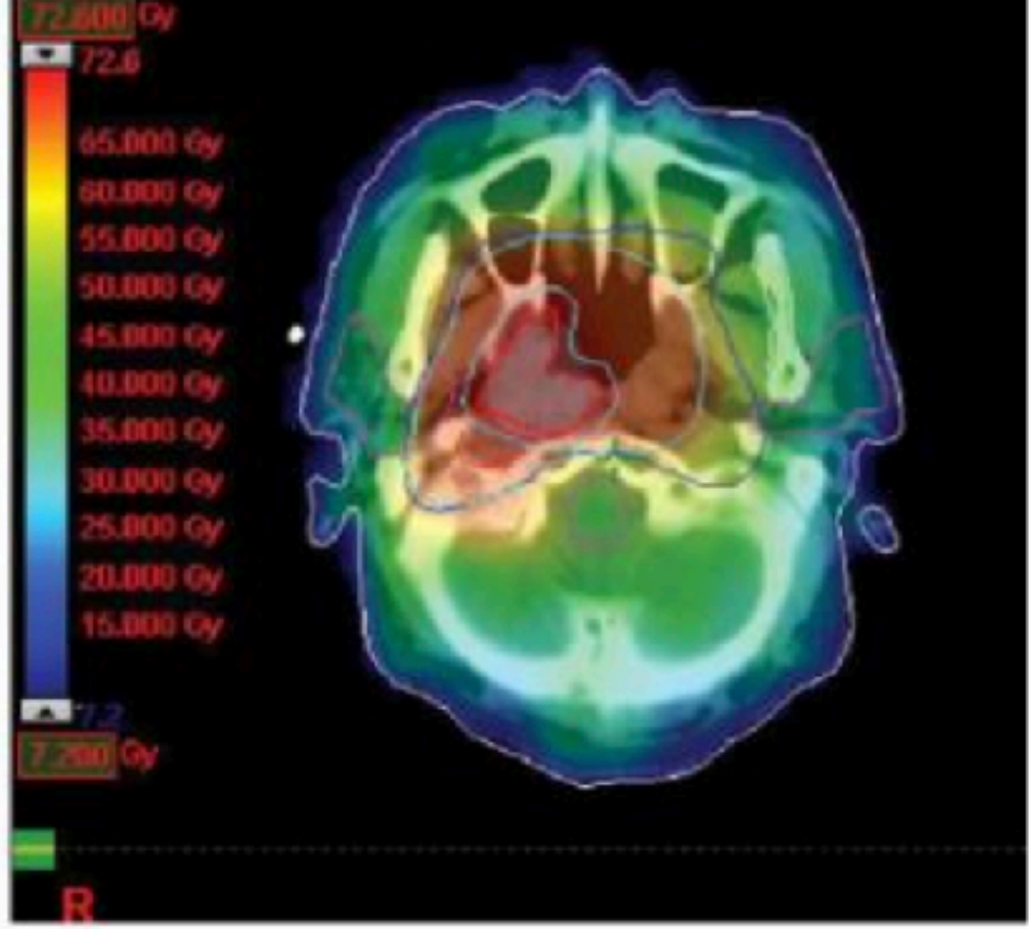
## The portrait that Van Gogh did not want the world to see

Toby Green • Thursday 31 July 2008 00:00 • Comments

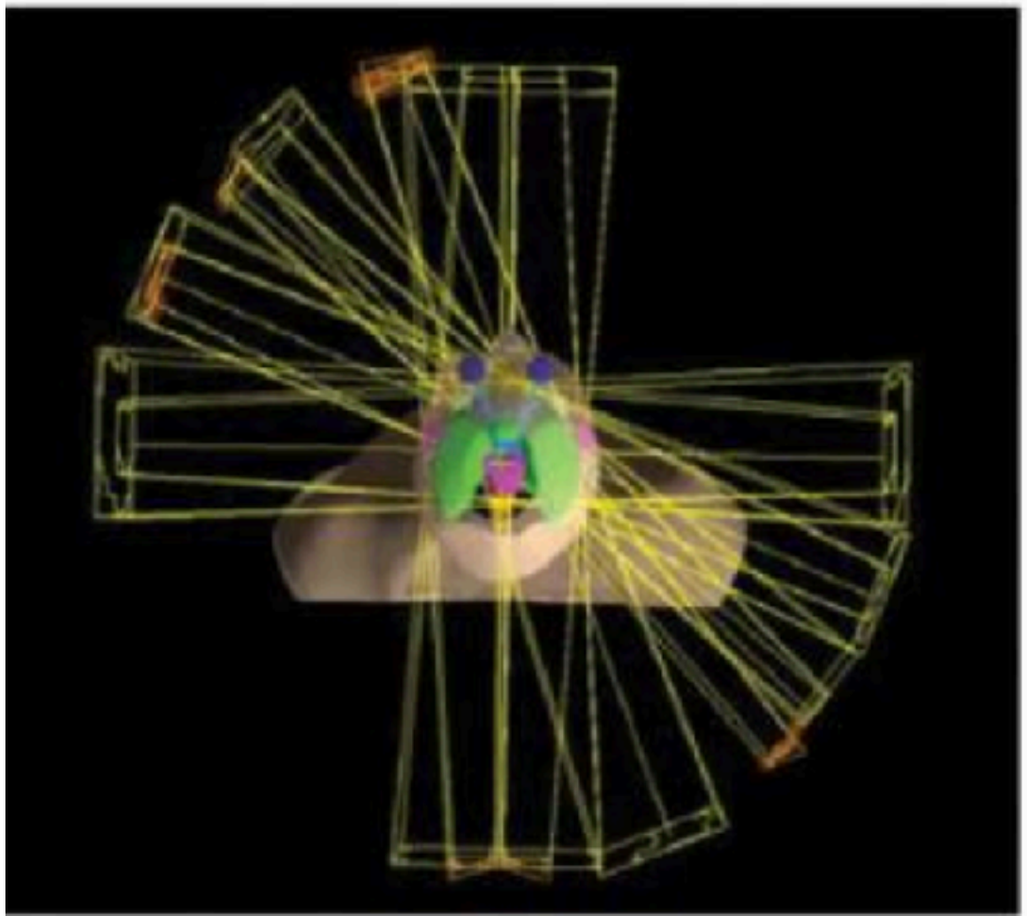


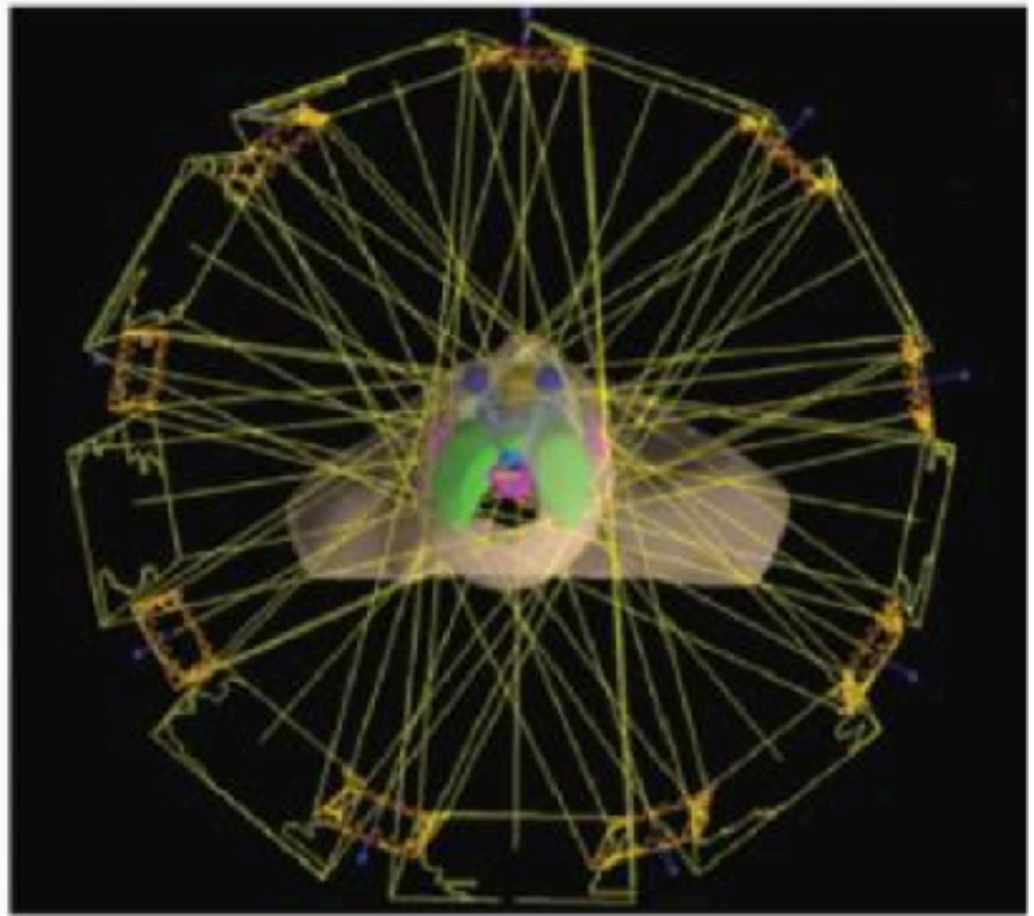

72.000 Gy
72.0
65.000 Gy
60.000 Gy
55.000 Gy
50.000 Gy
45.000 Gy
40.000 Gy
35.000 Gy
30.000 Gy
25.000 Gy
20.000 Gy
15.000 Gy
7.2
7.200 Gy
R

(a)


72.000 Gy
72.0
65.000 Gy
60.000 Gy
55.000 Gy
50.000 Gy
45.000 Gy
40.000 Gy
35.000 Gy
30.000 Gy
25.000 Gy
20.000 Gy
15.000 Gy
7.2
7.200 Gy
R

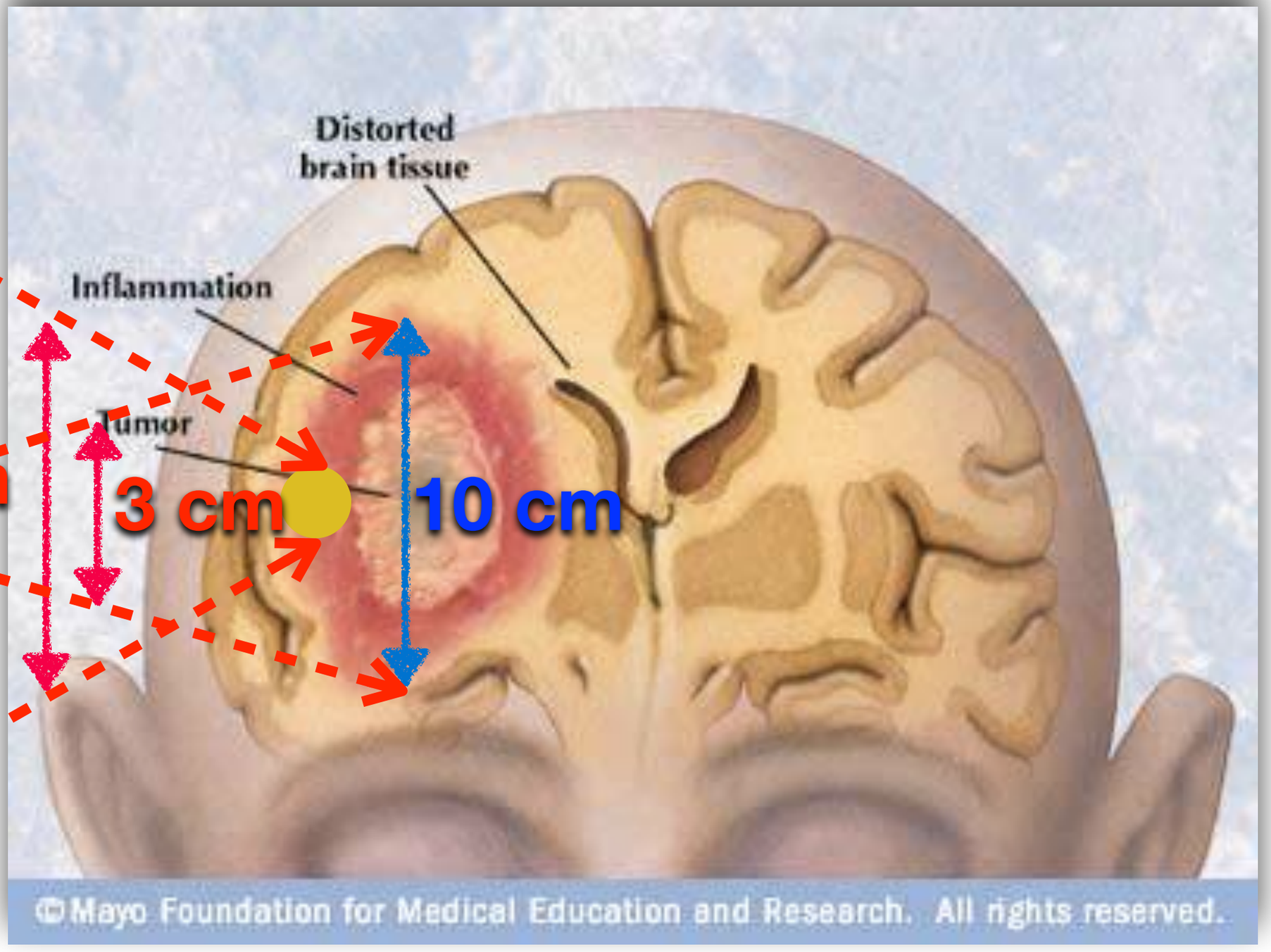
(b)





# Demeti Tanısı: Neleri ‘görmeliyim’?

- ✤ Konum
- ✤ Açı
- ✤ Profil
- ✤ Enerji
- ✤ Akım
- ✤ …

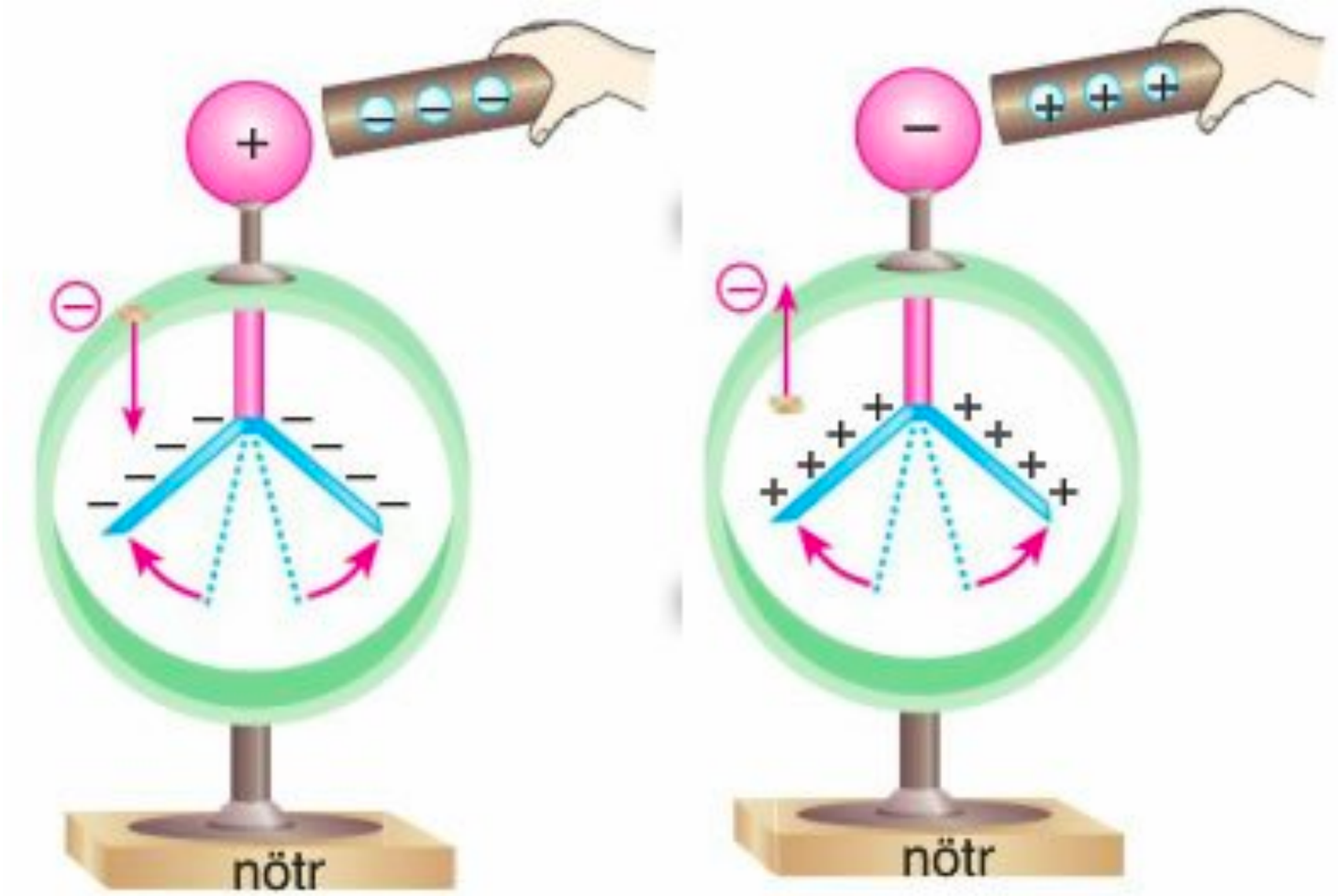


# 1. Sezon - Görelilik


**“Geçmiş, şu an ve gelecek arasındaki fark, inatçı bir illüzyondan ibarettir…”**

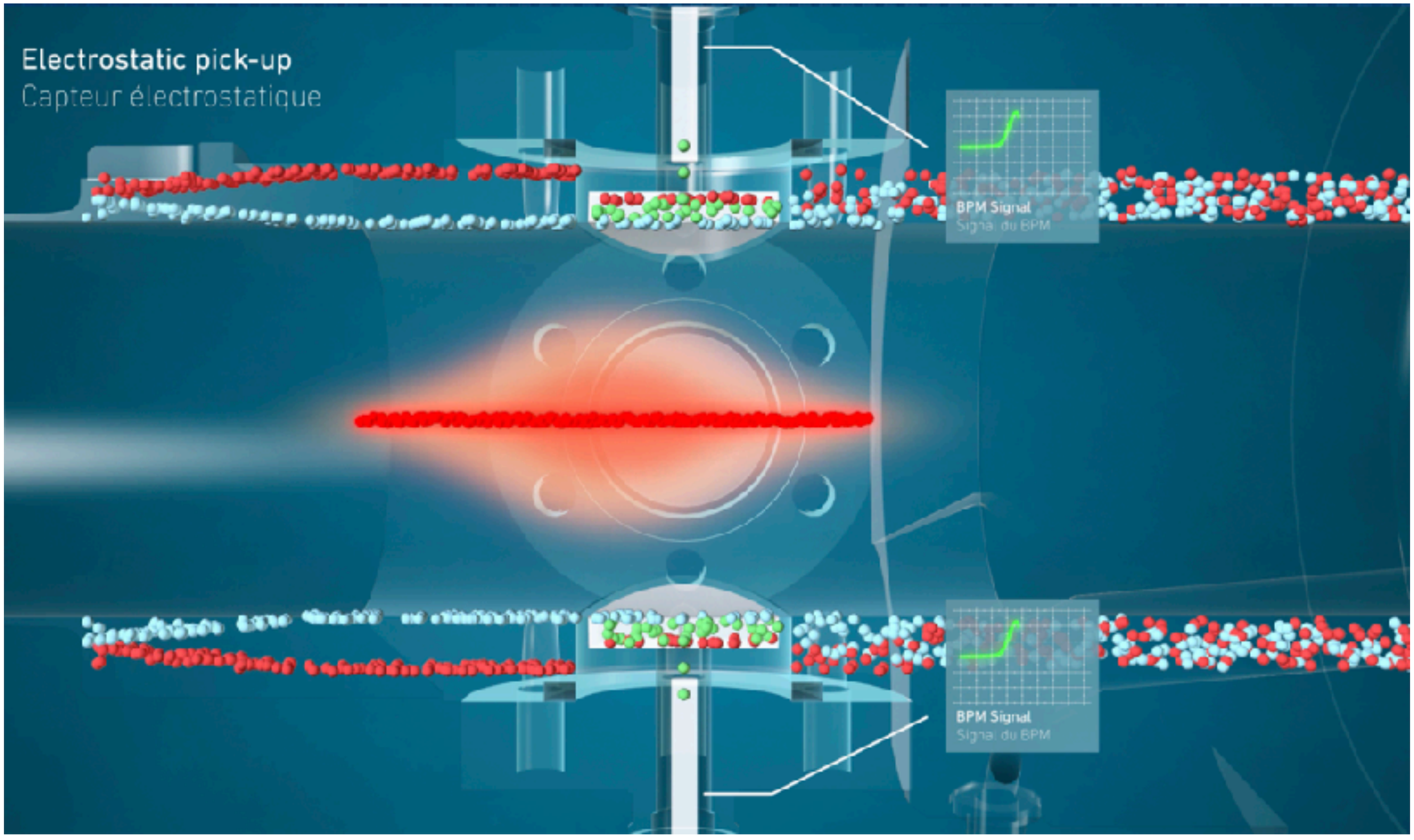
# 1 - Demet Konumu

## (Beam Position)




Yüklü çubuk yakınlaştıkça elektroskobun bacakları açılır.

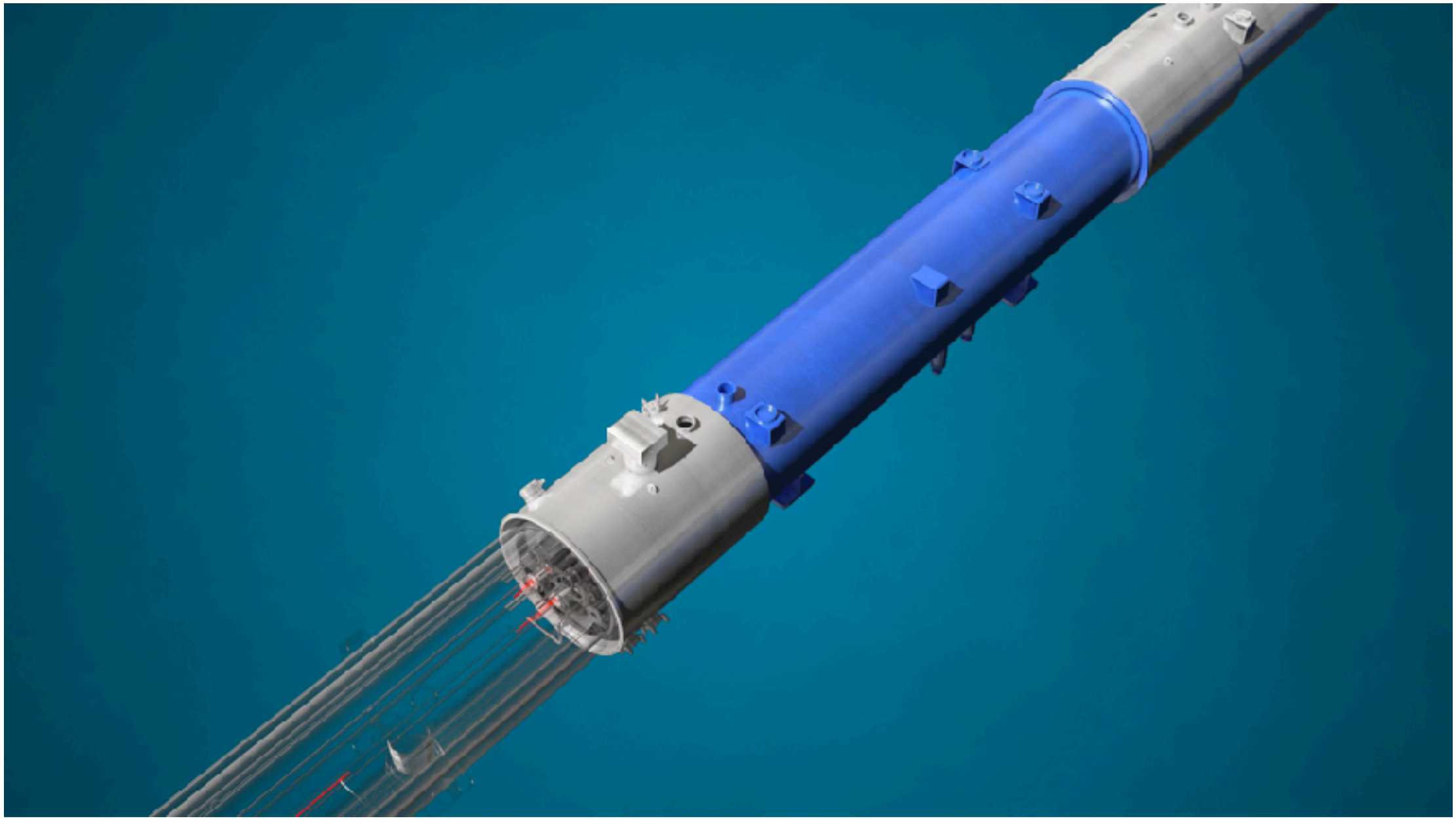
# 1.1. Demet Konum Ölçer
## (Beam Position Monitor)




**DKÖ (BPM) demetin merkezinin (centroid, reference, synchronous particle) konumunu ölçer.**

# 1.1. - Demet Konum Ölçer

## (Beam Position Monitor)



https://videos.cern.ch/record/2697274

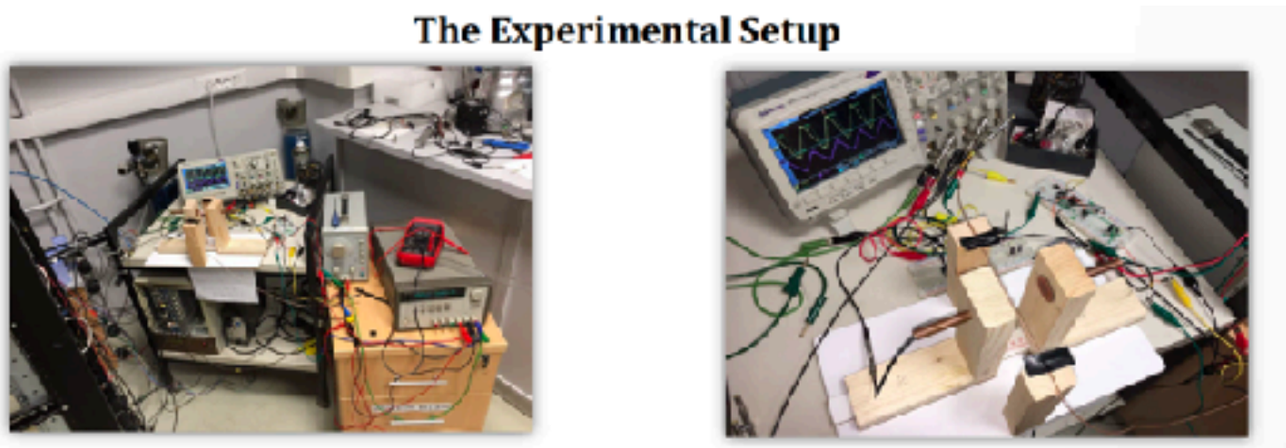
# 1.1. - Demet Konum Ölçer

## (Beam Position Monitor)

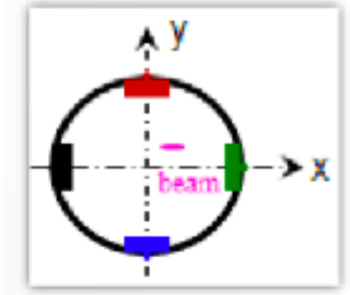
Design and Construction of Button Type Beam Position Monitor

O. KOCER[1]
A. ADIGÜZEL[1], S. OĞUR[2,3], V.E. ÖZCAN[3,4]
[1]Istanbul University, Vezneciler, Istanbul, Turkey [2]Boğaziçi University, Bebek, Istanbul, Turkey [3]CERN, Geneva, Switzerland
[4]Tran Güney Center for Physics and Mathematics, Boğaziçi University Üsküdar, Istanbul, Turkey
e-mail: oguzkocer@ogziu.ecu.tr

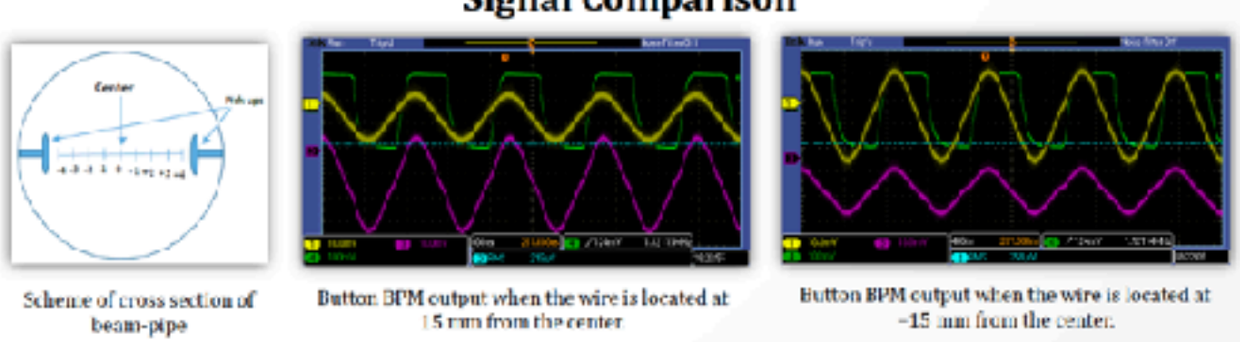
Abstract



The Experimental Setup




$$x = \frac{1}{S_x}\frac{V_{right} - V_{left}}{V_{right} + V_{left}} \qquad position = \frac{1}{S}\frac{\Delta V}{\Sigma V}$$

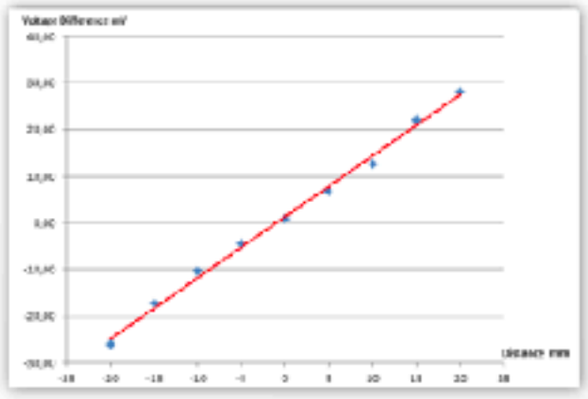


Signal Comparison

Scheme of cross section of beam-pipe

Button BPM output when the wire is located at 15 mm from the center

Button BPM output when the wire is located at −15 mm from the center.

