A NANOFABRICATED WIRESCANNER: DESIGN, FABRICATION AND FIRST EXPERIMENTAL RESULTS

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on behalf of:

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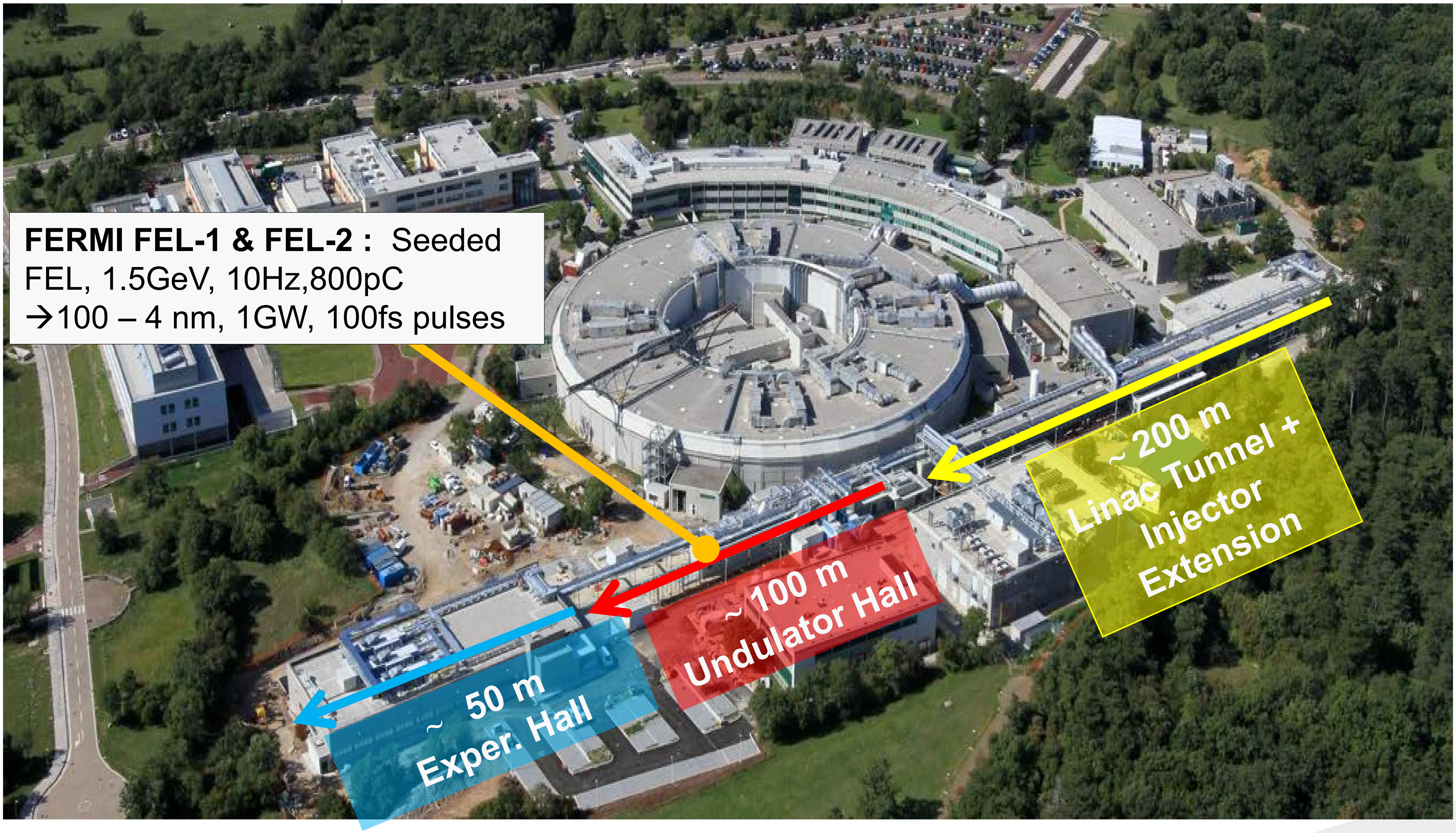
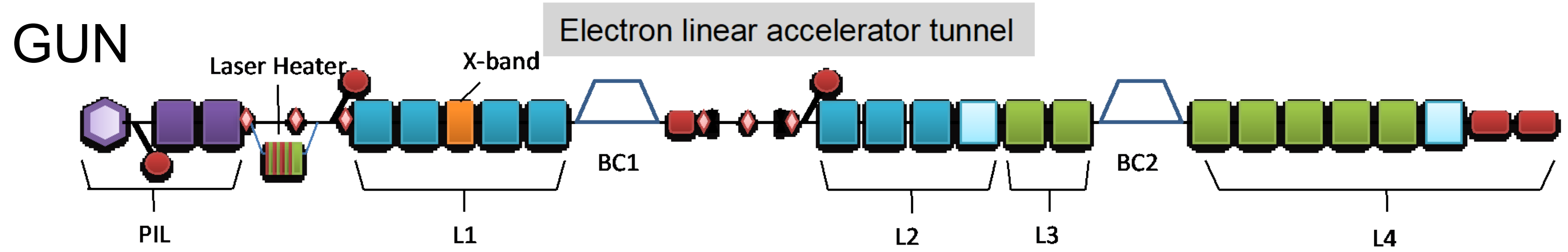
Outline