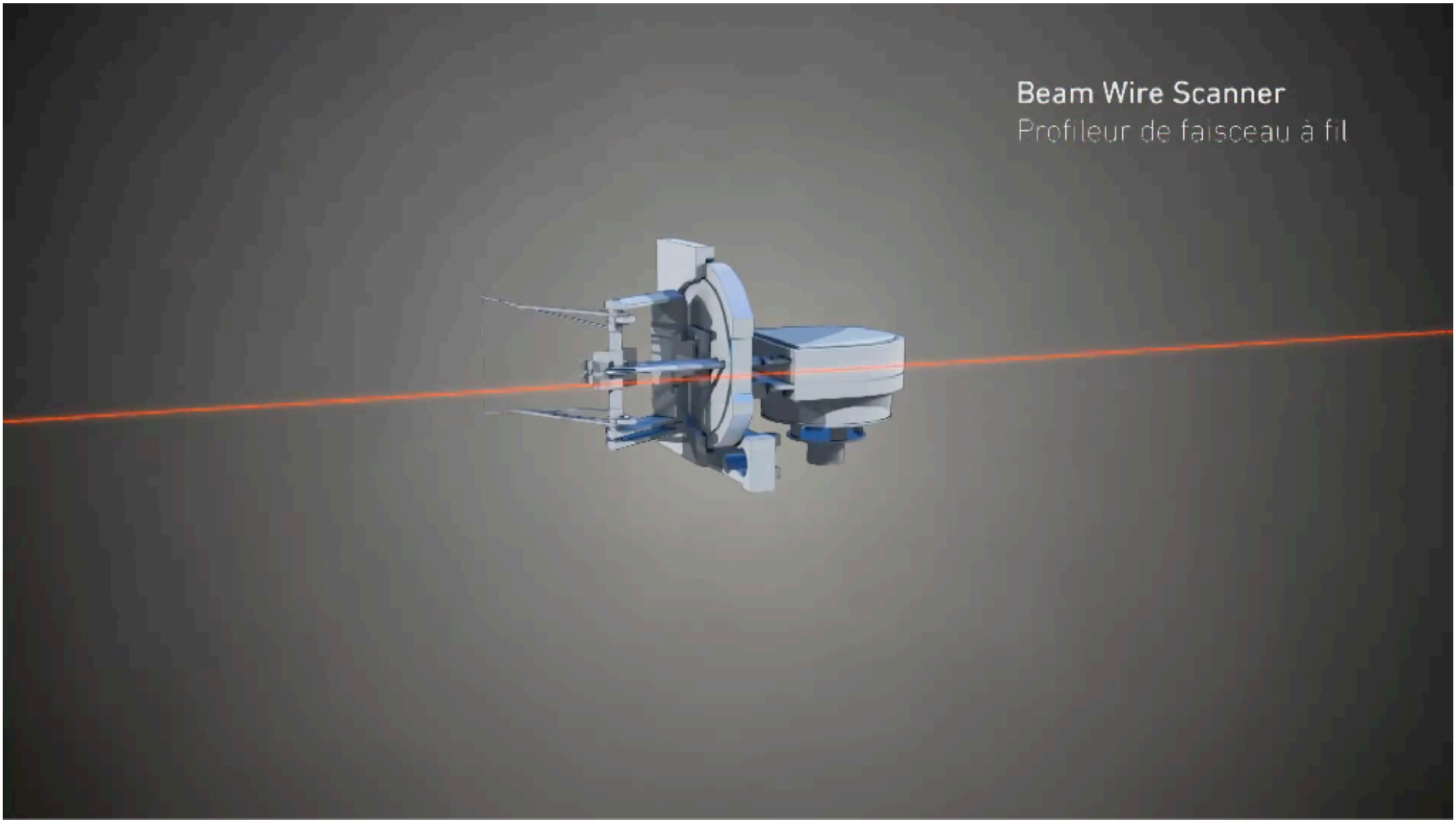


The voltage amplitude difference between the signals versus the wire (i.e. beam) position from the center has been plotted and is presented on the left.

It is observed that the relation between the beam displacement and the voltage amplitude difference is linear.

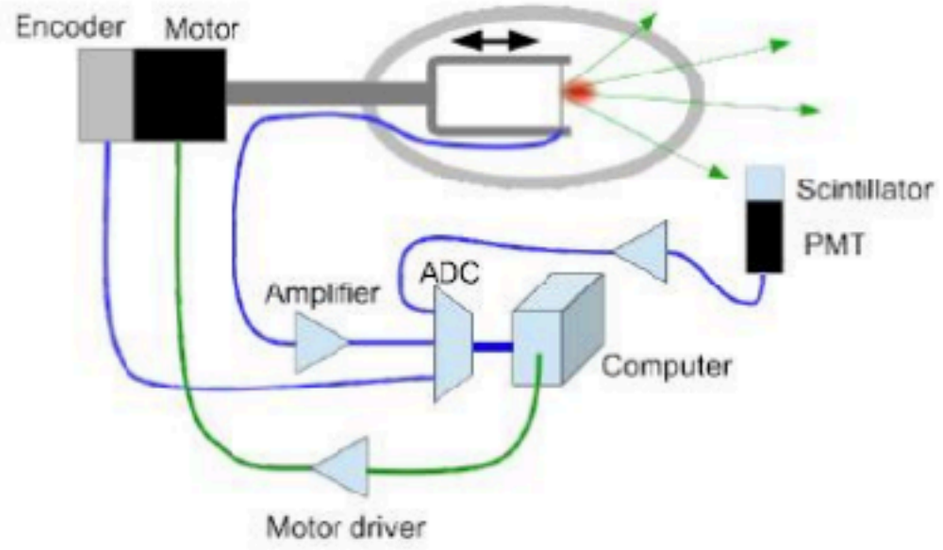
# 2.1. Demet Profil (+Konum)

## Tel Tarayıcı (Wire Scanner)

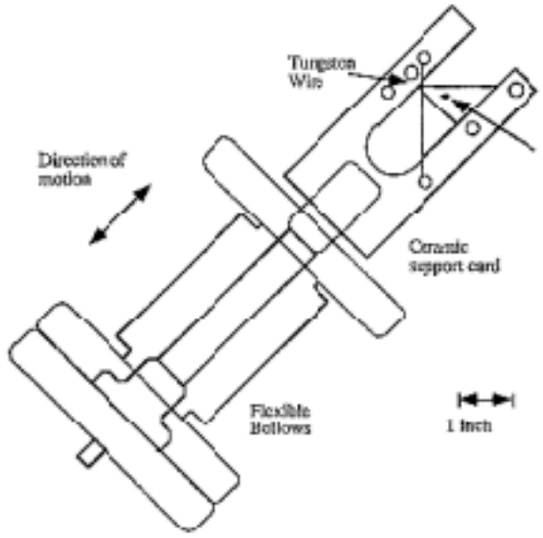


# 2.1. Demet Profil (+Konum)

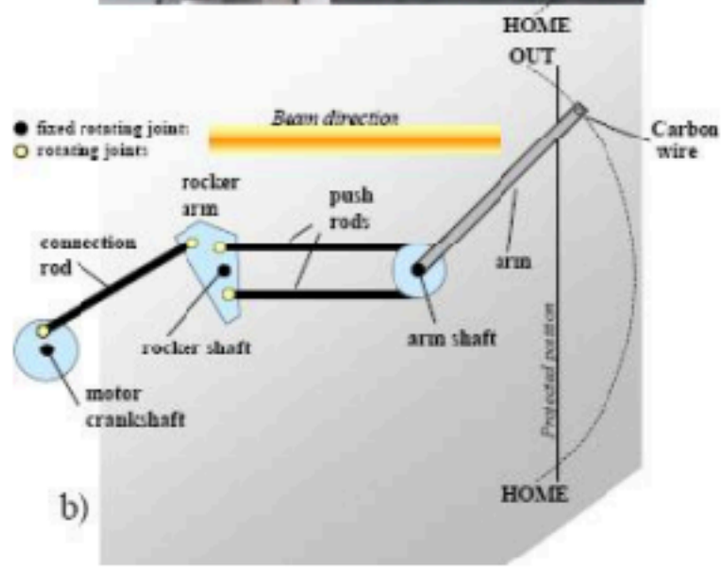
## Tel Tarayıcı (Wire Scanner)




Demeti tarayan ince bir tel (mikro-metre metresi bir kalınlıkta). Gelen (birincil) demeti değil o demetin metal telle etkileşmesinden kopan parçacıkların oluşturduğu akımı veya oluşan parçacıkları algılar, tabii oluşan parçacıklar fotonsa parıldar + Foton Çoğaltıcı Tübe ihtiyaç duyabilir.




SLAC SLC high resolution 3 axis scanners

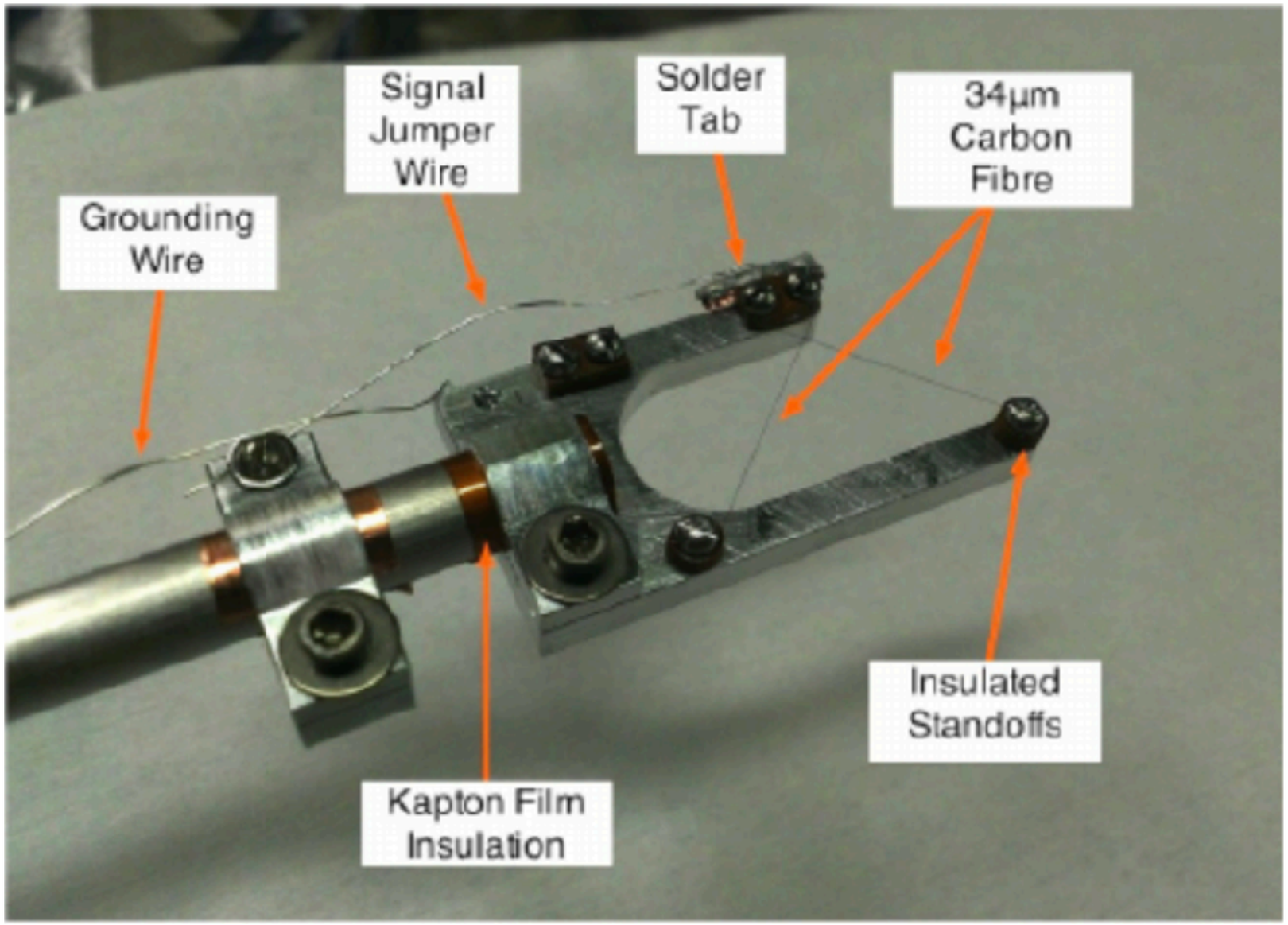




CERN “flying wires”

E. Bravin, Cern Accelerator School on Beam Instrumentation 2-15 June 2018, Tuusula, Finland

# 2.1. Demet Profil (+Konum)

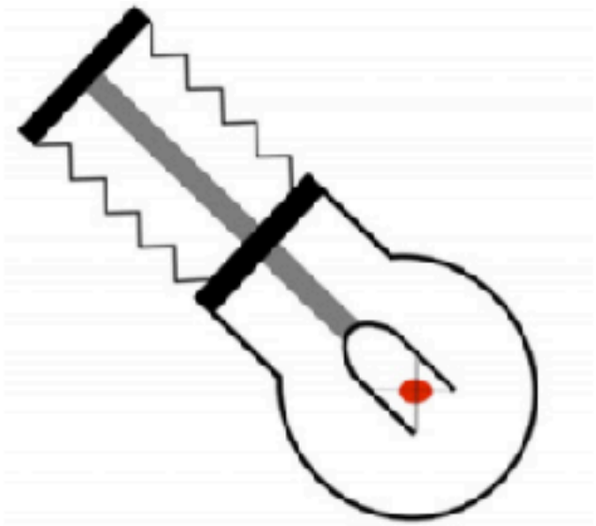
## Tel Tarayıcı (Wire Scanner)



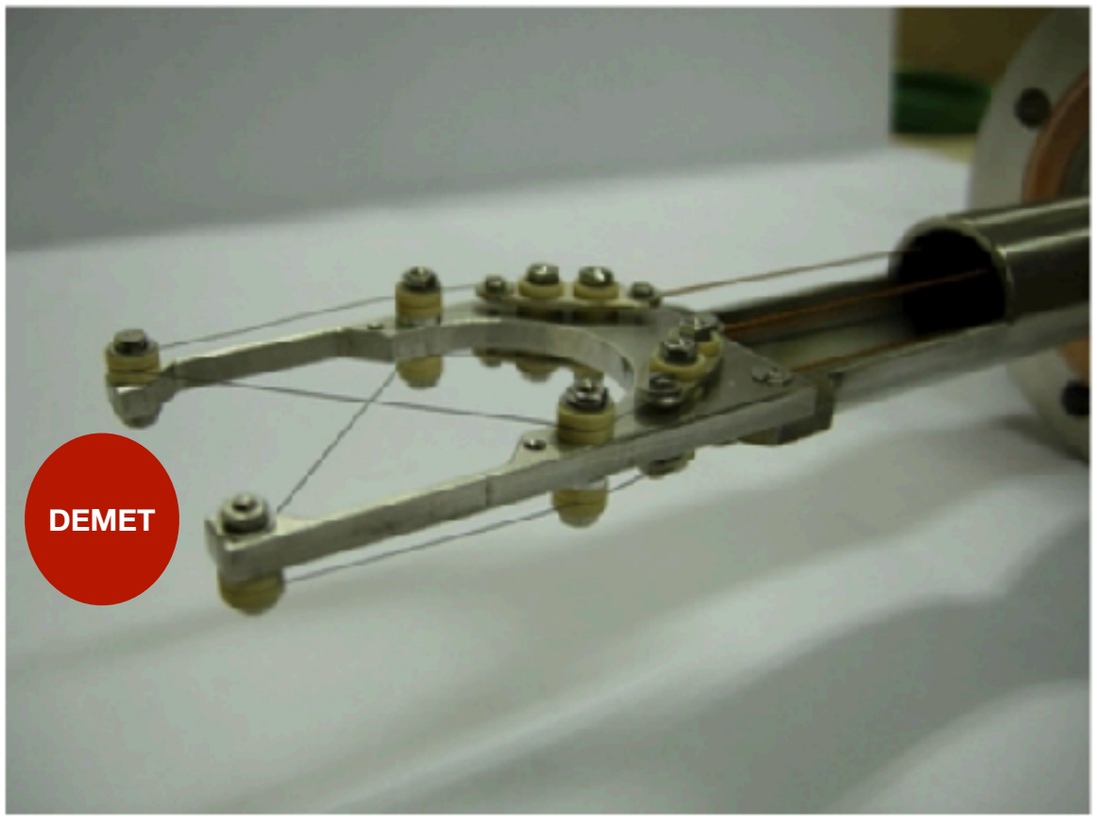

Aynı anda hem yatay hem düşey eksende ölçüm alabilir. Tabiki demetin içerisine 45 derece açıyla girip o eksende hareket ediyor.

# 2.1. Demet Profil (+Konum)

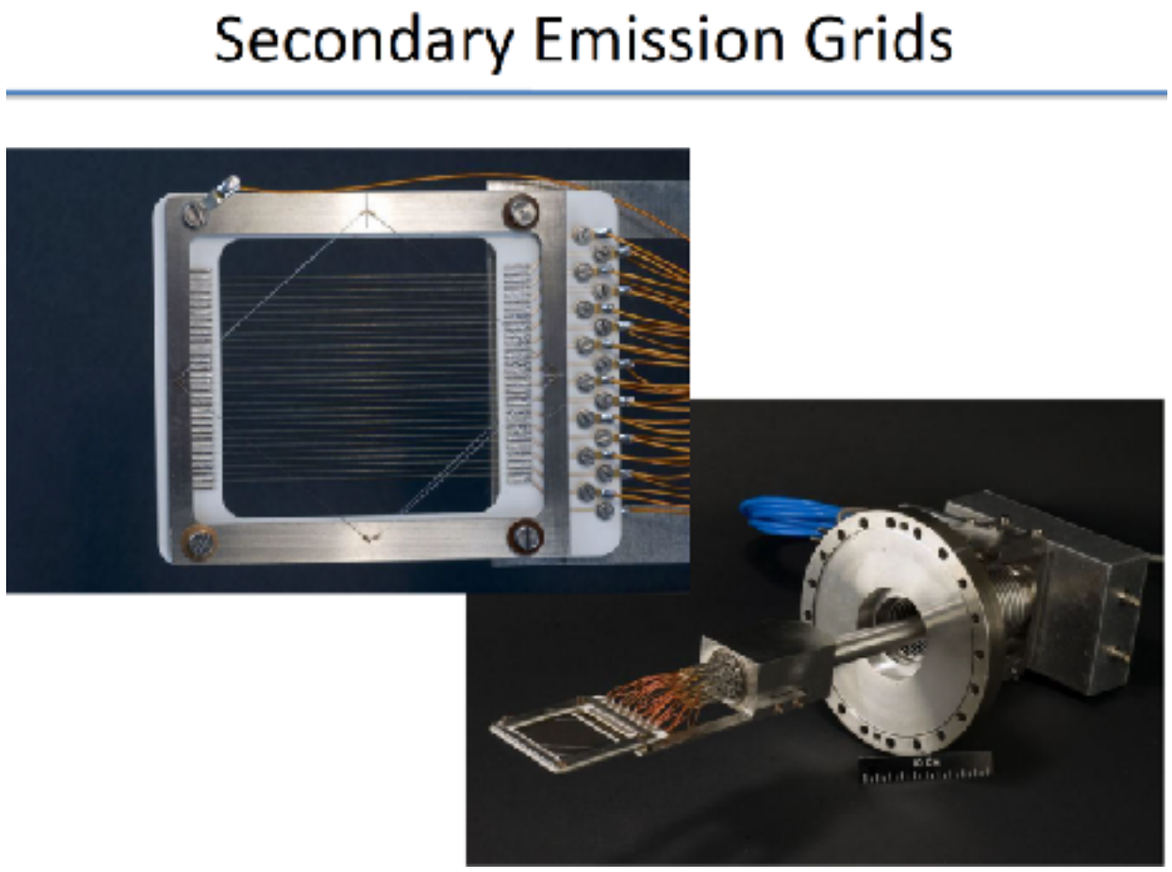
## Tel Tarayıcı (Wire Scanner)



Aynı anda hem yatay hem düşey eksende ölçüm alabilir. Tabiki demetin içerisine 45 derece açıyla girip o eksende hareket ediyor.



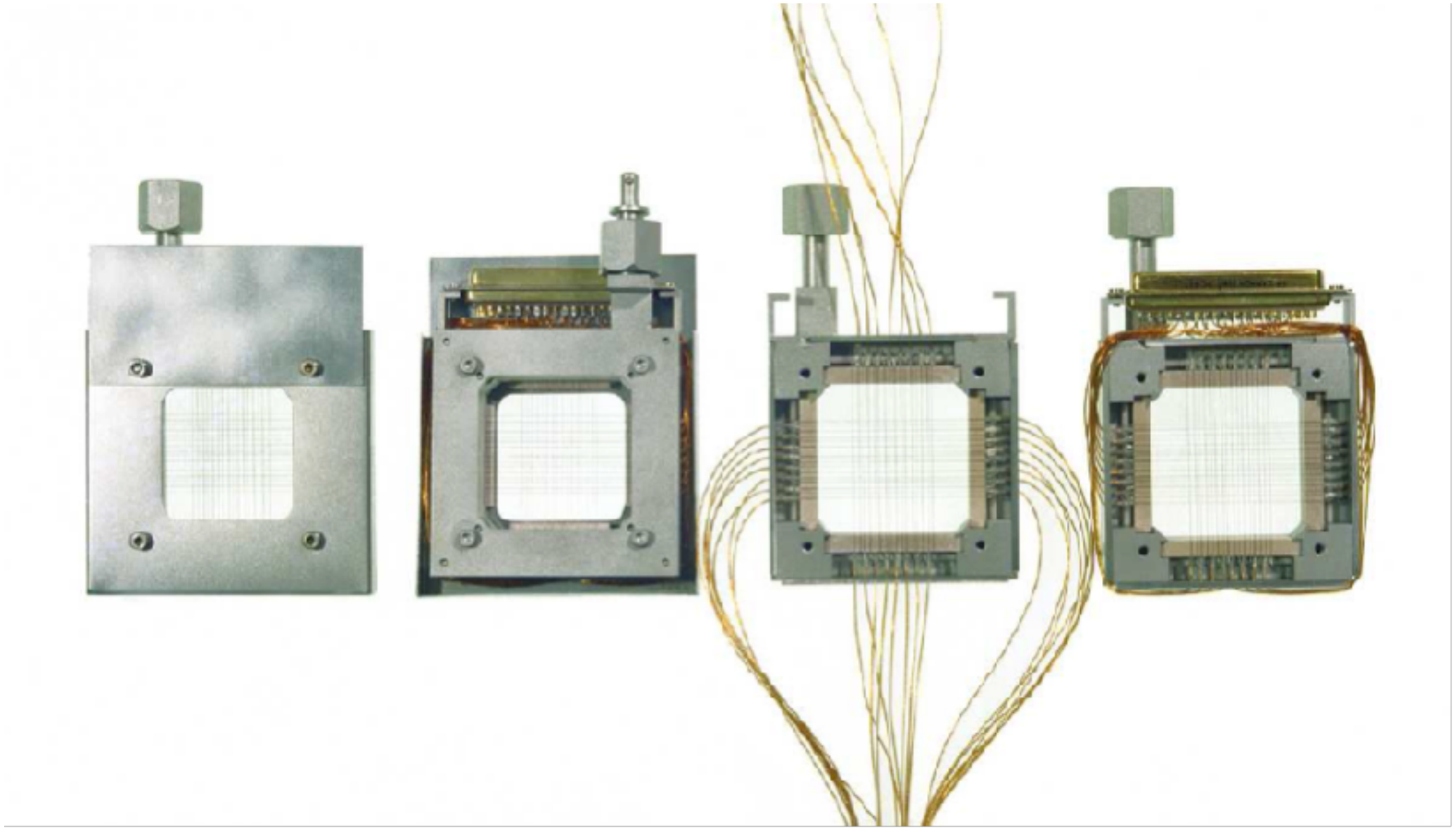
# 2.2. Demet Profili (+Konum)
# İkincil Parçacıklı Izgara (Secondary Emission Grid )



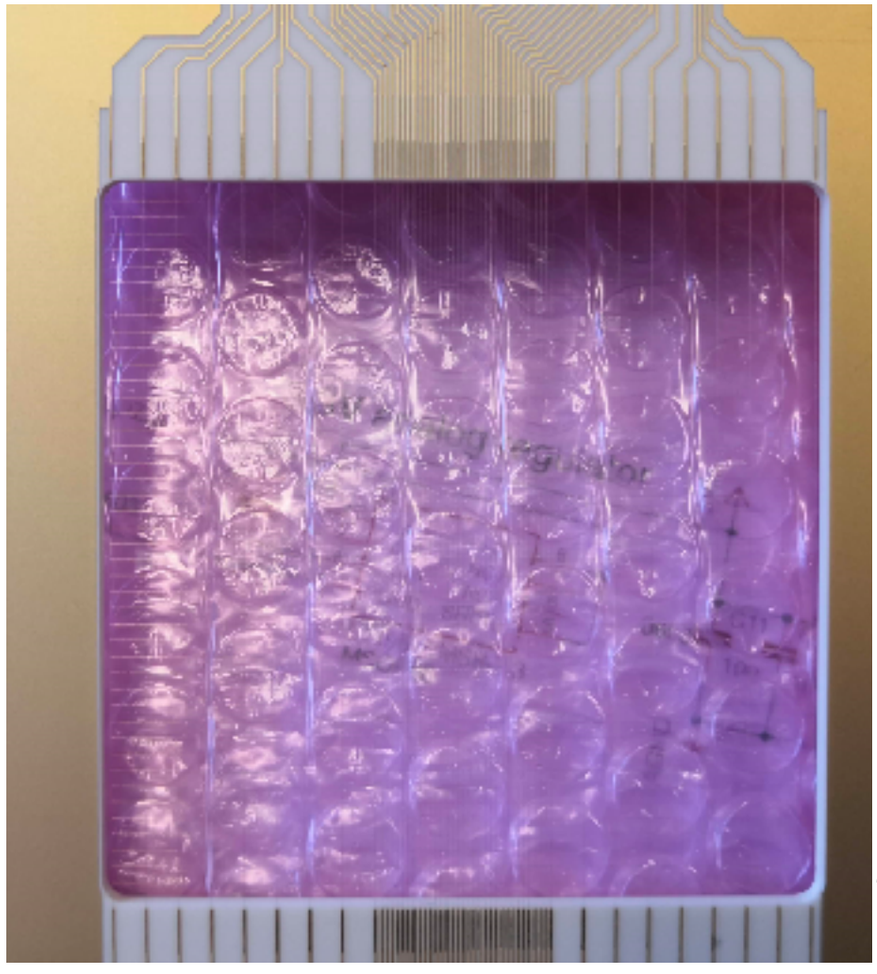

- Tellere çarpan parçacıklar, telden elektron koparırlar, kopan elektron telde akım (sinyal) oluşturur.
- Tel Çapları 0.05 - 0.5 mm aralığında teller arası mesafe mm mertebesinde.
- Her telin kendi elektroniği var, pahalı :(
- Demetin şeklini (profilini) ölçer.

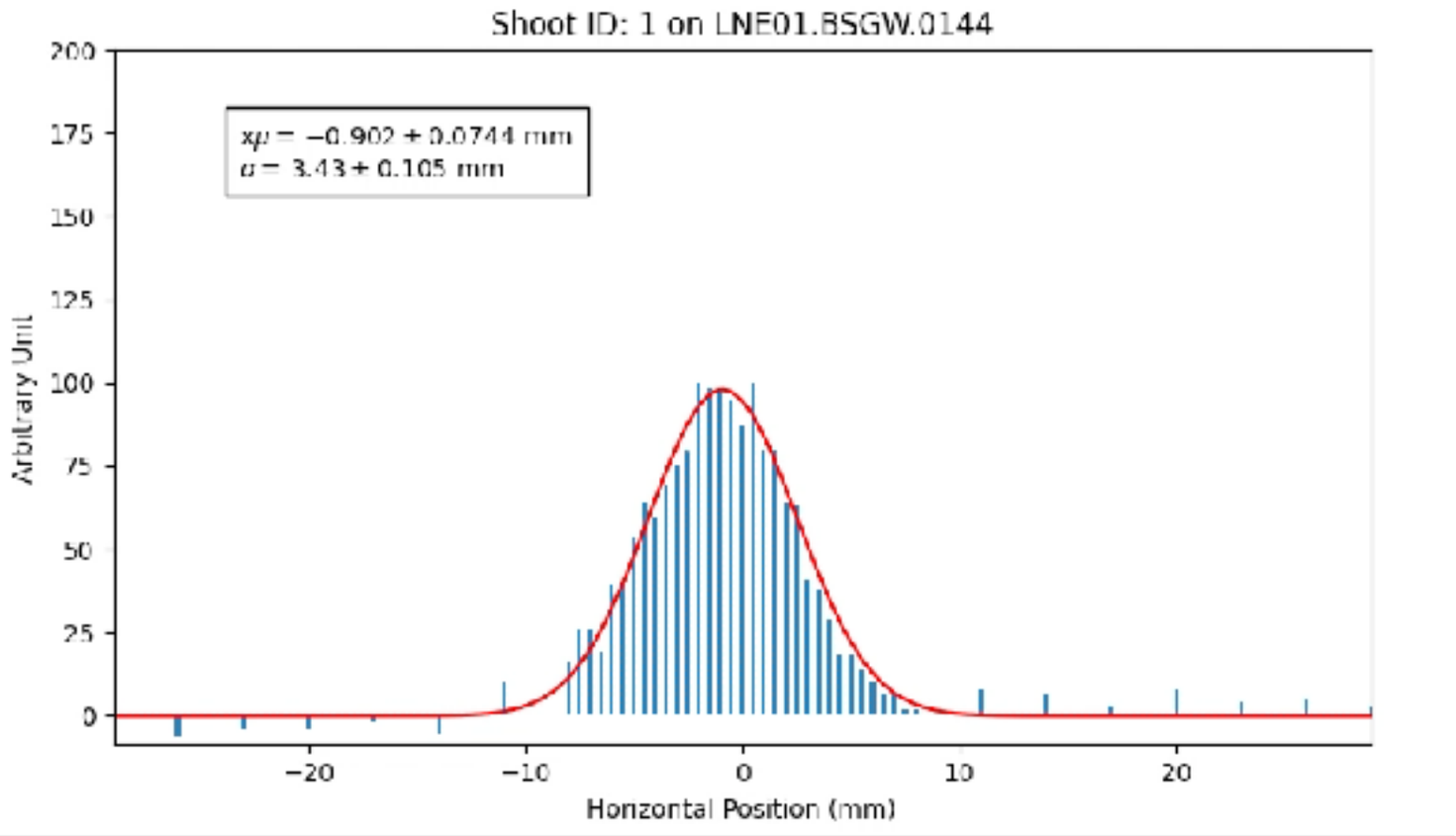
# 2.2. Demet Profili (+Konum)

# İkincil Parçacıklı Izgara (Secondary Emission Grid )



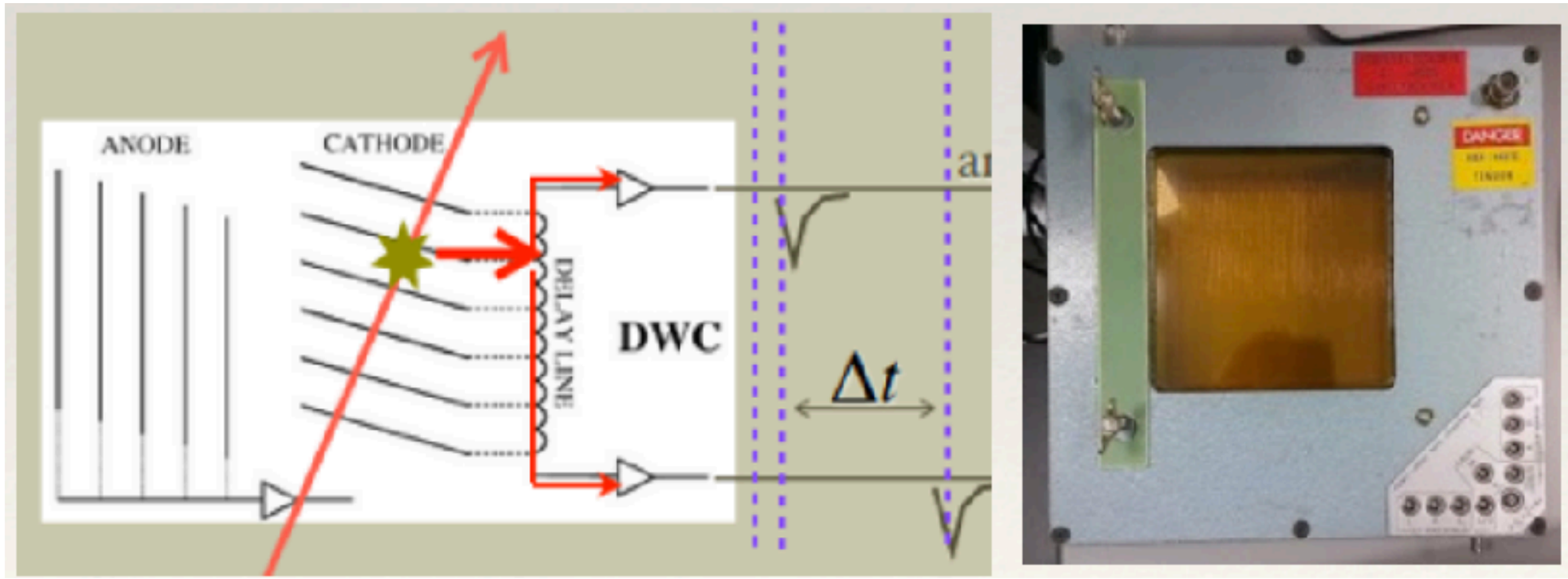
# 2.2. Demet Profili (+Konum)
# İkincil Parçacıklı Izgara (Secondary Emission Grid )





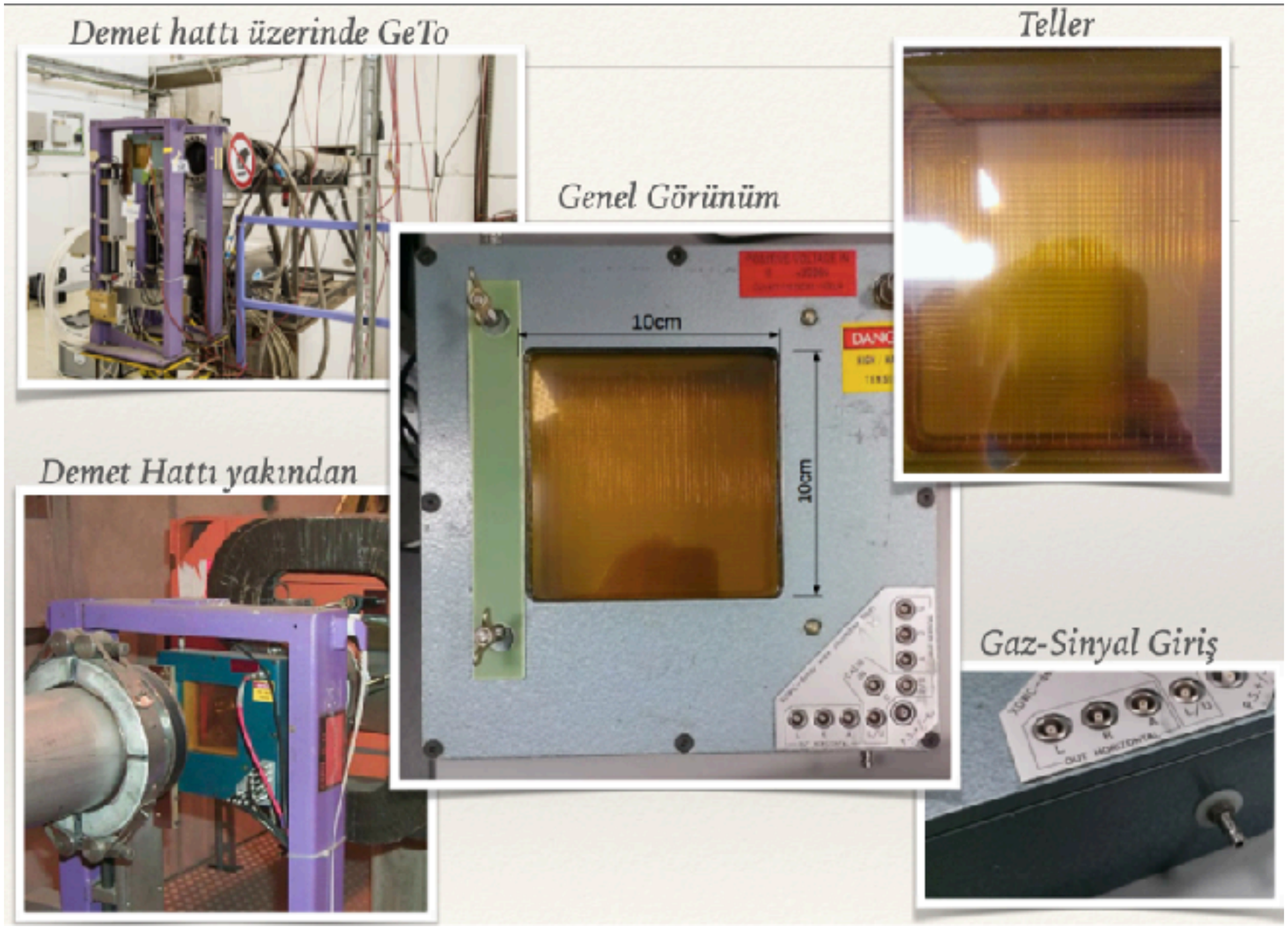

S. Oğur, ‘Extra Low Energy Anti-proton Ring Commissioning’

# 2.3. Demet Profili (+Konum)
# Gecikmeli Tel Odası (Delay Wire Chamber )



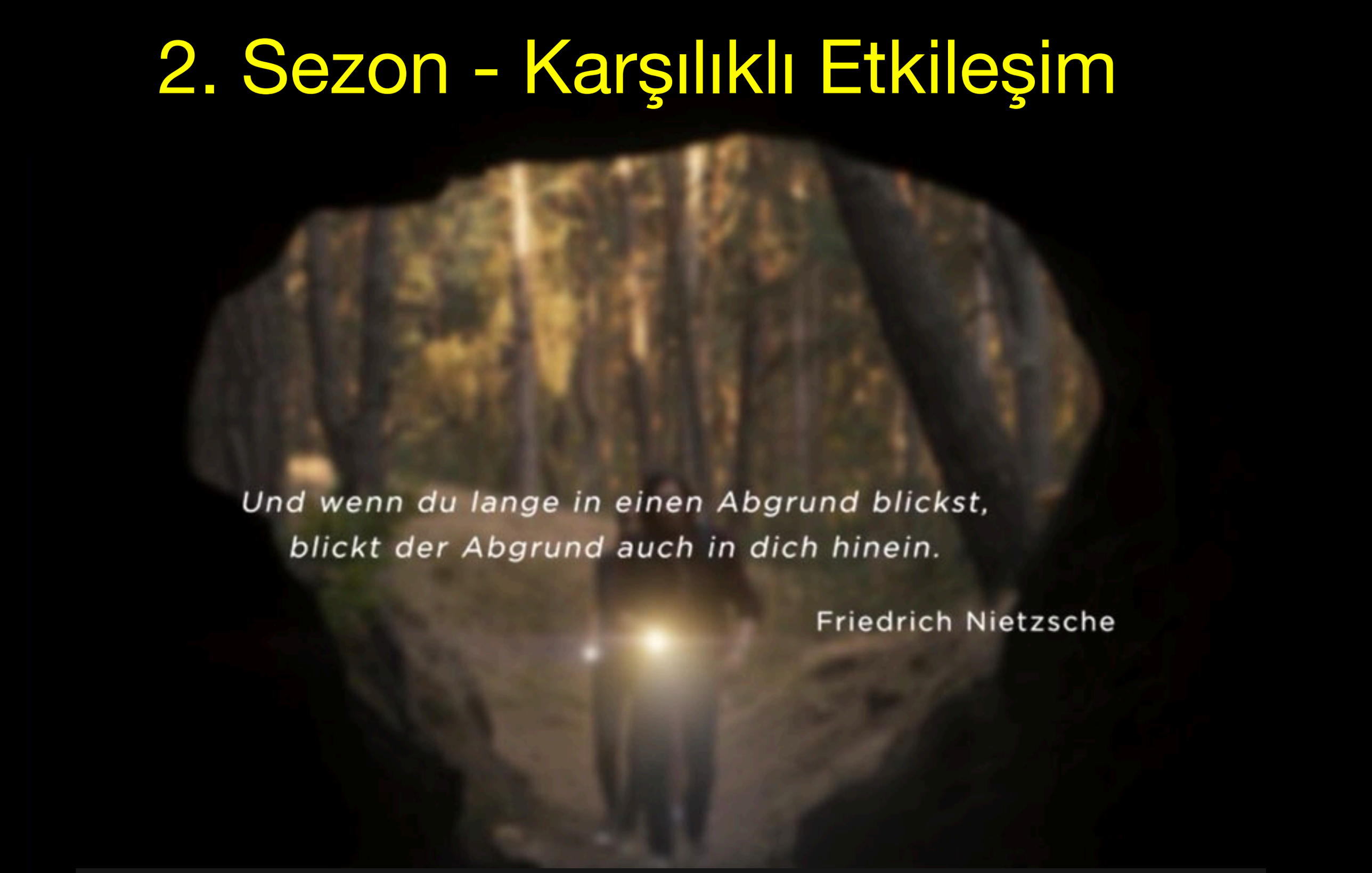

KahveLab https://indico.cern.ch/event/489217/contributions/2184759/attachments/1282817/1906648/hizalcalis_2016_geto.pdf

# 2.3. Demet Profili (+Konum)
# Gecikmeli Tel Odası (Delay Wire Chamber )




KahveLab https://indico.cern.ch/event/489217/contributions/2184759/attachments/1282817/1906648/hizalcalis_2016_geto.pdf

# 2. Sezon - Karşılıklı Etkileşim

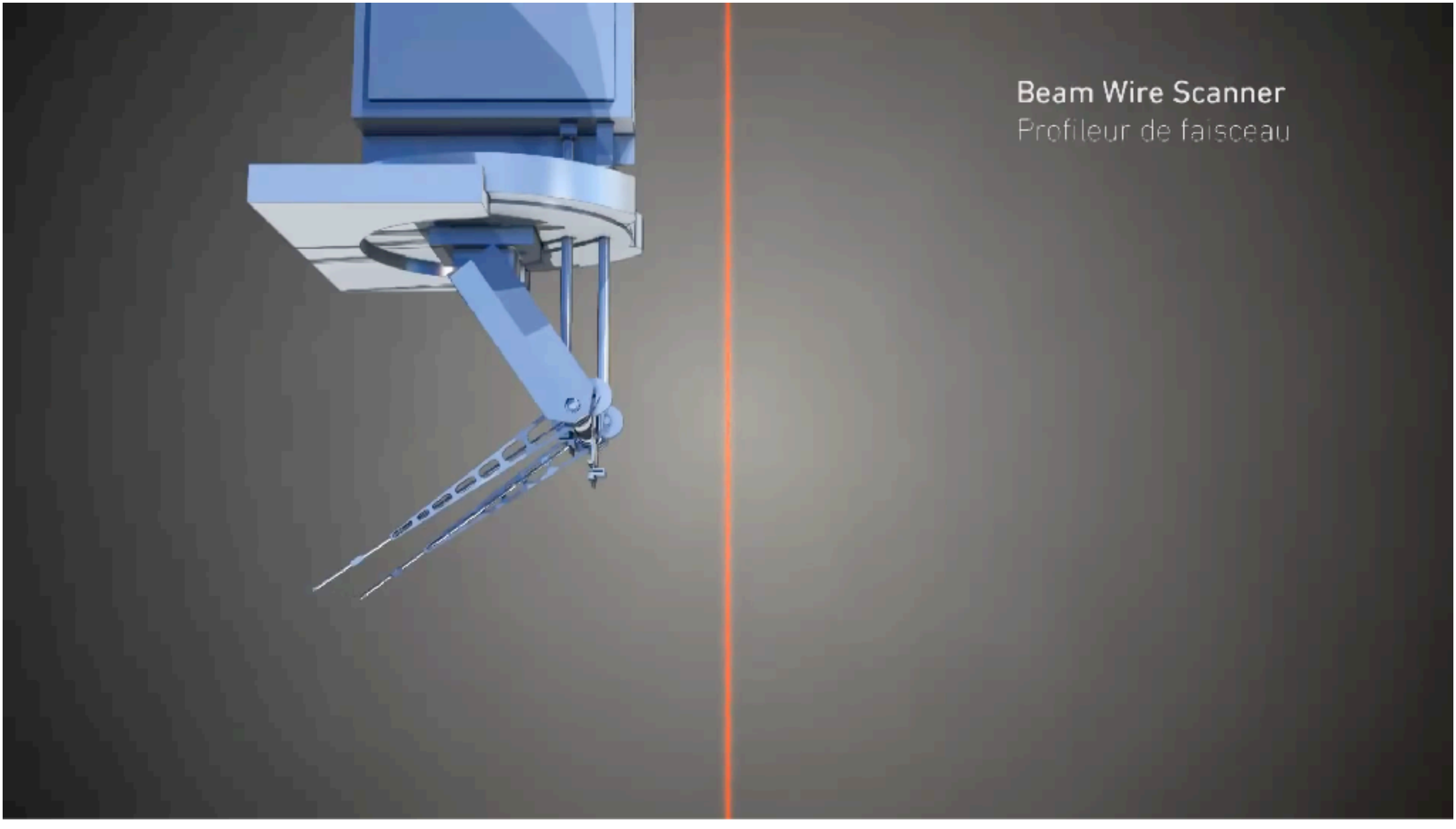



“Uçuruma baktığında uçurum da sana bakar.” F. Nietzsche

# 2.4. Demet Profili (+Konum)
# Demet Gaz İyonlaşması (Beam Gas Ionization)

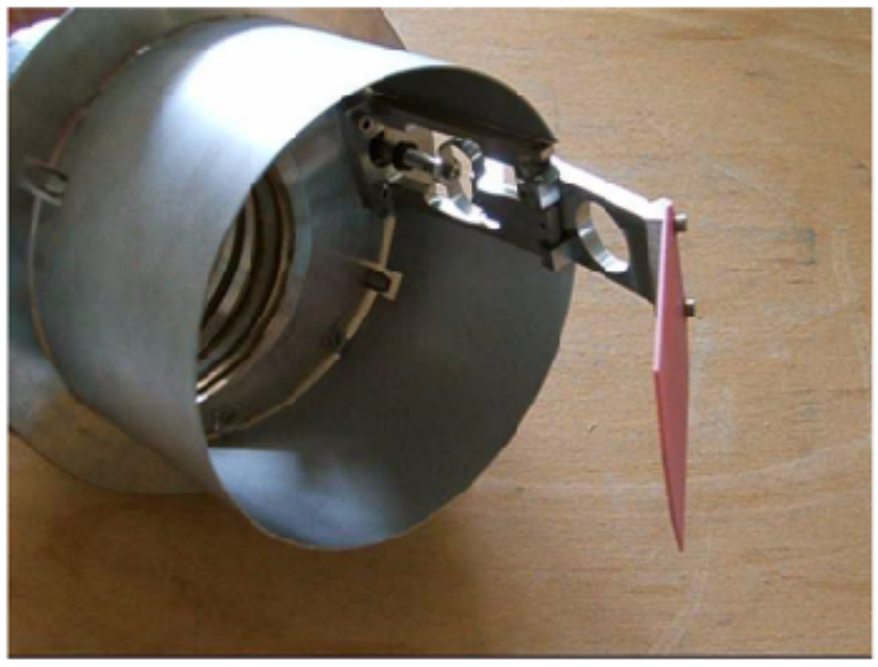
CERN Proton Synchrotron https://indico.cern.ch/event/838902/contributions/3519028/attachments/1891603/3119681/2019-08-08-LIU_PS-Update_on_BGI_data_analysis_activities.pptx

# 2.5. Demet Profili (+Konum)
# Ekranlar (Scintillators)



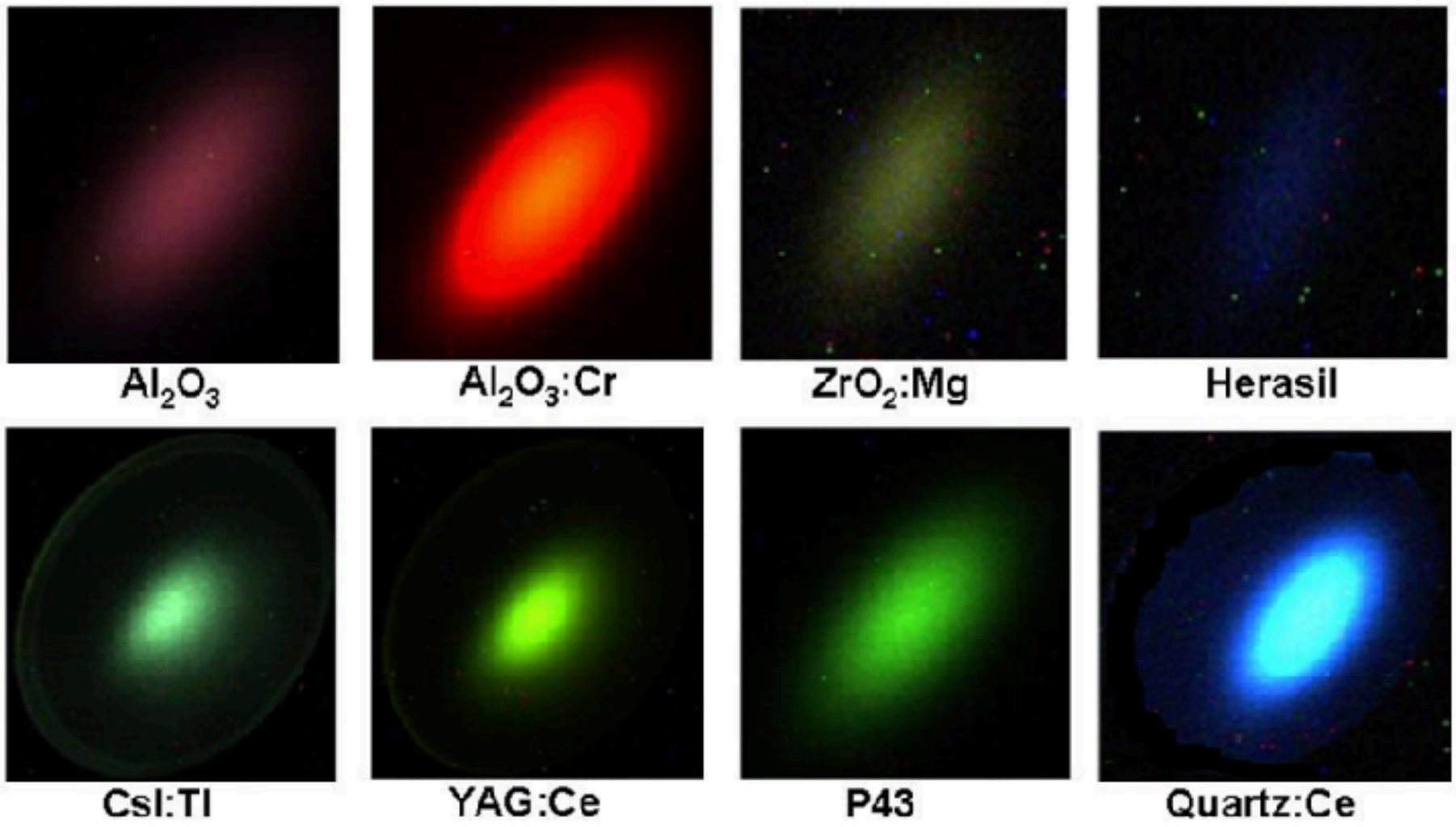
# 2.5. Demet Profili (+Konum)
## Ekranlar (Scintillators)

- Screen with graticule



# 2.3. Demet Profili (+Konum)

## Ekranlar (Scintillators)

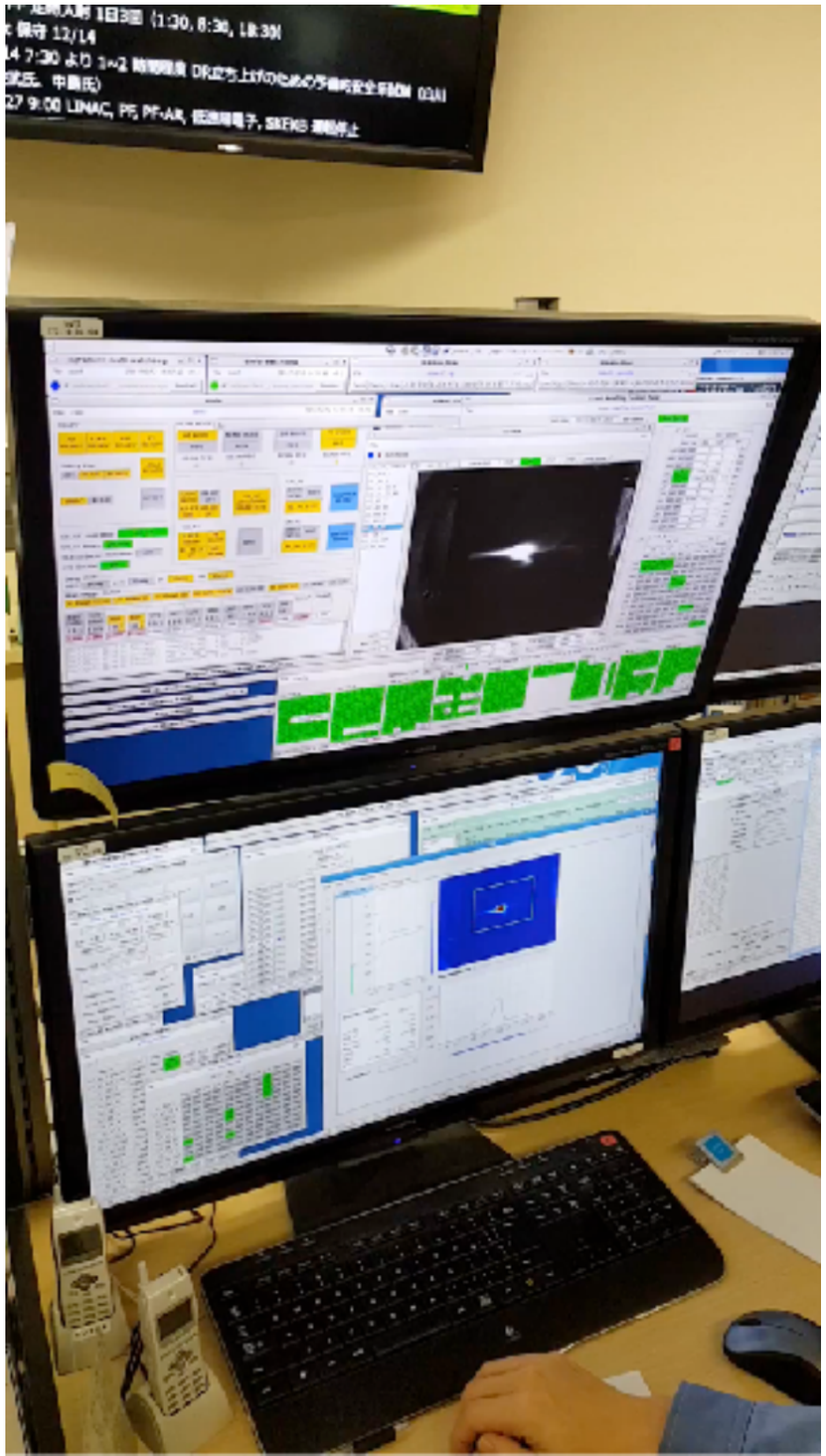



AVA school on Low Energy Antimatter Physics 25-29 June 2018
hao.zhang@cockcroft.ac.uk

**Bazı Parıldak (Scintillator) Işımaları**

# 2.3. Demet Profili (+Konum)
# Ekranlar (Scintillators)

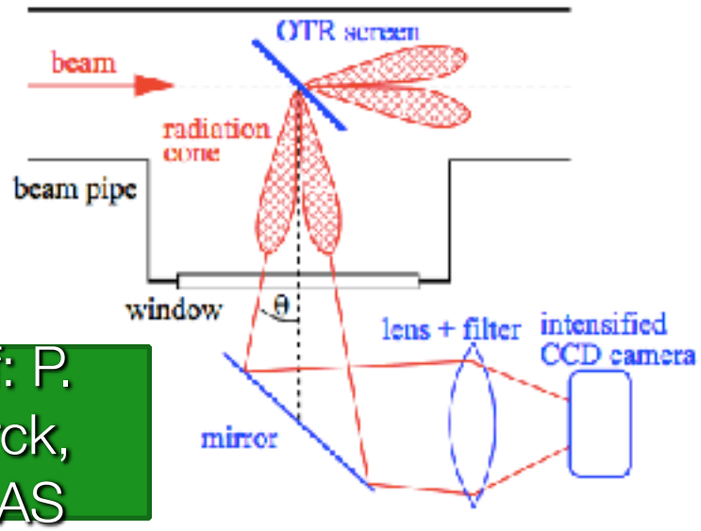

# 2.4. Demet Boyuna Profili - Parıldak Ekran (Scintillators)



RF Acceptance versus Synchronous Phase

### 3.7 Optical transition radiation screens

At electron accelerators with relativistic particles the profile is determined from the electromagnetic radiation at an intercepting thin metallic foil by the so called Optical Transition Radiation OTR. The OTR is a pure classical electrodynamic process including special relativity, as produced by a charged particle passes from one medium into another. At the vacuum in front of the foil, the particle has a certain electro magnetic field configuration, which is different from the field inside the medium, because the foil has a (complex) dielectric constant different from vacuum. By approaching the foil, the particle's electro magnetic field leads to a time dependent polarization at the foil boundary. The change of this polarization emits the radiation, which combines coherently from different points at the foil to a characteristic intensity and angular distribution.




Ref: P. Forck, JUAS

Figure 3.24: The scheme of an OTR screen measurement.

A typical setup of an OTR measurement is shown in Fig. 3.24. The foil is inserted under 45° with respect to the beam path in most cases. The foil is made of Aluminum or Aluminum coated on Mylar with a thickness 1 µm or less. The light is emitted in the forward direction as well as at 90°, because the metallic surface acts as a mirror. Depending on the particle energy, the angular distribution is peaked at the angle $\theta = 1/\gamma$ with $\gamma$ the relativistic Lorentz factor, see below. For typical values, 100 to 1000 beam particles yield 1 photon in the optical wavelength range. With appropriate optics, an image of the foil is recorded with a CCD camera. In most cases an image amplified CCD device is used due to the relatively low number of photons.

# 2.4. Demet Boyuna Profili - Parıldak Ekran (Scintillators)

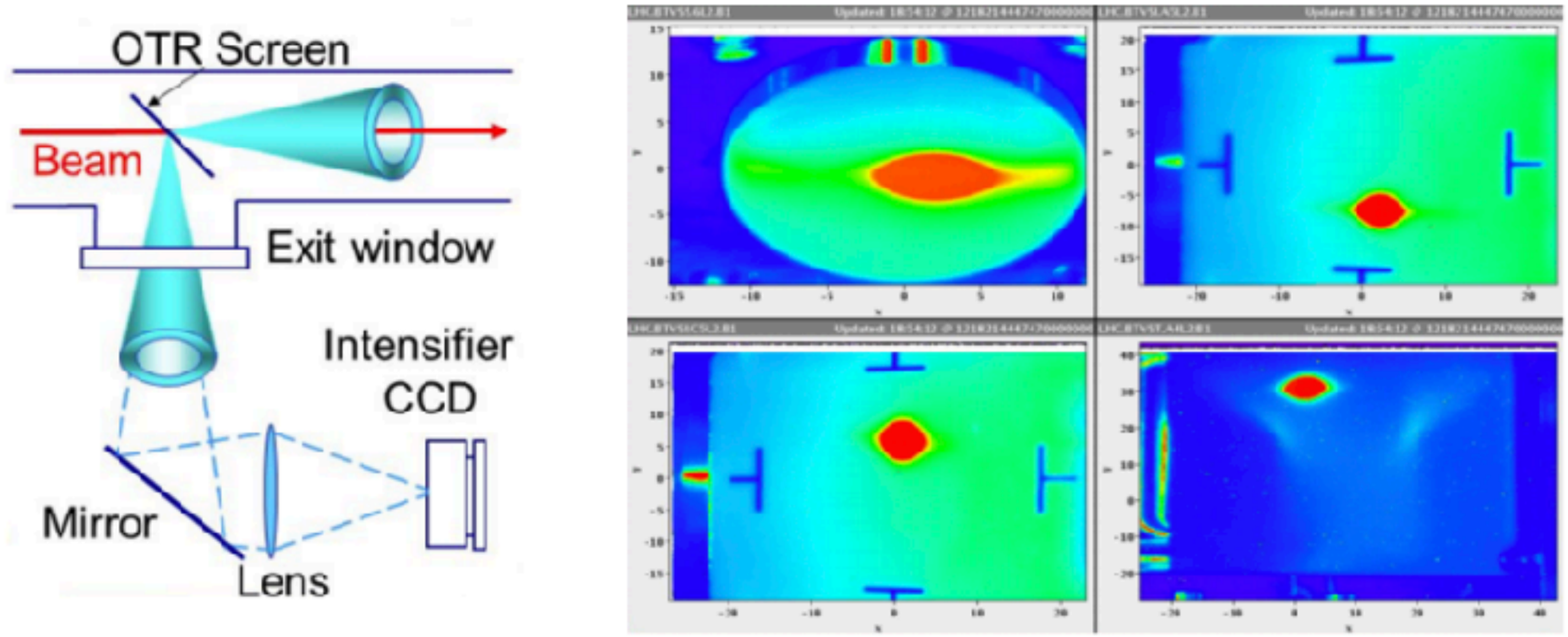
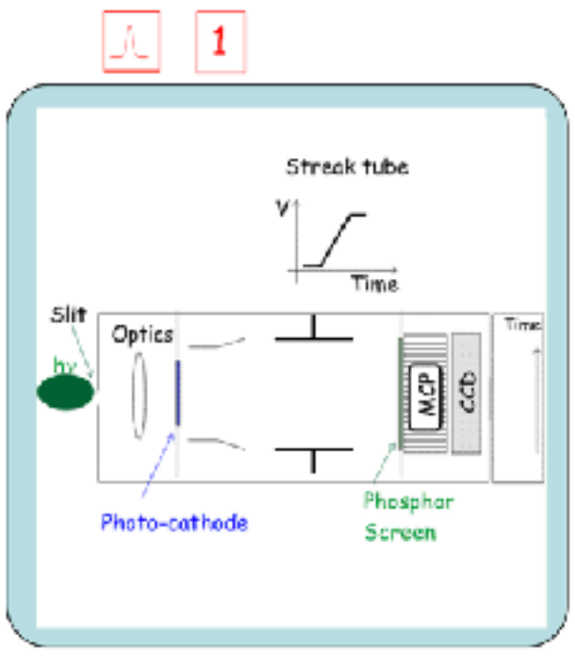



Figure 1.13 – OTR monitor working principle (left) and first beam observations with OTRs on the LHC (right) [18]

## OTR & LHC First Beam

# 2.4. Demet Boyuna Profili - Streak Camera

## Streak Camera




*'Streak cameras uses a time dependent deflecting electric field to convert time information in spatial information on a CCD'*

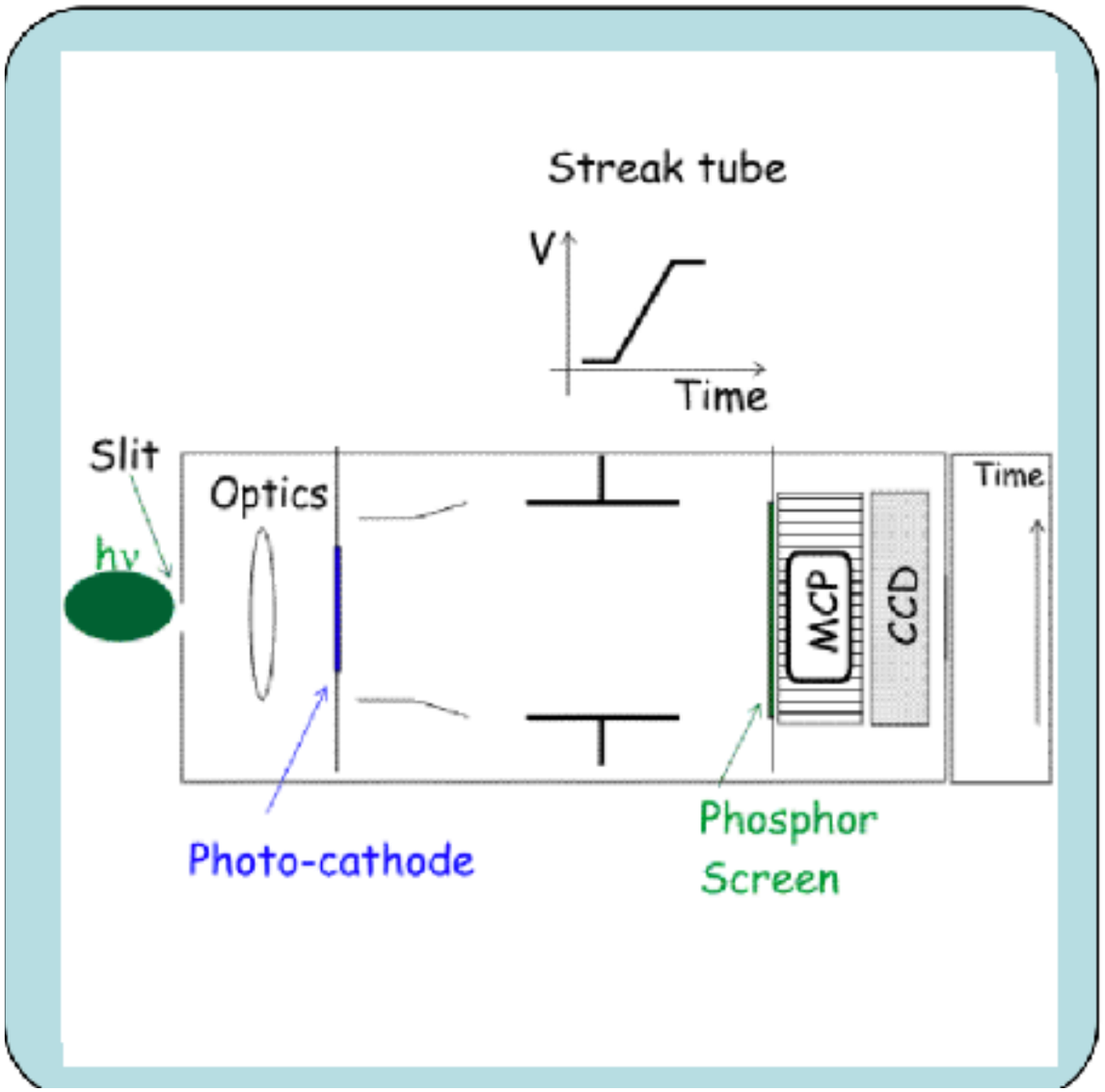
*Mitsuru Uesaka et al, **NIMA 406 (1998) 371***

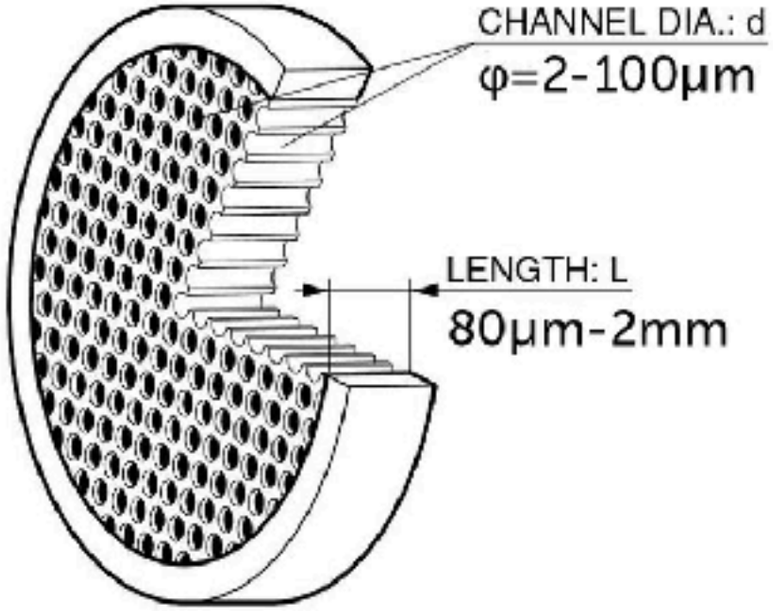
200fs time resolution obtained using reflective optics and 12.5nm bandwidth optical filter (800nm) and the Hamamatsu FESCA 200

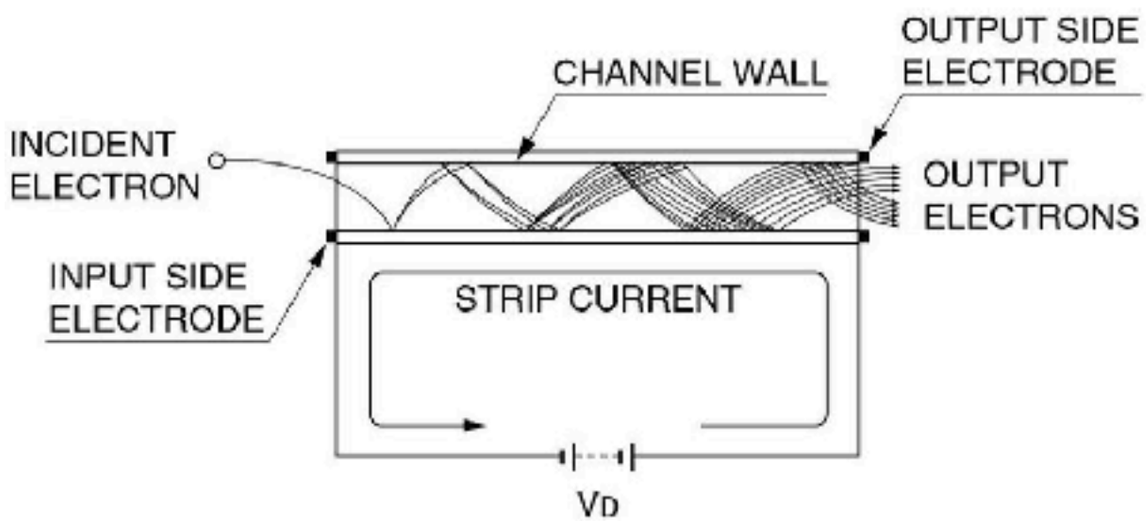
**Limitations : Time resolution of the streak camera :**

(i) Initial velocity distribution of photoelectrons : *narrow bandwidth optical filter*
(ii) Spatial spread of the slit image: *small slit width*
(iii) Dispersion in the optics

# 2.4. Demet Boyuna Profili - Streak Camera

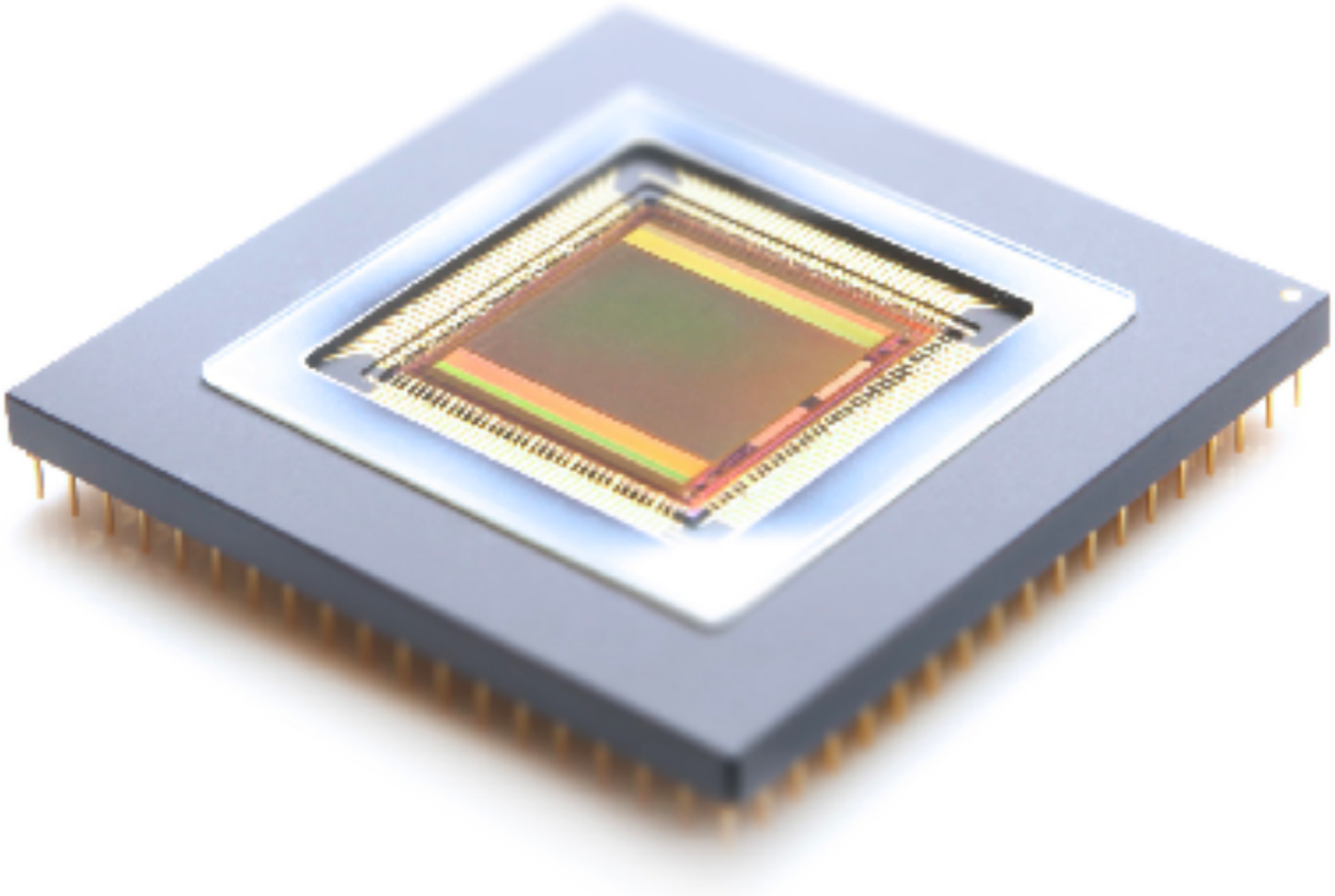


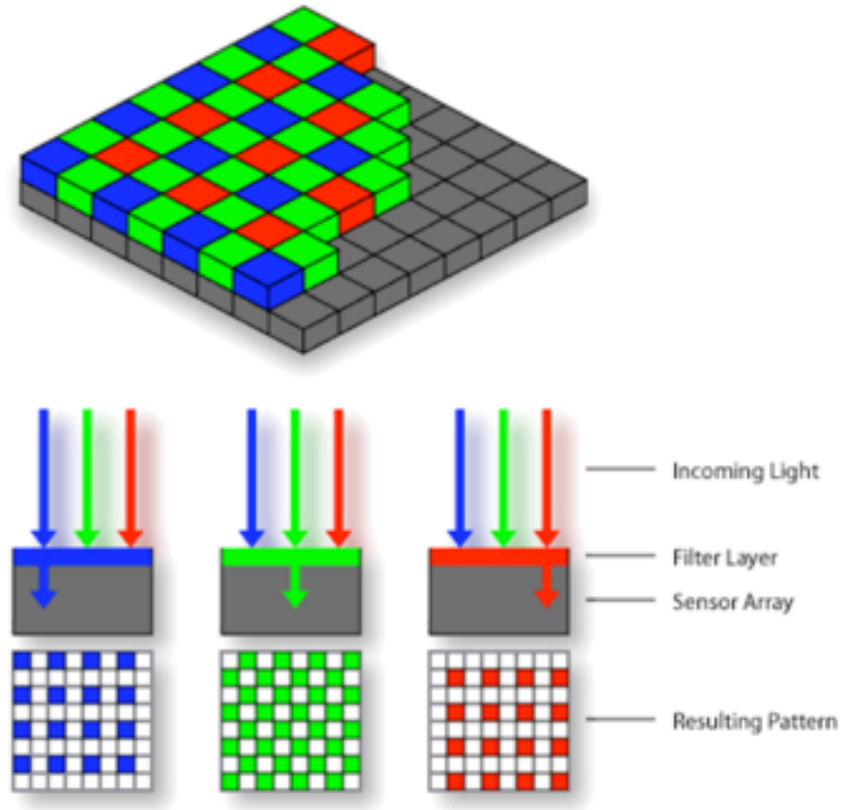




## Multi Channel Plate Çok Kanallı Plaka

# 2.4. Demet Boyuna Profili - Streak Camera - CCD






Charged Coupled Detector - Eş Yükleşmeli Algıç

webb.nasa.gov/content/observatory/instruments/nircam.html

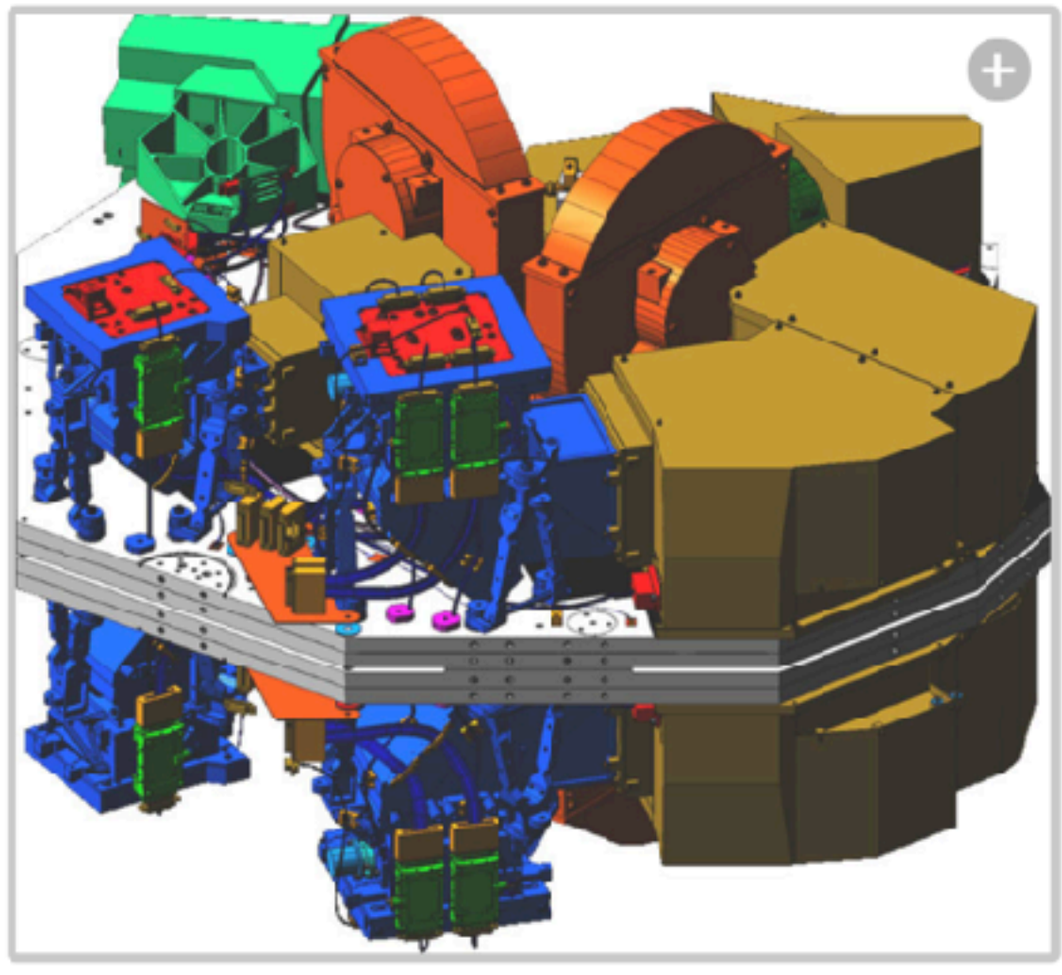
NIRCam was built by the University of Arizona and Lockheed Martin.

## IN DEPTH: Technical Details For NIRCam

The NIRCam has ten mercury-cadmium-telluride (HgCdTe) detector arrays. These are analogous to CCDs found in ordinary digital cameras. The NIRCam is a science instrument but also an Optical Telescope Element wavefront sensor, which provides something similar to instant LASIK vision correction.

## Other Resources

- Space Telescope Science Institute has a technical page on NIRCam
- Archive of NIRCam images
- Our page about the detectors in our instruments

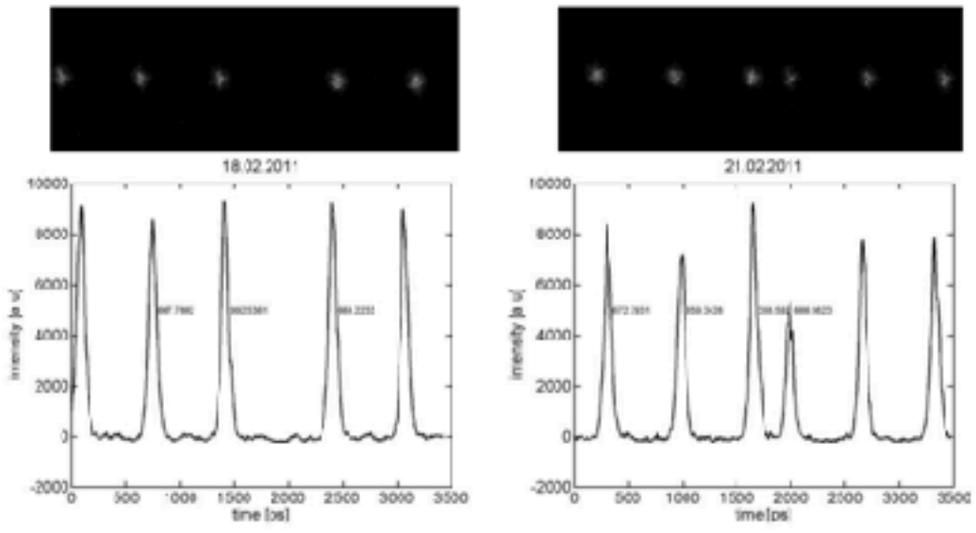


*NIRCam Engineering Diagram*

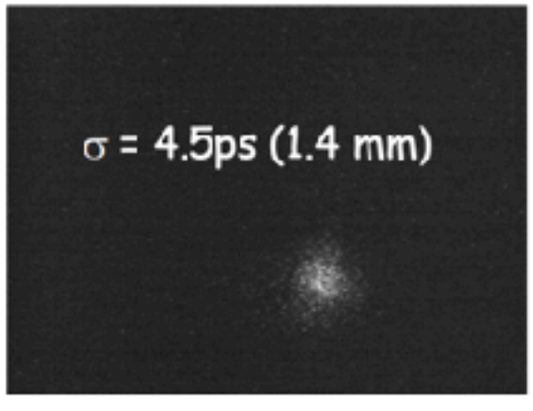
# 2.4. Demet Boyuna Profili - Streak Camera

## Streak camera examples

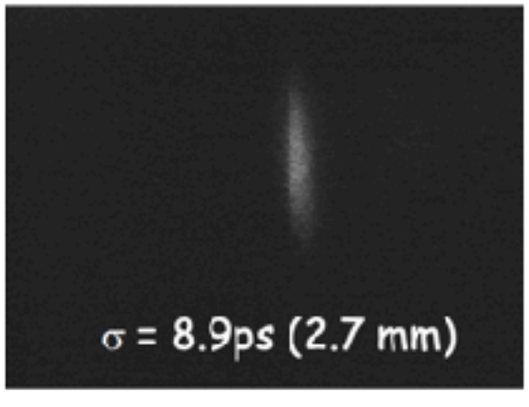
Observation of 5MeV electron bunch train using cherenkov
Sweep speed of 250ps/mm




Measure of bunch length using OTR and OSR

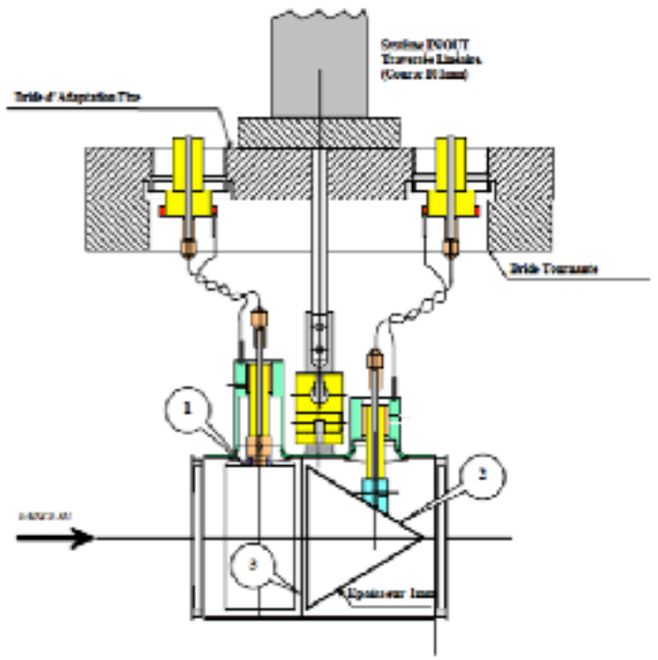


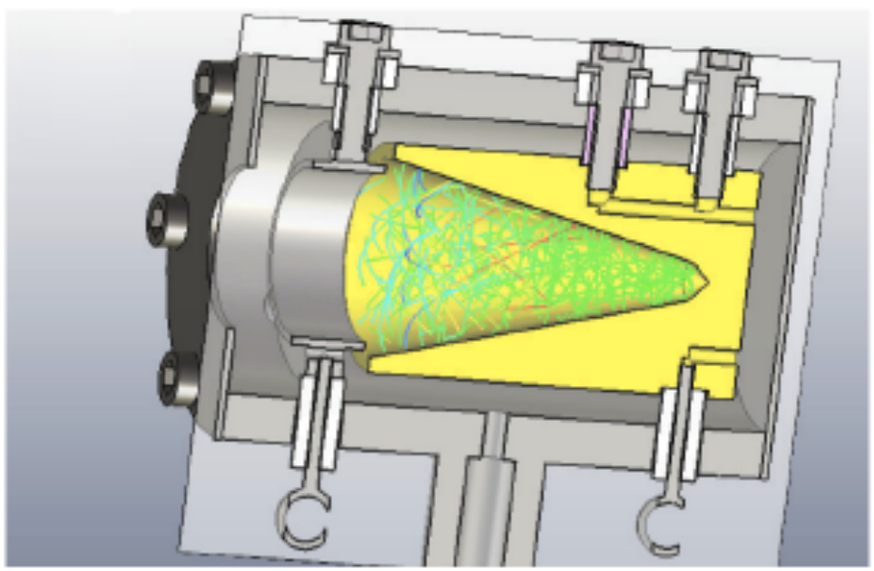

*Sweep speed of 10ps/mm*

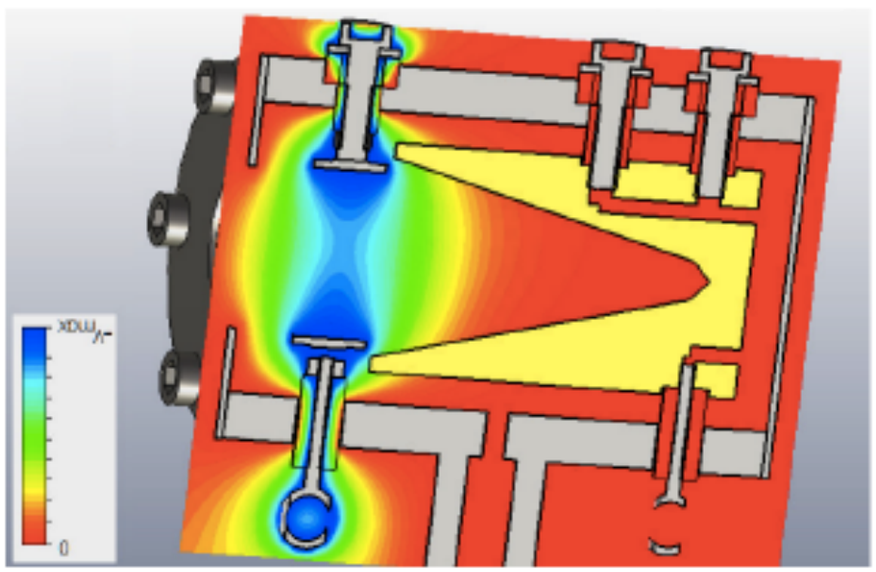



T. Lefevre *"Longitudinal Beam Profile Measurements" - 2nd Ditanet School on Beam diagnostic - Stockholm– 2011*

# 3.1. Demet Akımı - Faraday Kupası (Faraday Cup)



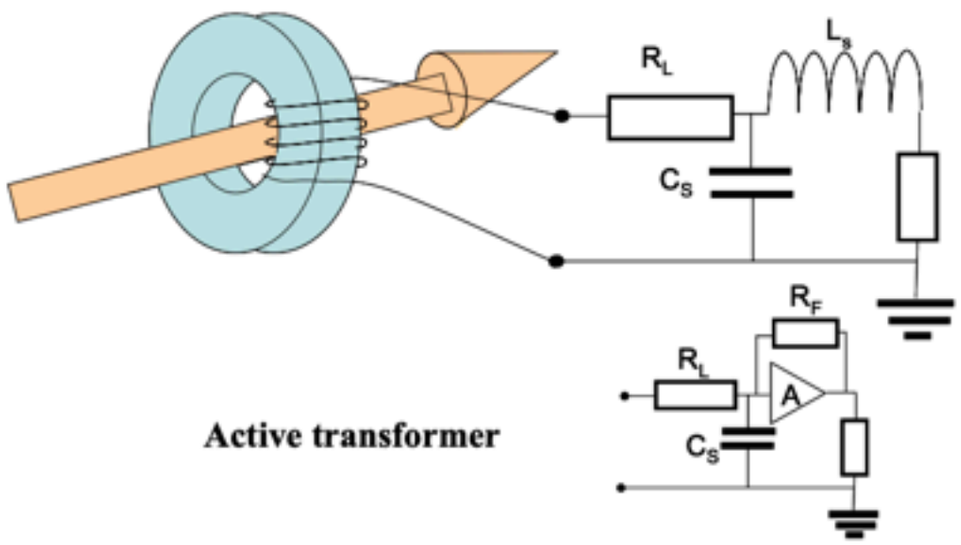


# 3.2. Demet Akımı -

## Direkt Akımdan Akım Ölçer (DC Current Transformer)

$$I_{\text{beam}} = \frac{qeN}{t} = \frac{qeN\beta c}{l}$$

where $q$ is the charge state, $N$ the number of particles, $l$ unit of length and $\beta = v/c$ the particle speed.




Active transformer

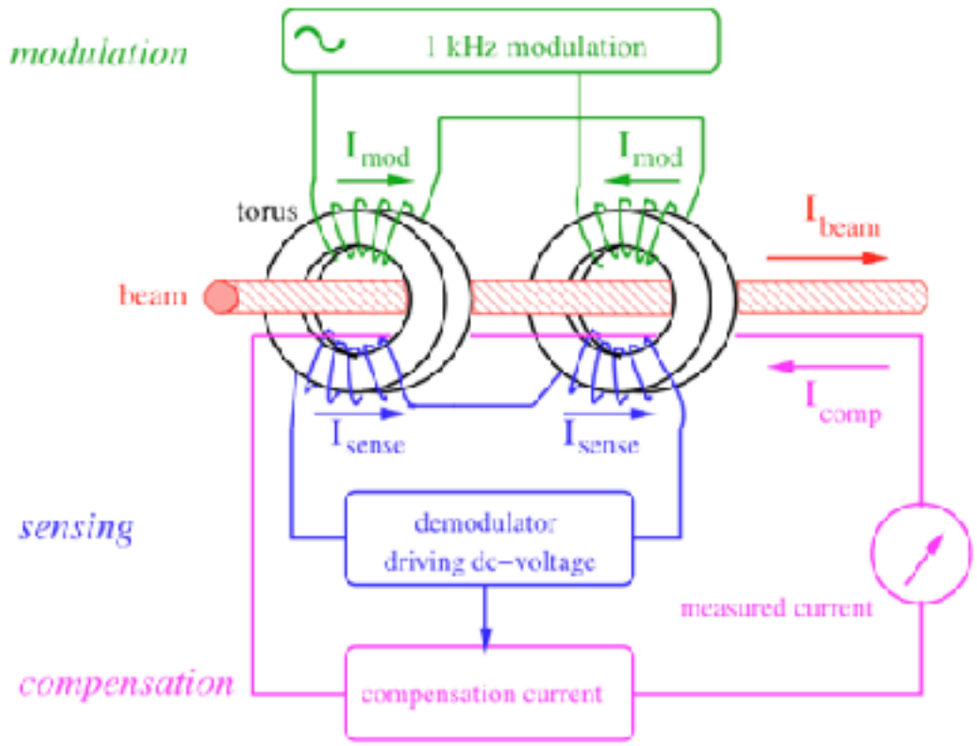
https://cds.cern.ch/record/1005058/files/p297.pdf

# 3.2. Demet Akımı -

## Direkt Akımdan Akım Ölçer (DC Current Transformer)

How to measure the DC current? The current transformer discussed sees only changes in the flux.
The DC Current Transformer (DCCT): look at the magnetic saturation of the torus.

- Modulation of the primary windings forces the torus into saturation twice per cycle.
- Secondary windings sense modulation signal and cancel each other.
- But with the $I_{beam}$, the saturation is shifted and $I_{sense}$ is not zero
- Adjust compensation current until $I_{sense}$ is zero once again.



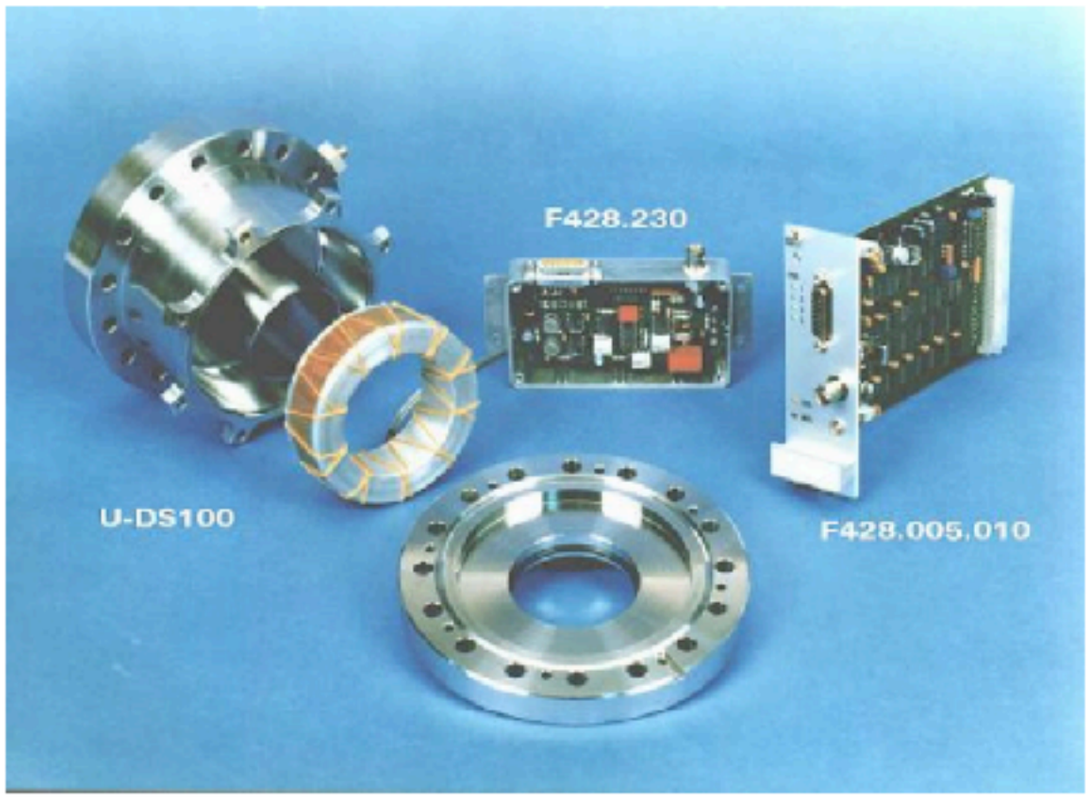

DC Transformer Operation, see [1]

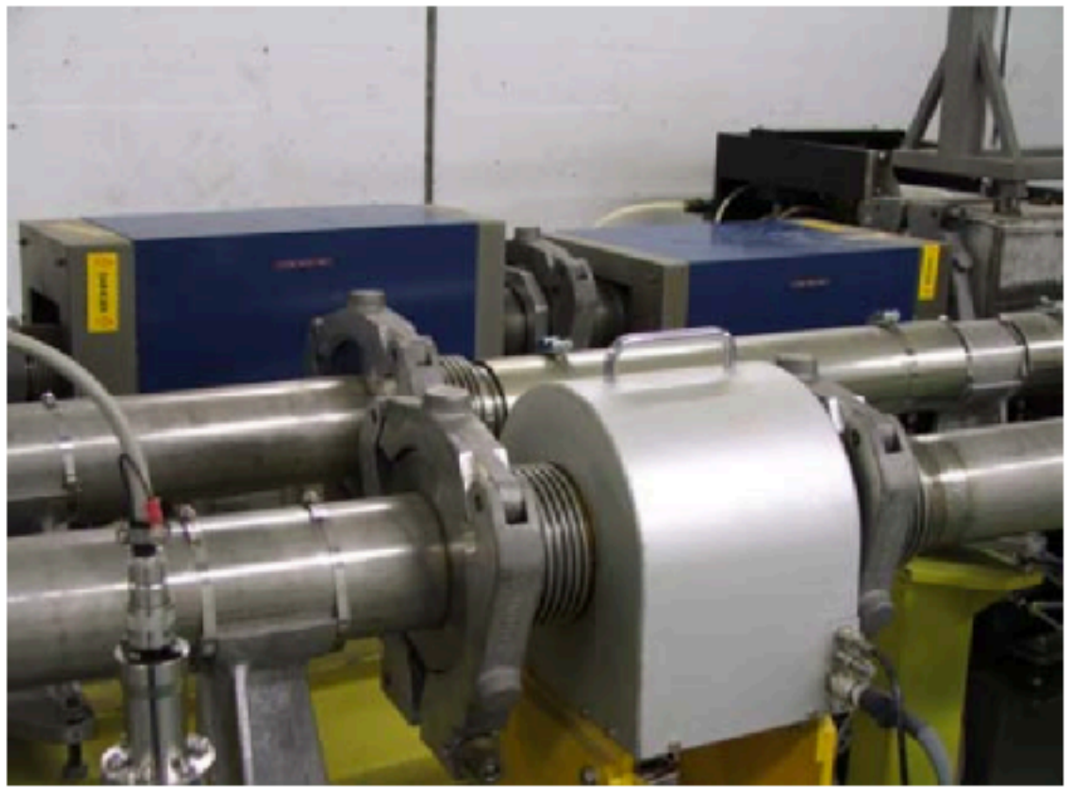


https://uspas.fnal.gov/materials/09UNM/BeamCurrentMonitors.pdf

# 3.2. Demet Akımı -

## Direkt Akımdan Akım Ölçer (DC Current Transformer)



https://cds.cern.ch/record/1005058/files/p297.pdf

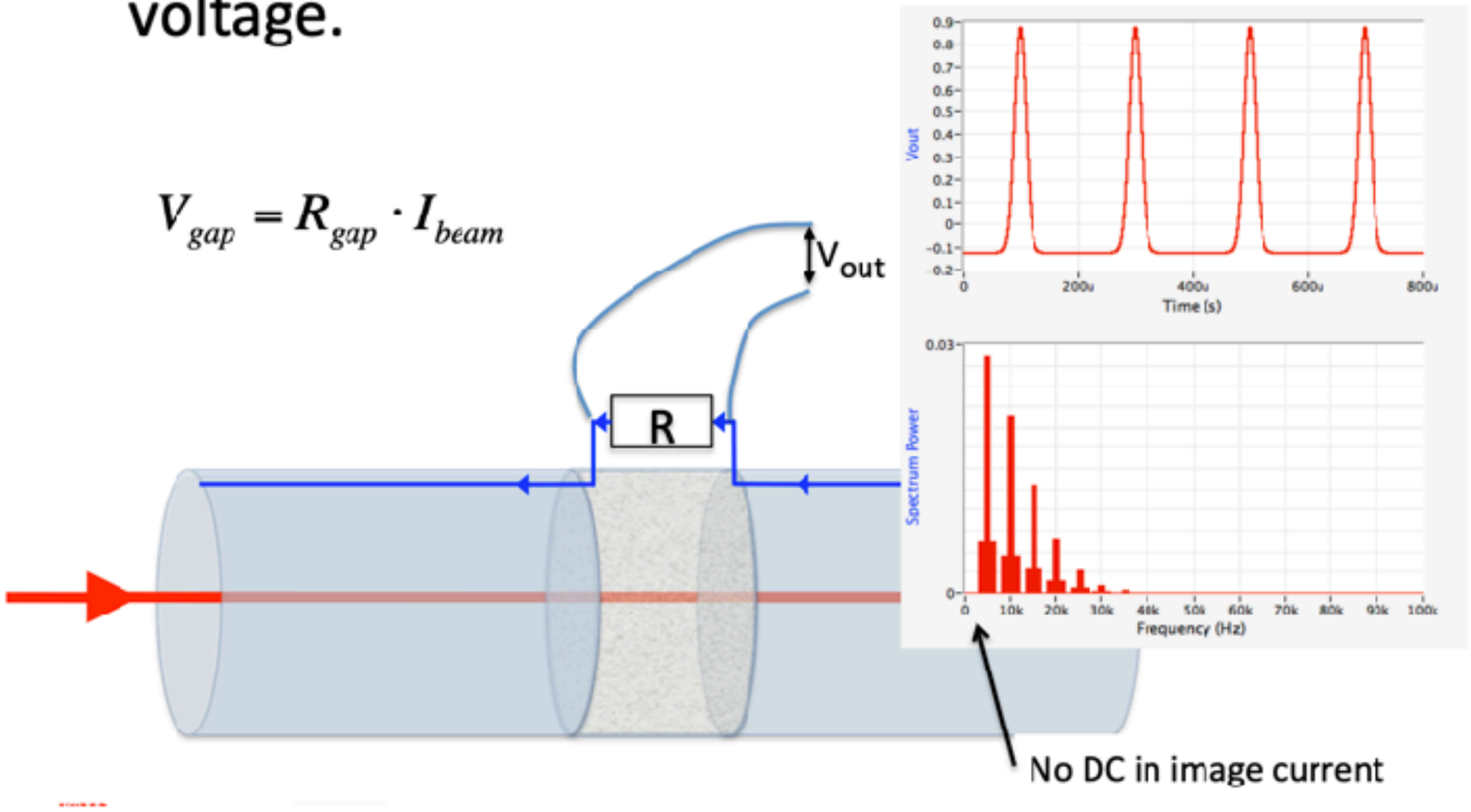
# 3.3. Demet Akımı -

## Çeper Akım Ölçer (Wall Current Transformer)

### Wall Current Monitor

- Put a resistor over the gap and measure its voltage.

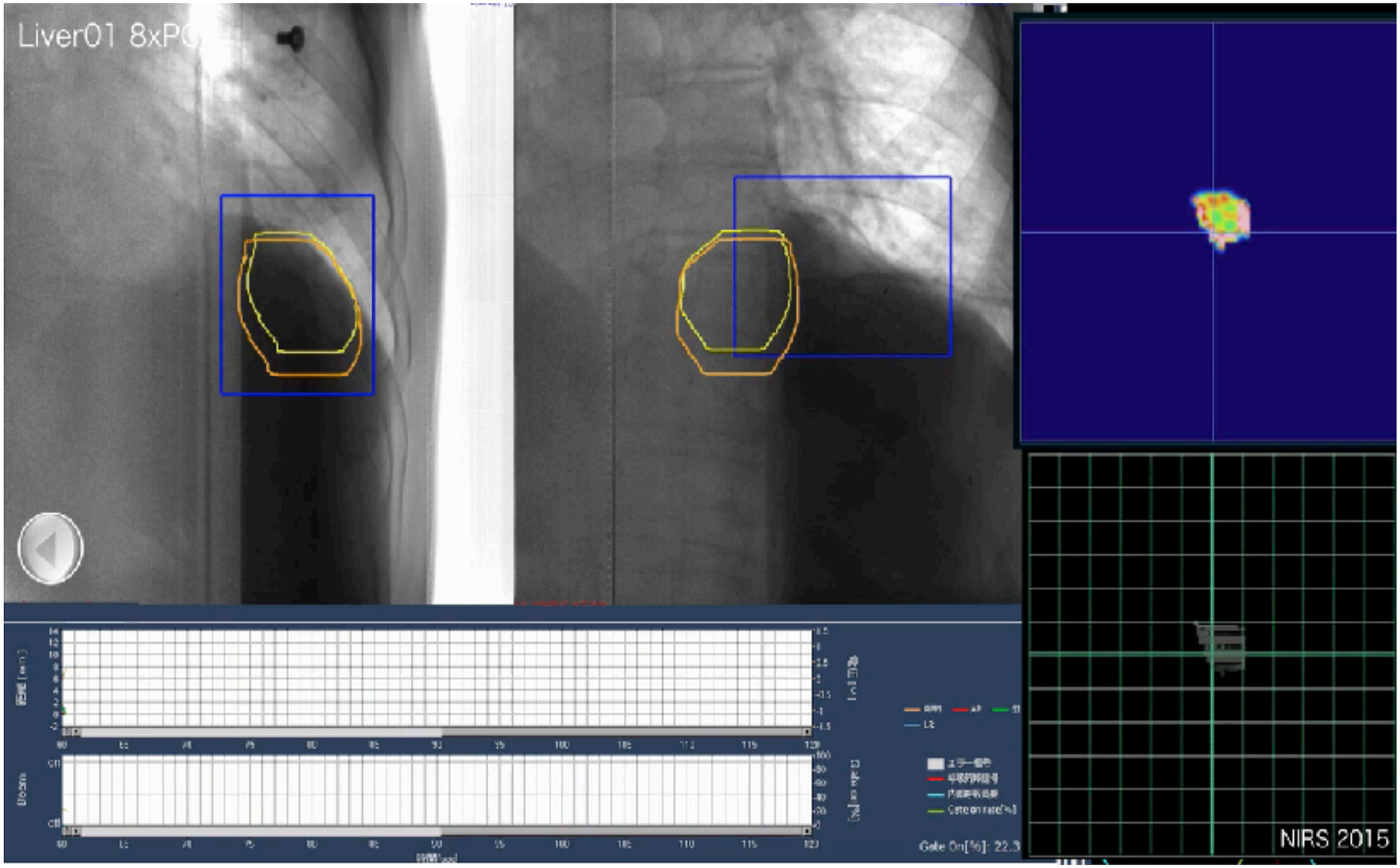
$$V_{gap} = R_{gap} \cdot I_{beam}$$




https://uspas.fnal.gov/materials/09UNM/BeamCurrentMonitors.pdf

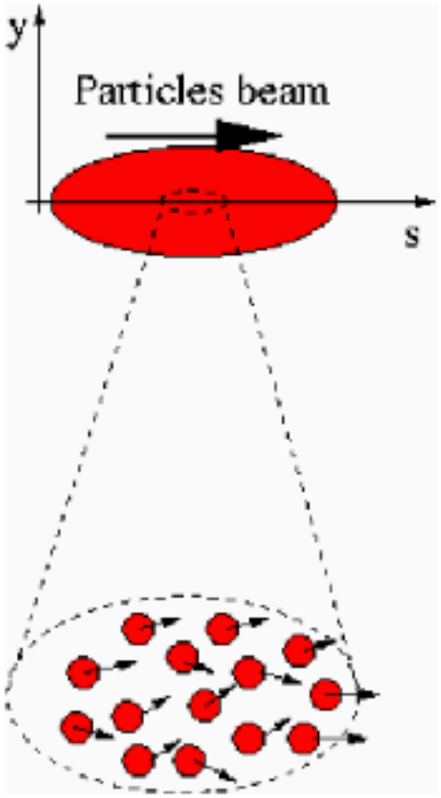
# Demet Tanısı

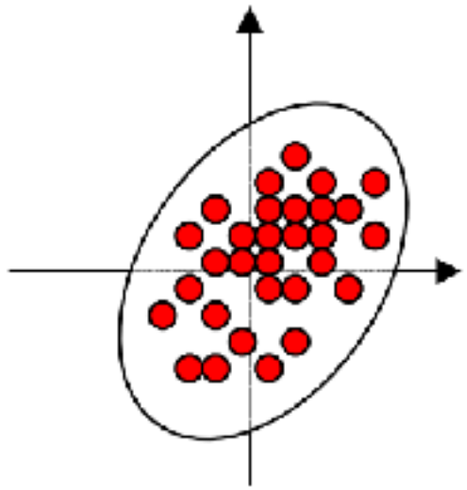
- Medical beam delivery (K. Noda):



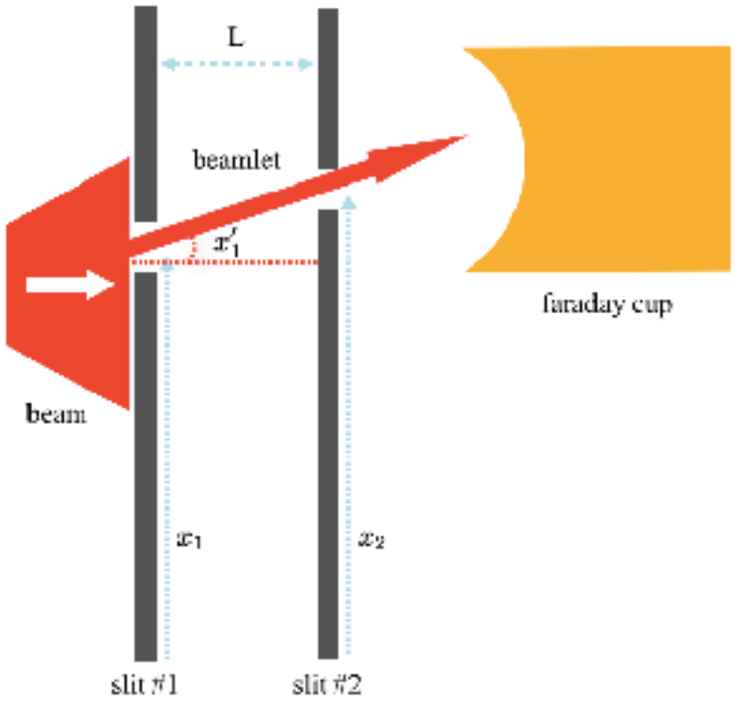

Parçacıkların  Konumu, Açısı, Enerjisi, Yoğunluğu ölçülmek önemli.

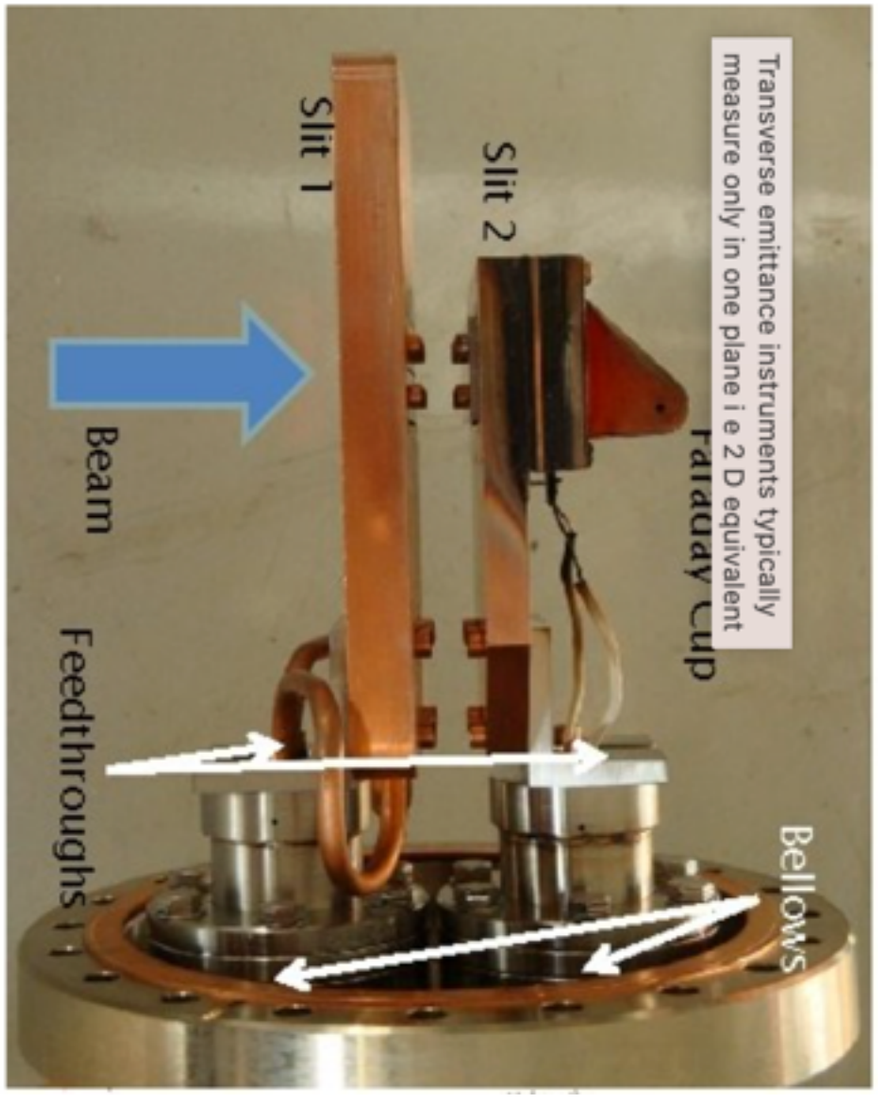
# 4- Demet Yayınımı (Açısı) Emittance



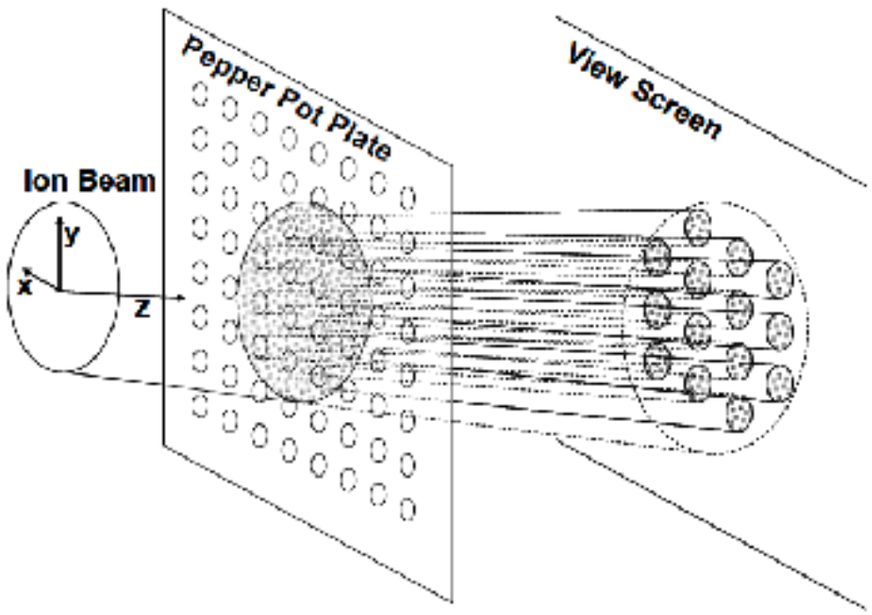
# 4.1. Demet Yayınımı (Konum + Açı + Yoğunluk)

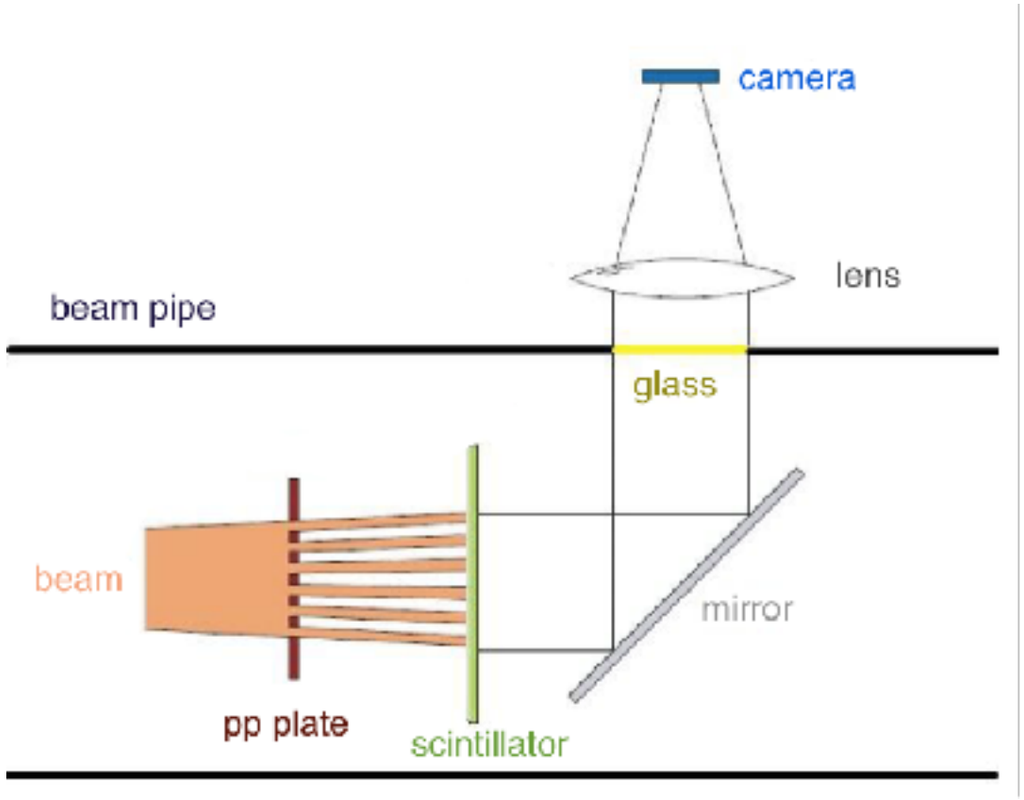



✤ İki yarık ve Faraday Kupası ile yayınım ölçümü (Slit-slit-faraday cup emittance meter)

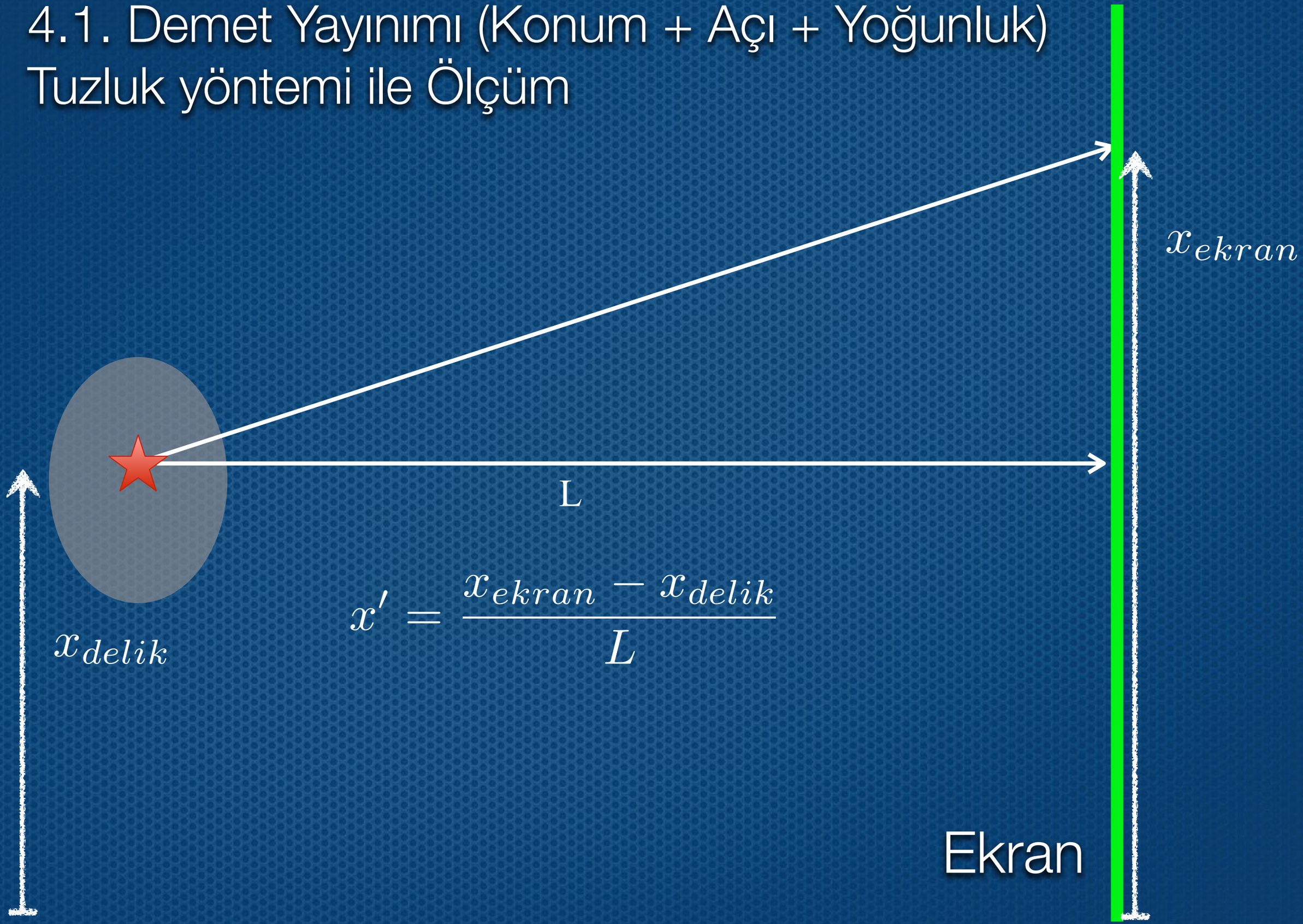
# 4.1. Demet Yayınımı (Konum + Açı + Yoğunluk)



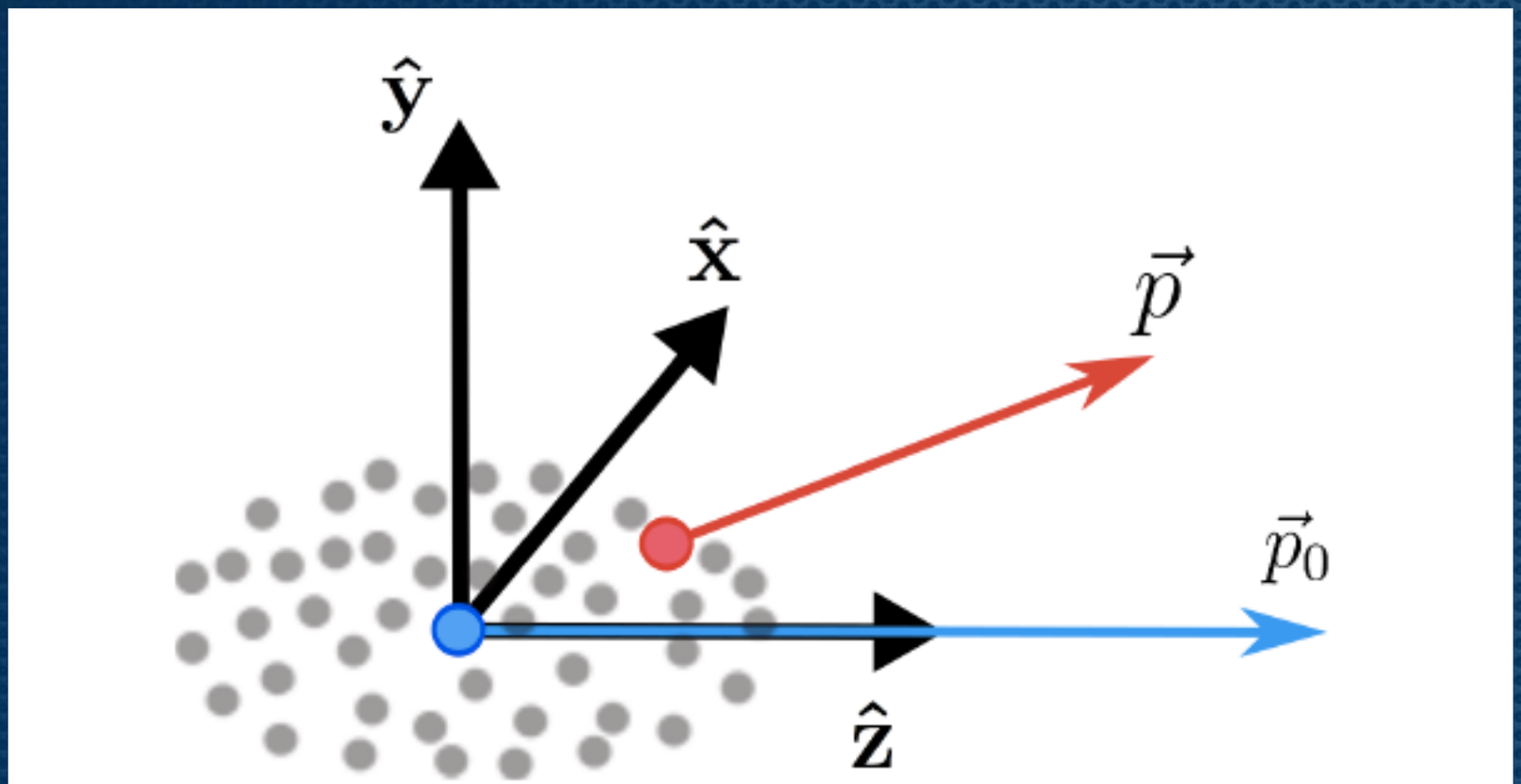

✤ Tuzluk yöntemi ile yayınım ölçümü (Pepper-pot Emittance Meter)

# 4.1. Demet Yayınımı (Konum + Açı + Yoğunluk) Tuzluk yöntemi ile Ölçüm




$$x' = \frac{x_{ekran} - x_{delik}}{L}$$

# 4- Demet Yayınımı (Açısı) Emittance




$$x' = \frac{dx}{dz}$$

$$p_x = p_z x'$$

$$p_x = \gamma_{rel}\beta_{rel}\ m\ c\ x'$$

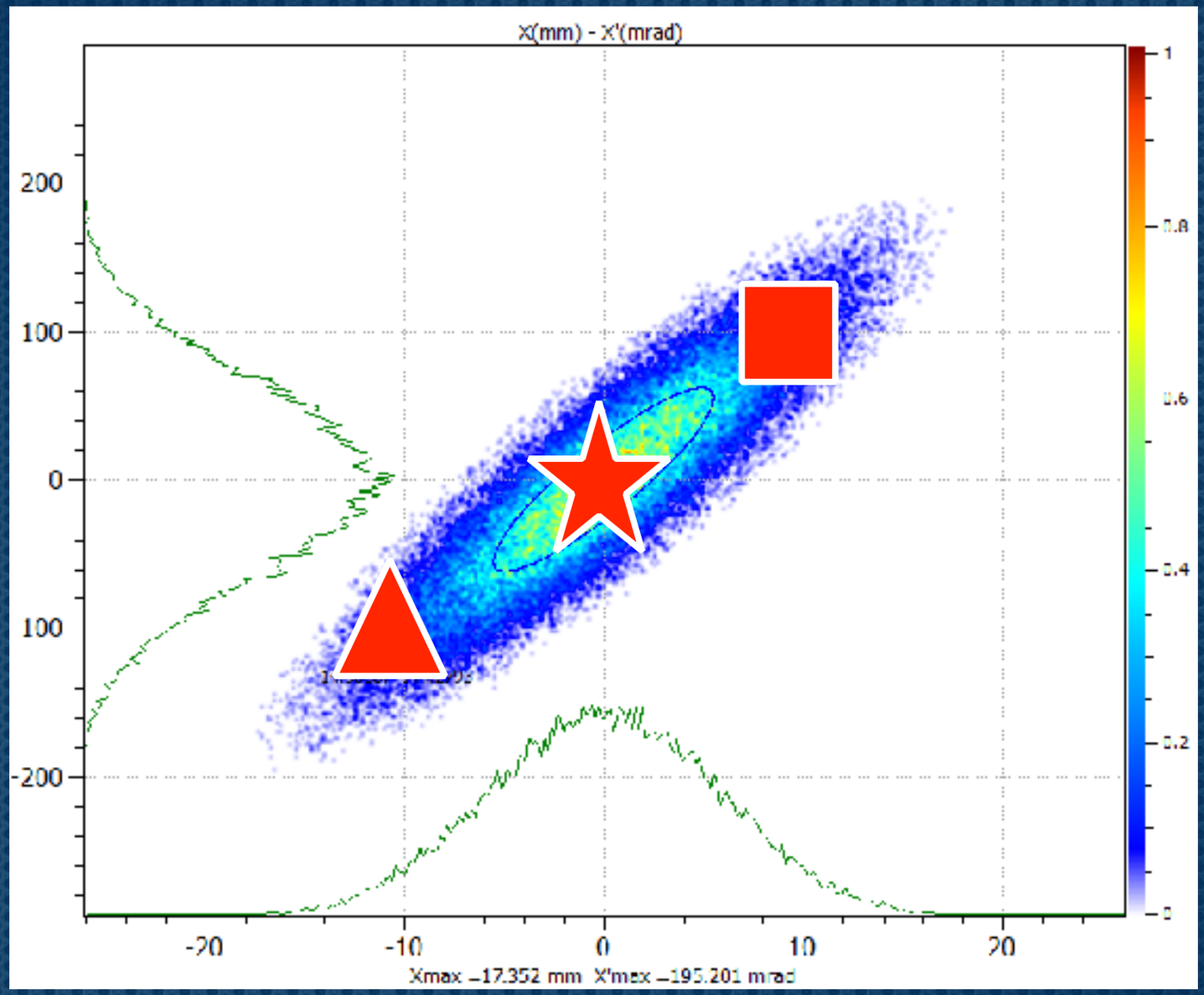
- Hızlandırıcılarda Demet akımı mili-Amper mertebesinde

$$1\ e = 1.6 \times 10^{-19}\ C$$

$$1\ mA = 6 \times 10^{15}\ e$$

# 4- Demet Yayınımı (Açısı) Emittance

**Hızlandırıcının en ÖNEMLİ parametrelerinden biri**

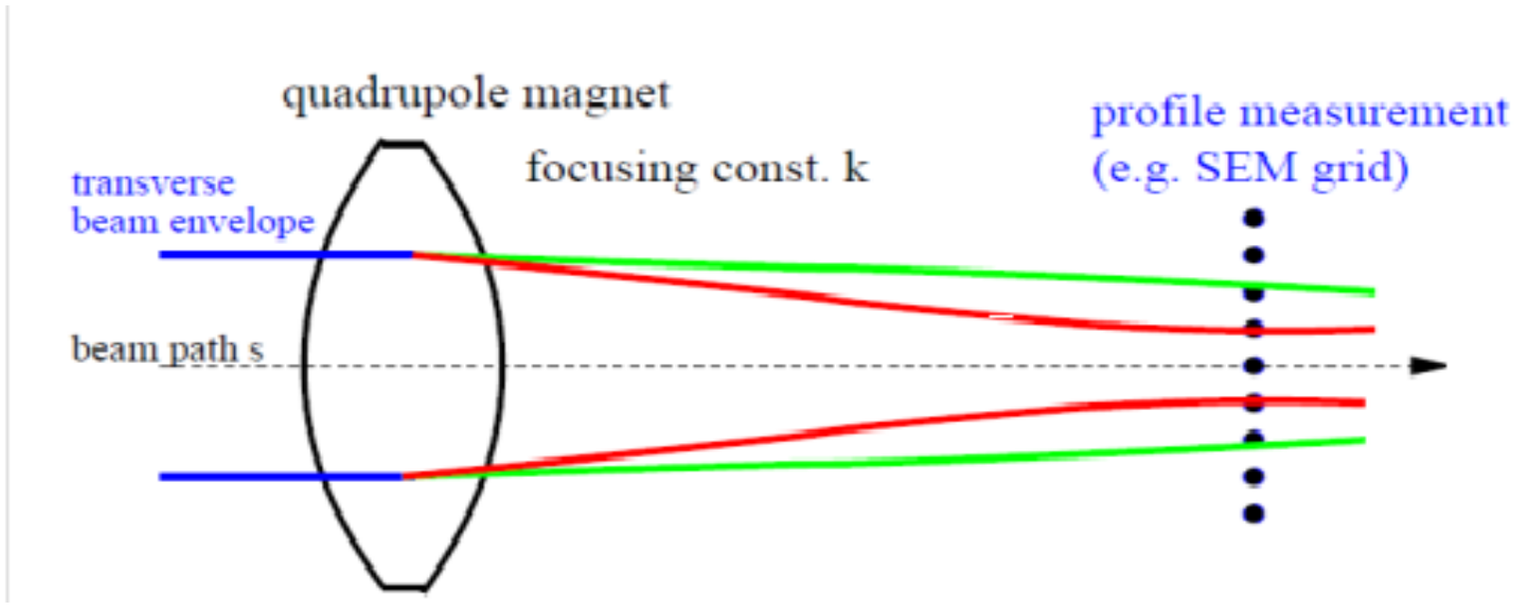


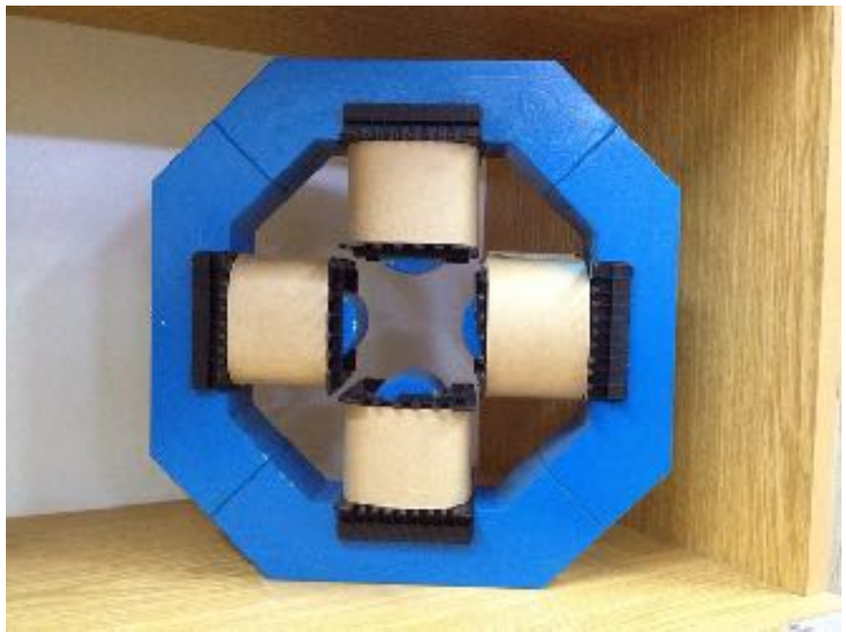

$$(x, x') = (x, p_x)$$

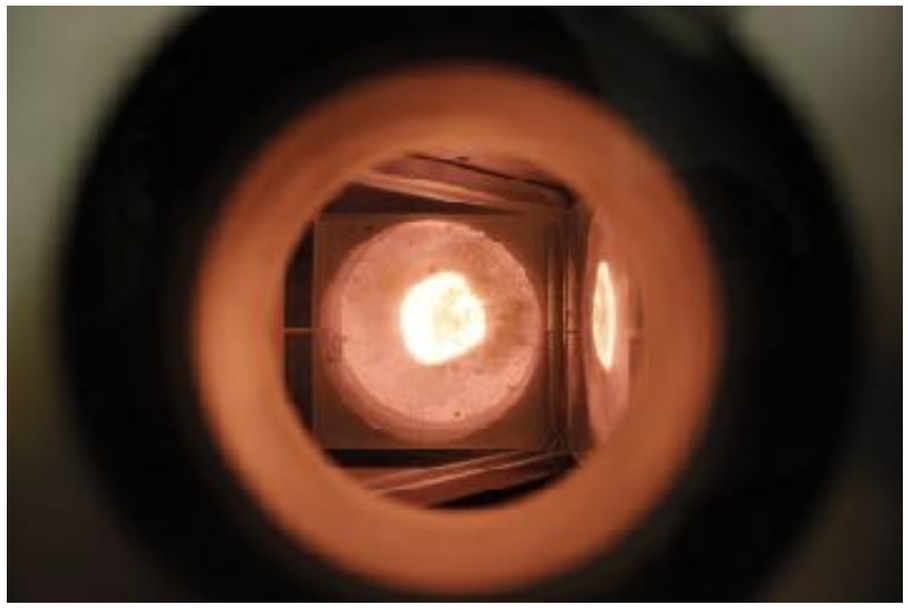
$$\epsilon_{normalize} = \gamma_{rel}\beta_{rel}\epsilon$$

Kanonik Eşleniği - > Hamilton Mekaniği - > Korunum; Yayınım

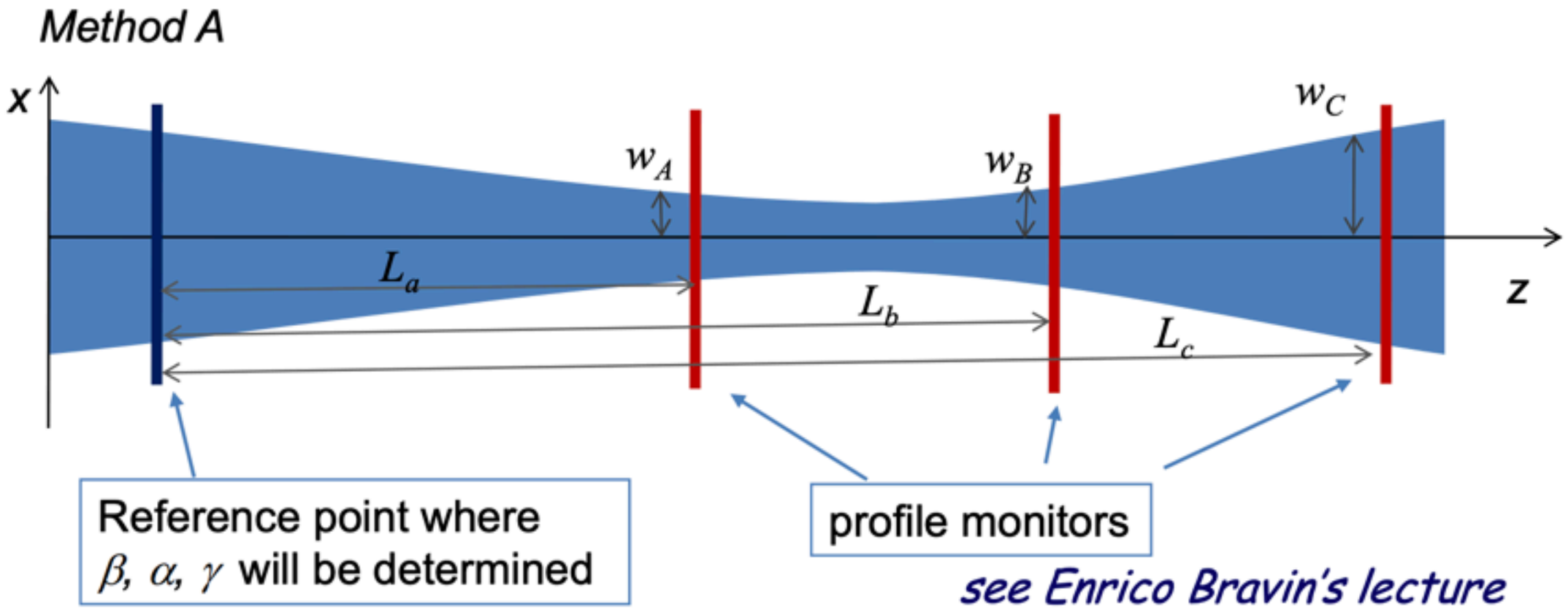
# 4.3. Yayınım (Emittance) - 4Kutuplu Mıktanıs Yöntemi



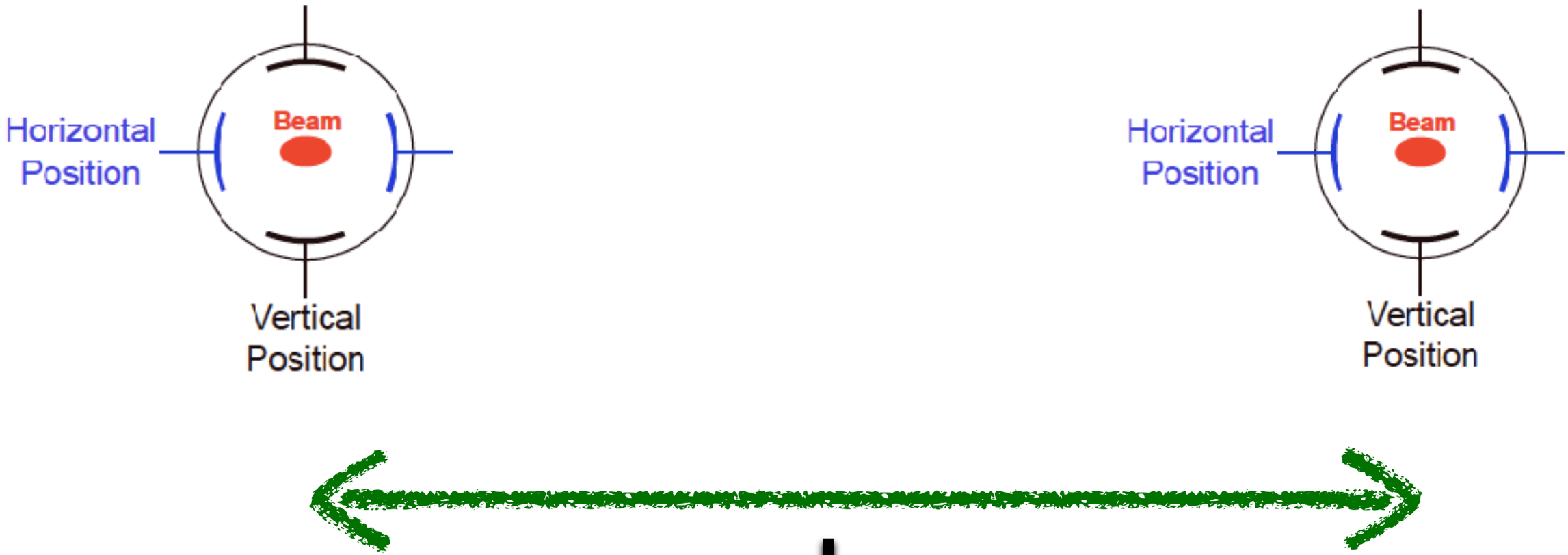





# 4.4. Yayınım (Emittance) - 3 veya Daha Fazla Ekranla Ölçme Yöntemi

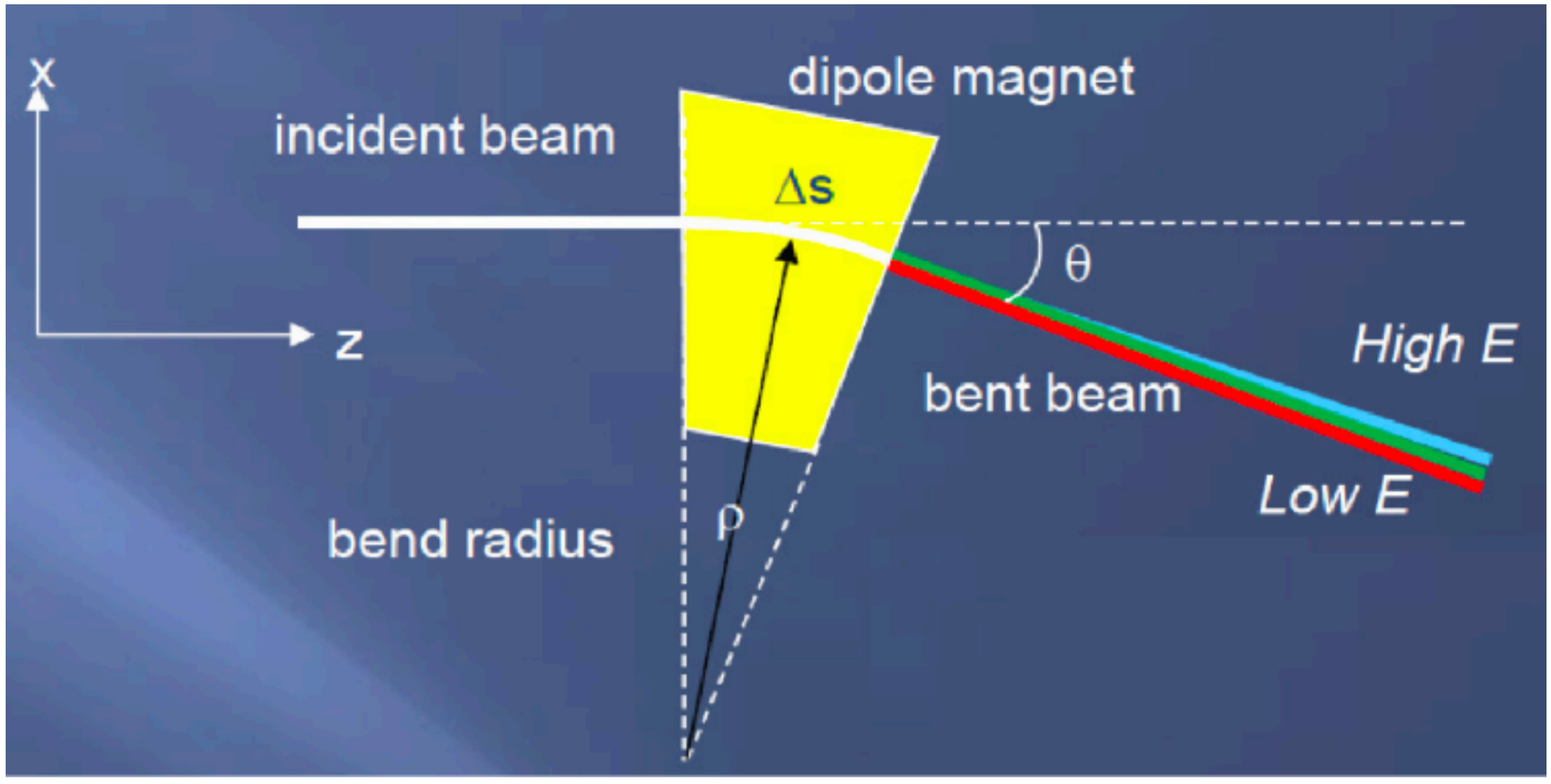


# 5.1. Enerji Ölçümü - Uçuş Süresi (Time of Flight)




**v= L/t , t difference in time between two signals for low energy beam, otherwise determination of energy via bending magnets.**

# 5.2. Enerji Ölçümü -Manyetik Spektroskopi




**Enerjisi yüksek parçacık aynı manyetik alanda daha az bükülür.**

# 3. Sezon - Zorundalık :)

*Der Mensch kann zwar tun, was er will,*

*aber er kann nicht wollen, was er will.*

Arthur Schopenhauer

**İSTEDİĞİMİZİ YAPABİLİRİZ**
**AMA İSTEKLERİMİZİ SEÇMEKTE ÖZGÜR DEĞİLİZ.**

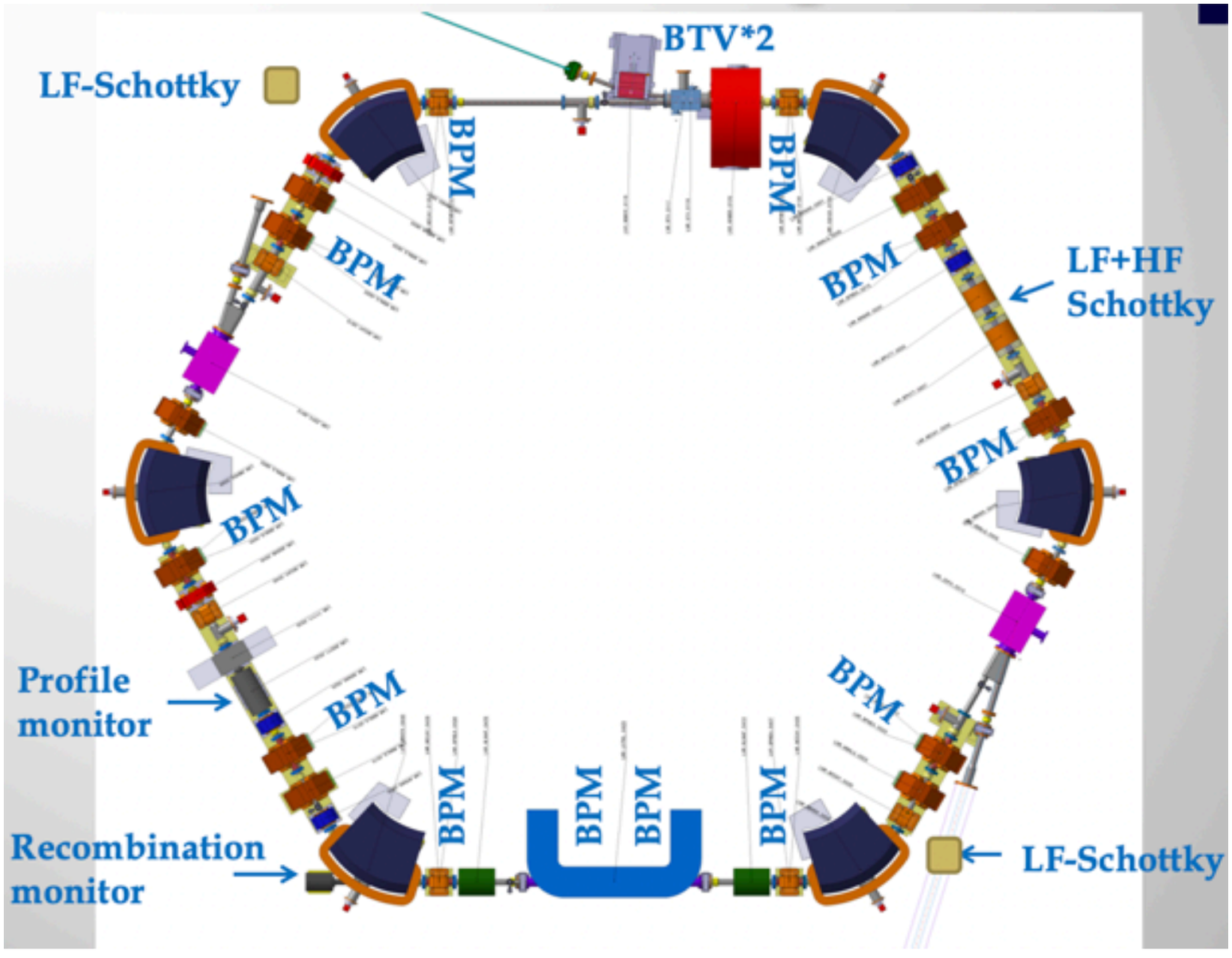
# CERN Linac4 Beam Diagnostics

CERN-ATS-2010-222

Table 2: LINAC 4 Diagnostics Overview

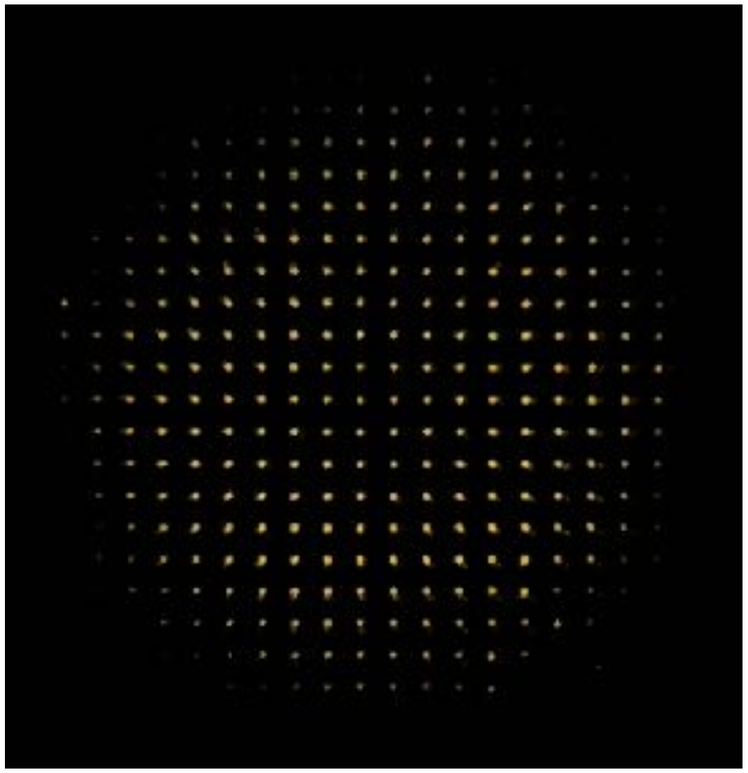
| Location | E [MeV] | BPM | BCT | SEM GRIDS | WS | BTV | BLM |
|---|---|---|---|---|---|---|---|
| Diagn. Bench | 3-12 MeV | 3 | 2 | 2H+1V | - | - | - |
| LEBT | 0.045 | - | 1 | 2H+1V | - | - | - |
| MEBT | 3 | - | 2 | - | 2 | - | 1 |
| DTL | 50 | 2 | - | - | - | - | 2 |
| CCDTL | 102 | 7 | 1 | 2H+2V | 2 | - | 4 |
| PIMS | 160 | 6 | 1 | 2H+2V | 2 | - | 3 |
| TL to PSB | 160 | 12 | 7 | 3H+3V | | 3 | 11 |
| DL | 160 | - | 1 | | | 1 | - |

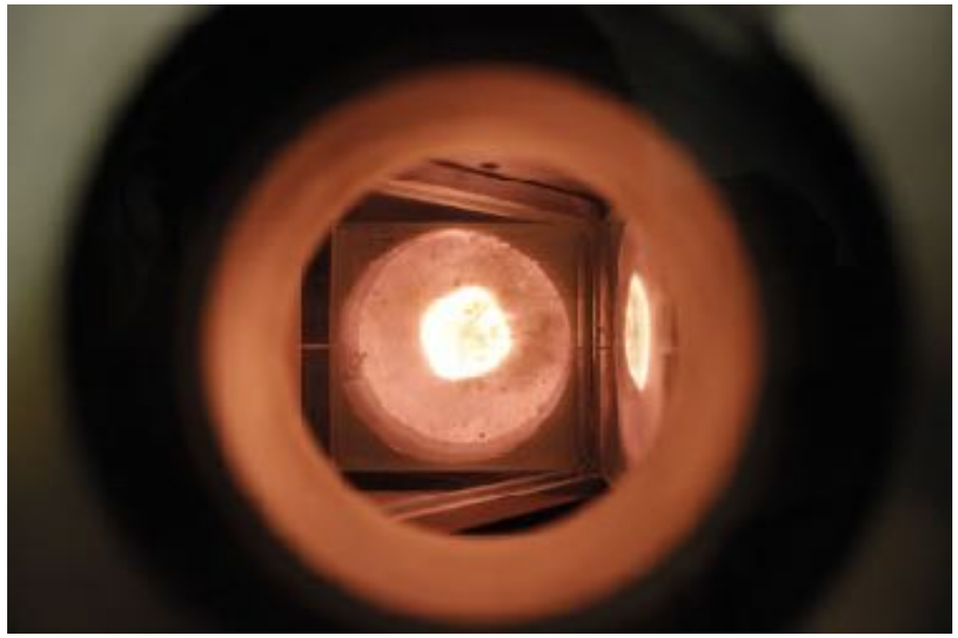
# ELENA Halkası - CERN

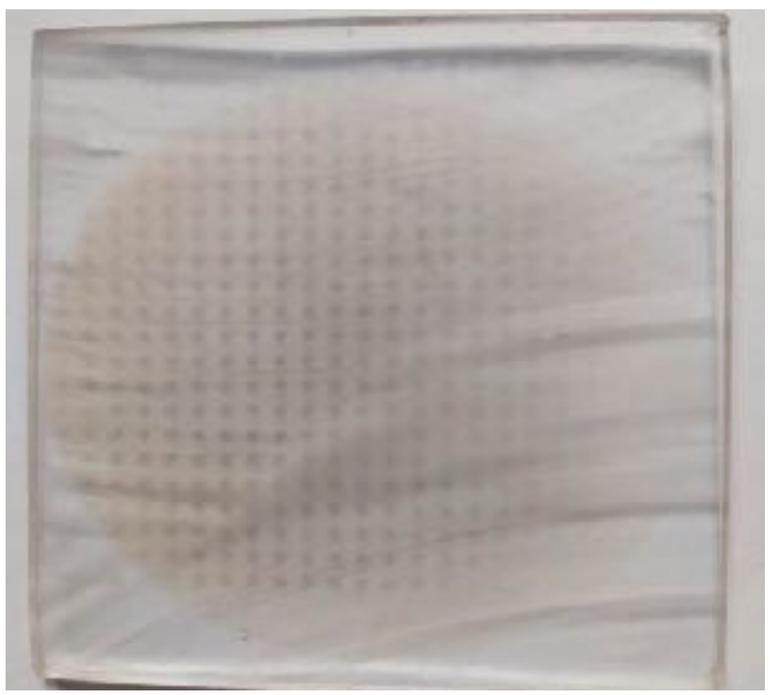


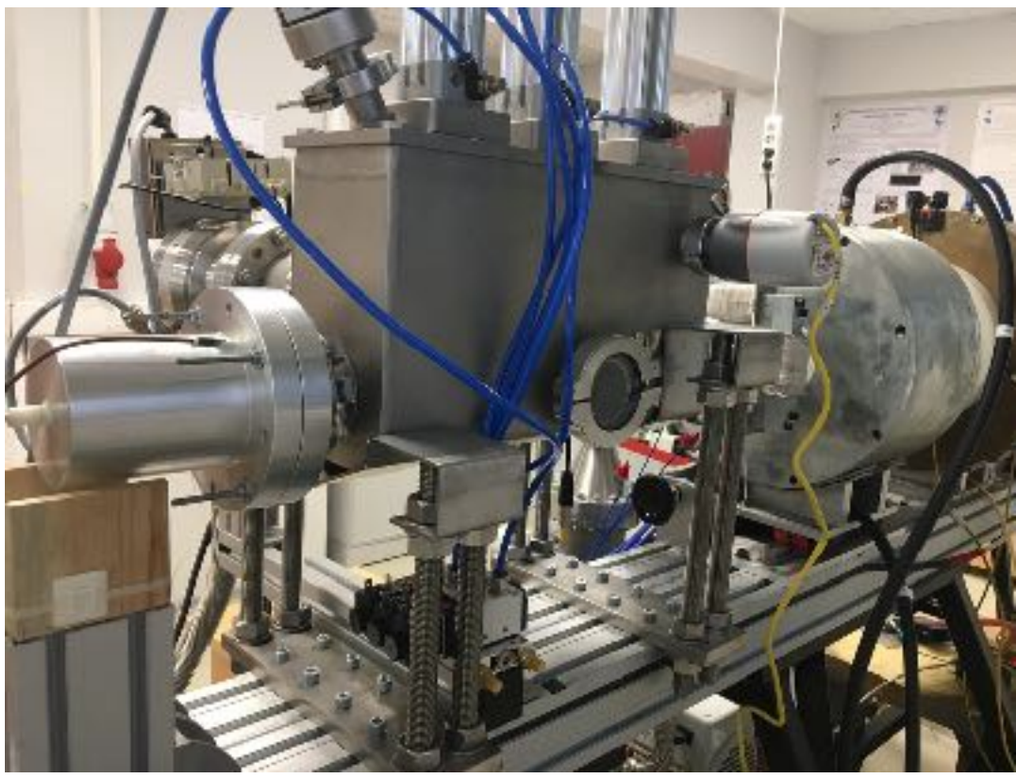

✤ Extra Low Energy Anti-proton Ring, CERN'ün en küçük halka hızlandırıcısı, çevresi 30 metre.

# KahveLab (Boğaziçi Ü.)









# TARLA (Ulusal Lab.)

**TARLA demet diagnostic elemanları**

YAG:Ce Demet görüntüleme ekranları

Kamera

FCT/ICT

BPM

Beam Dump

Slit mask

Makropulser Thermocouple Feedthrough

Makro pulser Current Feedthrough

Beam Loss Monitor

Düğme tip antenli demet pozisyon monitörü (NTG marka).

Demet Pozisyon monitörü analizörü (Libera single pass)

Faraday cup için elektrometre (Keithley 6517B)

FCT (Fast current transformer Bergoz )

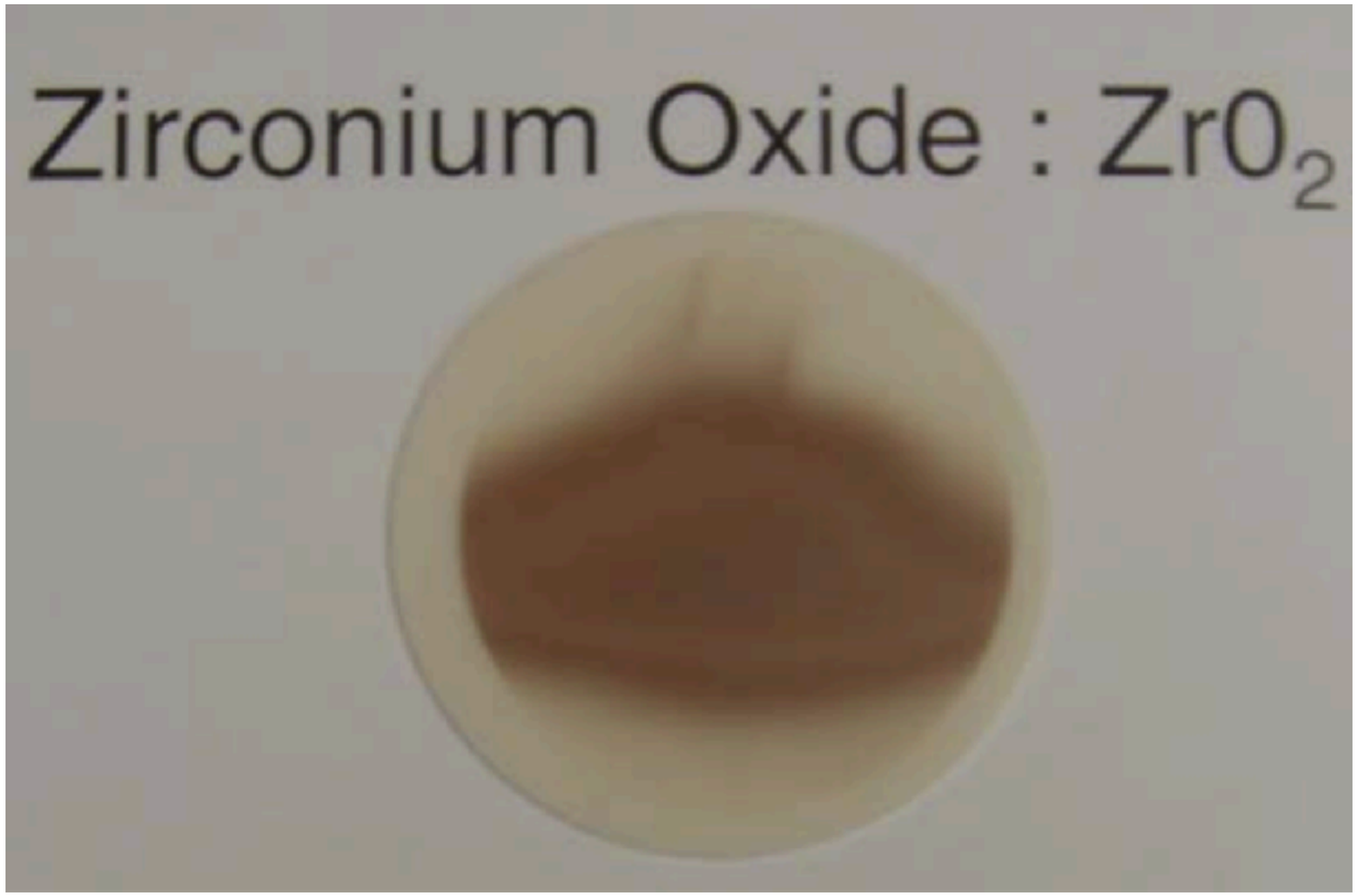
ICT ( Integrating current transformer Bergoz)

FCT/ICT analizörü ( Bergoz IntegrateHoldReset Beam Charge Monitor) .

Demet Kayıp Monitörü (TARLA Yapımı).

Faraday cup.

# Problemler: Sıcaklık, Radyasyon




https://cds.cern.ch/record/1005058/files/p297.pdf

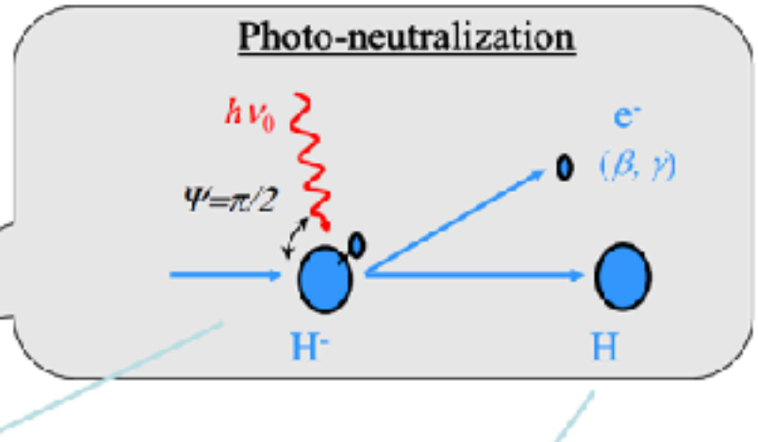
# İleri yöntemler

## Laser Wire Scanner : Photo-neutralization

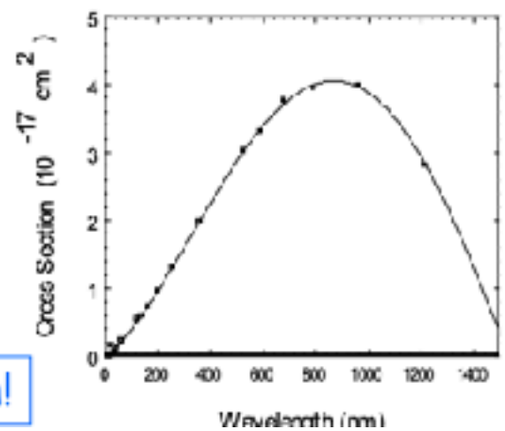
High power laser

Scanning system

$H^-$ beam




- First ionization potential for $H^-$ ions is 0.75eV
- Photo-neutralization cross section : $\sigma \sim 4.10^{-17}\ cm^2$





***Detection system based on***

- The measurement of released electrons using a magnet and a collector (faraday cup, MCP,..)

- *Measured the conversion of $H^-$ into H with a current monitor*

https://cds.cern.ch/record/1005058/files/p297.pdf

# İleri Yöntemler- Dispersion

## Measurement Date: 06 November 2020

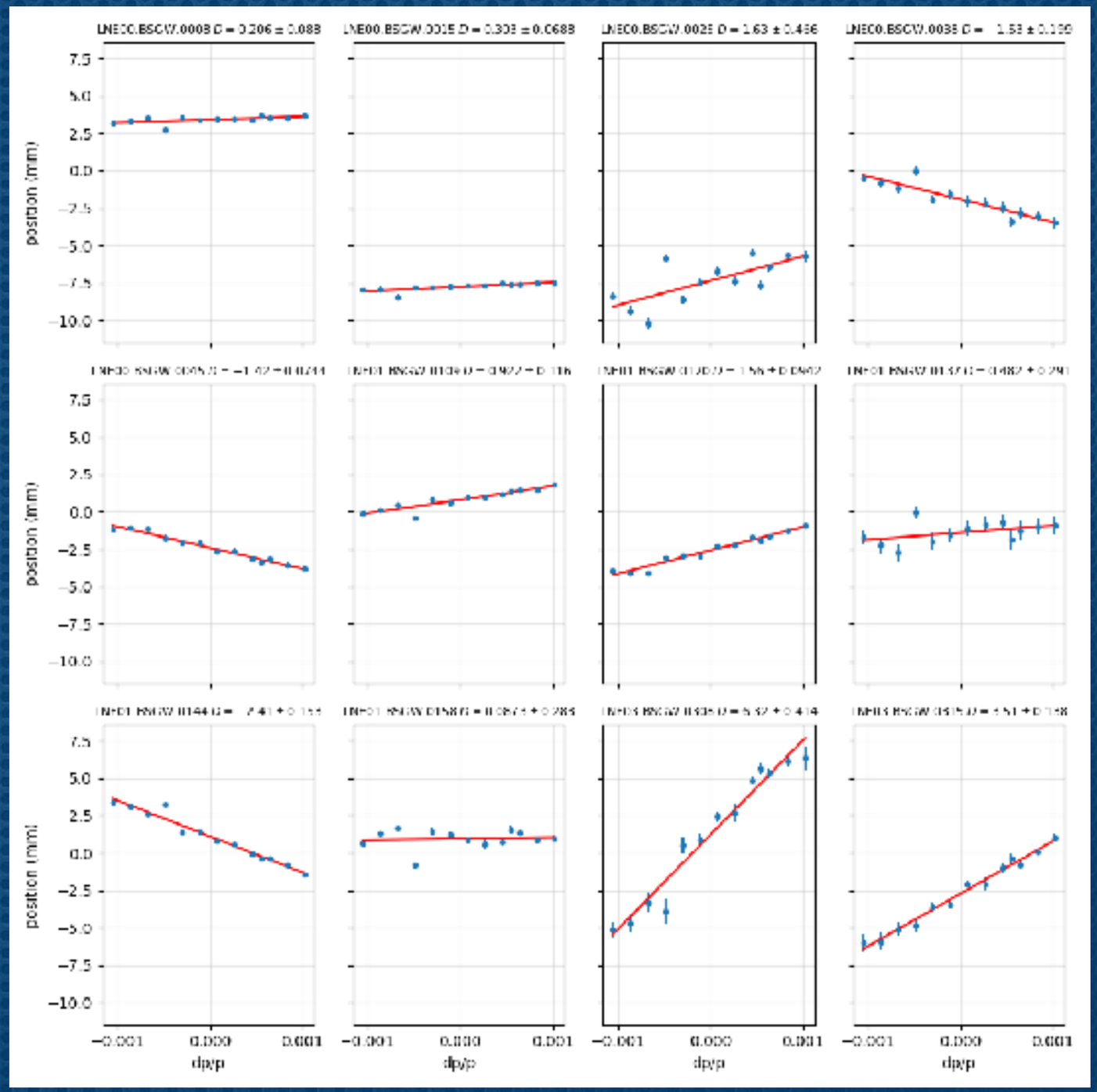
$$\frac{\Delta p}{p} = -\frac{1}{\eta_p}\frac{\Delta f}{f}$$

$$\eta_p = \frac{1}{\gamma_T^2} - \frac{1}{\gamma_{rel}^2}$$

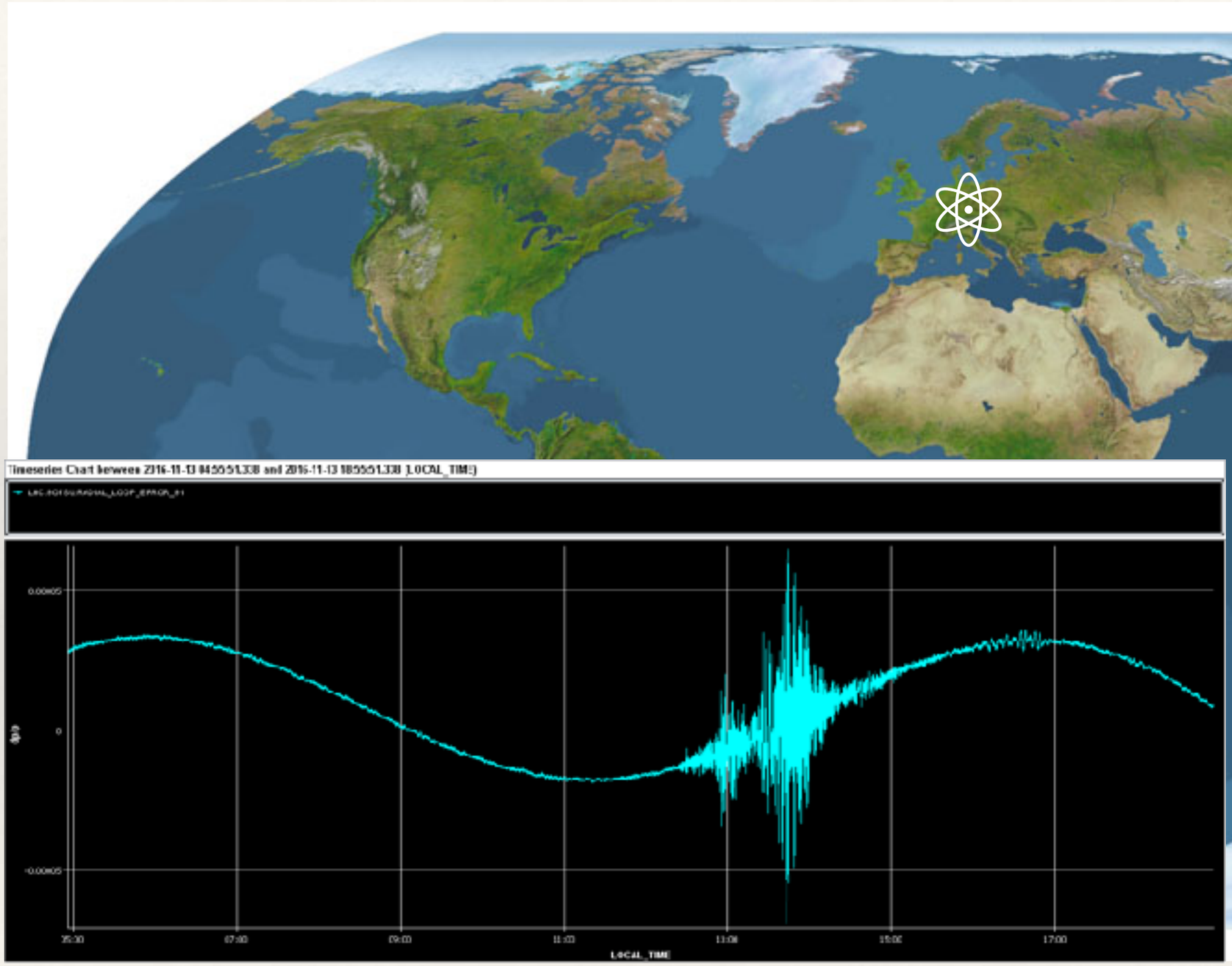
$$\Delta x = D\frac{\Delta P}{P} = D\delta$$

where **D** is the dispersion function, $\delta$ is momentum spread and $\eta_p$ is the slippage factor of ELENA.

** BSGW.0151 is discarded.



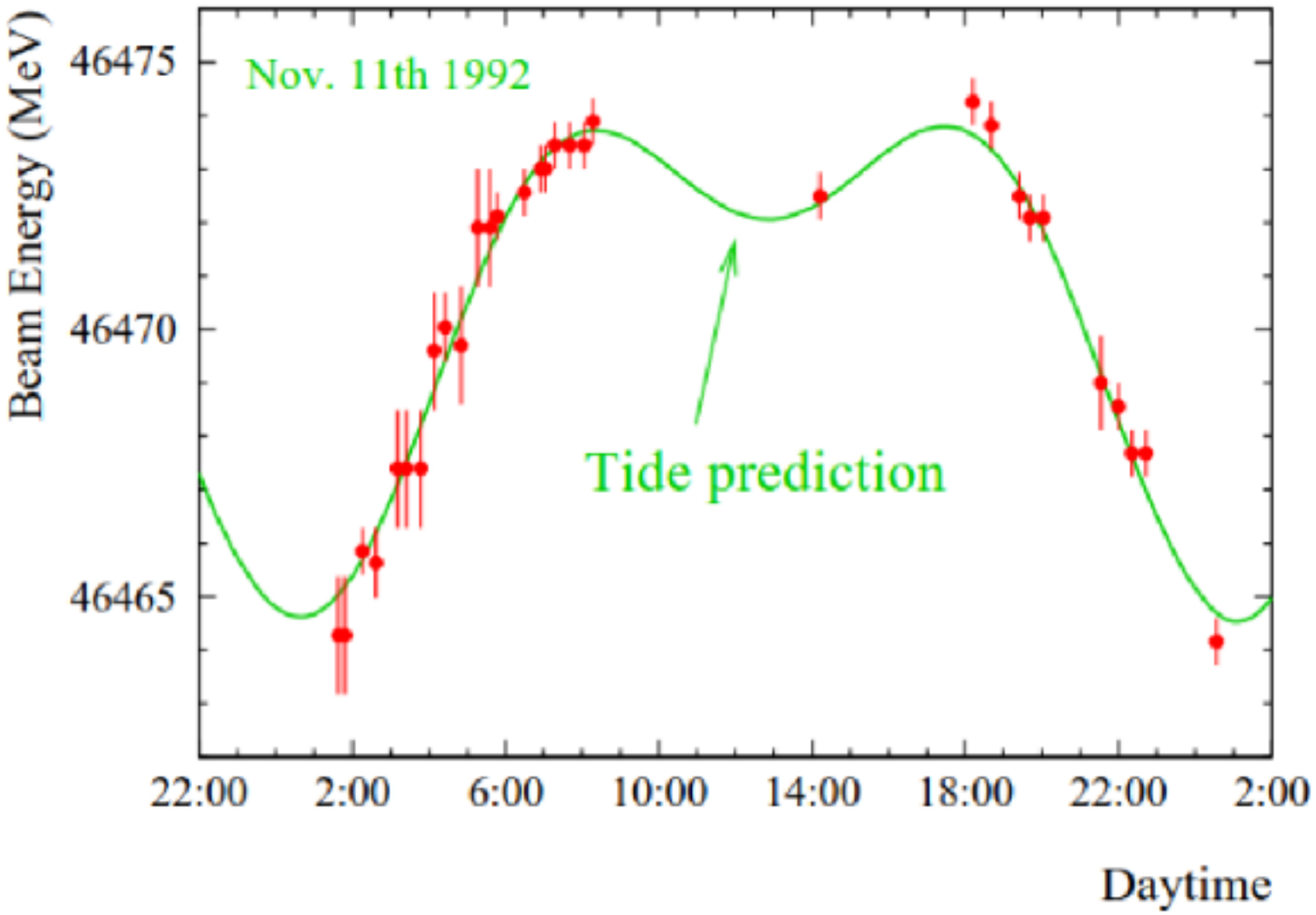
# Real Problems at LHC




✓The pressure waves induce a modulation of the circumference.

# Moonrise over LEP

**November 1992** : A historic tide experiment during new moon




The total strain is $4 \times 10^{-8}$ ($\Delta C = 1$ mm)

Ref: Jorg Wenniger- Mini-Workshop on Stray Fields

# Real Problems during LEP

## Success in the Press !

**Moon Found Behind Particle-Accelerator Puzzle**

By MALCOLM W. BROWNE

**In Physics, the Moon Factor**

GENEVA (IHT) — Scientists at the European Laboratory for Particle Physics will have to consult the phase of the moon in future before calibrating instruments on the Large Electron Positron collider outside Geneva.

Long puzzled by variations in the energy of the circulating beam made up of hundreds of millions of subatomic particles, physicists have now discovered that these correspond exactly to minute deformations in the Earth's crust caused by lunar attraction. Over the 27 kilome-

**SCIENCES**

Au LEP, près de Genève

**Les effets de Lune dévoilés par les physiciens**

*Dans le grand accélérateur européen de particules, les mesures*

**Physicists look to the moon for atomic answers**

**PHYSIQUE DES PARTICULES** *Mystère élucidé*

**Comment la lune a trompé le CERN : les physiciens expliquent**

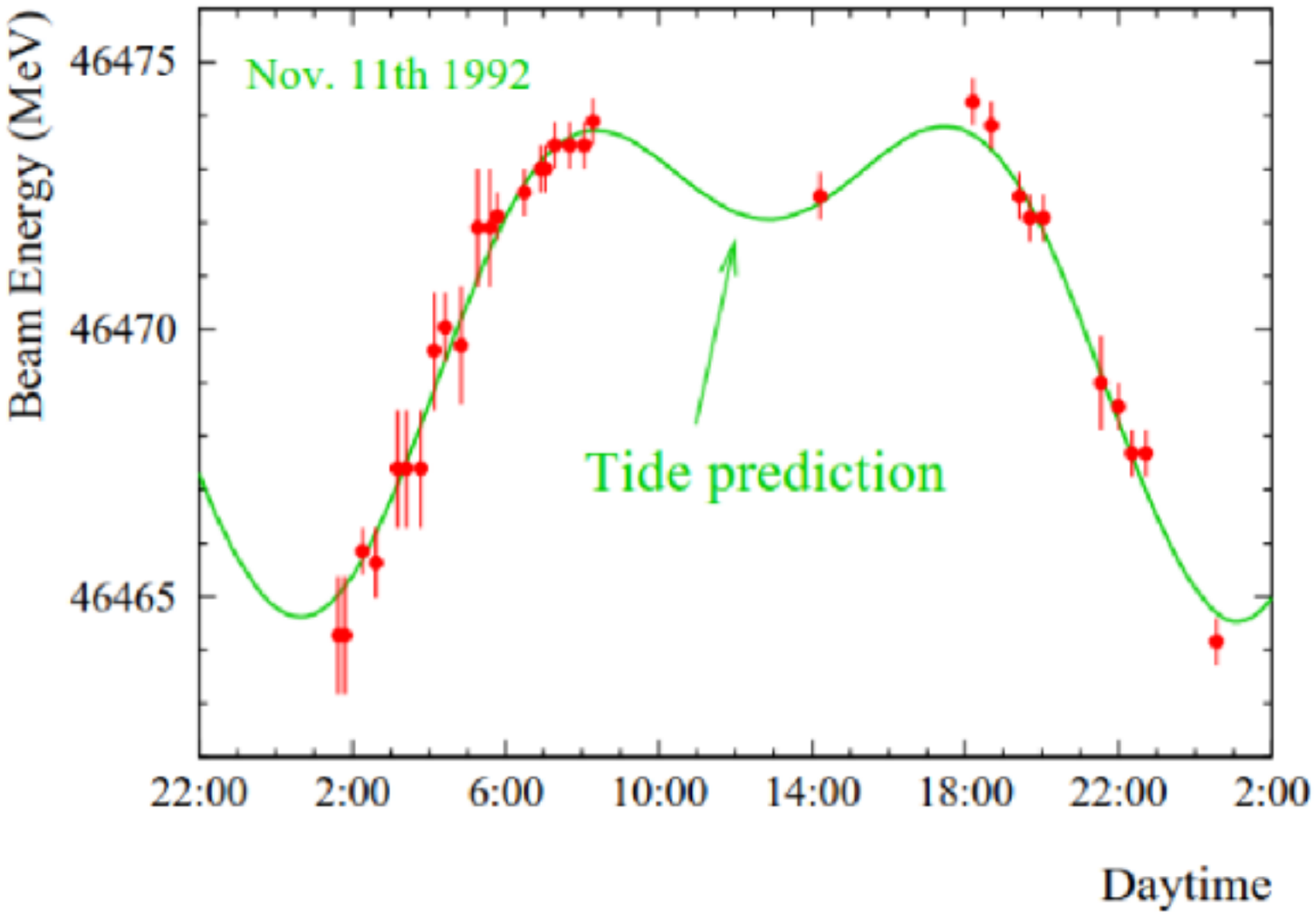
*Les scientifiques ont enfin trouvé l'origine d'une imprécision qui entachait leurs expériences : des « marées terrestres » provoquées par la lu*

**La lune trouble le CERN**

L'énergie des particules circulant dans l'anneau du LEP se modifie en fonction des phases lunaires.

# Moonrise over LEP

**November 1992** : A historic tide experiment during new moon




The total strain is $4 \times 10^{-8}$ ($\Delta C = 1$ mm)

Ref: Jorg Wenniger- Mini-Workshop on Stray Fields

# Sonuçlar

1- Görelilik: Demet ölçümleri parçacıkların sinyal oluşturabilmelerini esas alır, parçacıklar yüklerinden ve(ya) enerjilerinden ötürü bir sinyal yaratırlar.

2- Karşılıklı etkileşim: Demet ölçümleri yapabilmek için demetin dedektörle kısmi (noisy) veya tamamen etkileşmesi (destructive) gerekebilir.

3- Zorundalık: Demetin konumu, açısı, yayınımı, akımı, enerjisi, demetin 3-Boyutlu profil kesitleri... hızlandırıcı boyunca farklı noktalarda ölçülmeli.