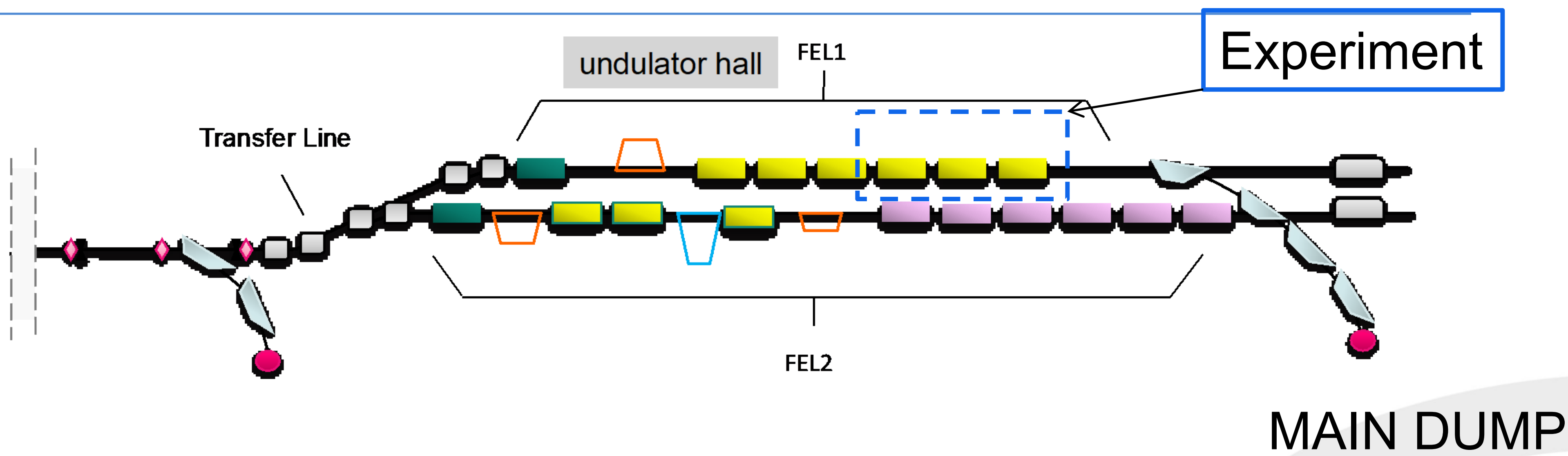
- Introduction
- Conceptual design
- Simulations
- Nanofabrication
- Experimental results

FERMI FEL at Elettra - Sincrotrone Trieste (Italy)



EXPERIMENT AT FERMI





WIRESCANNERS @ FERMI

- No wirescanner installed in FERMI up to 2015
- First experience with commissioning of PSI wirescanner* in LINAC.

  Very positive and stimulating.

Desiderata for new WSC in undulator hall:

- system online: running while the FEL is operative
- installed just before modulator undulator
- compact and delivering negligible dose to undulators downstream

IDEA: Low Z nanofabricated wires ***(NF wires)***

Long standing collaboration with nanofabrication lab of IOM CNR

*G.Orlandi et.al. PRSTAB, 19, 092802, (2016)

NANOFABRICATED WIRES

What is Nanofabrication ?

→ lithography + etching protocols on semiconducting substrates

Starting point: silicon wafer coated with silicon nitride (SiN)

RESULT: A 10x15mm device with an aperture bridged by wires

Advantages:

- Low Z, Low density material + Low thickness: 0.5-2 μm
  → Low dose → negligible de-magnetization of undulators
- With lithography the wires width can be very small : → 0.5 μm
  → Potentially high resolution is achievable

Device Nanofabrication

Mask + classical UV photolithography → One side → aperture

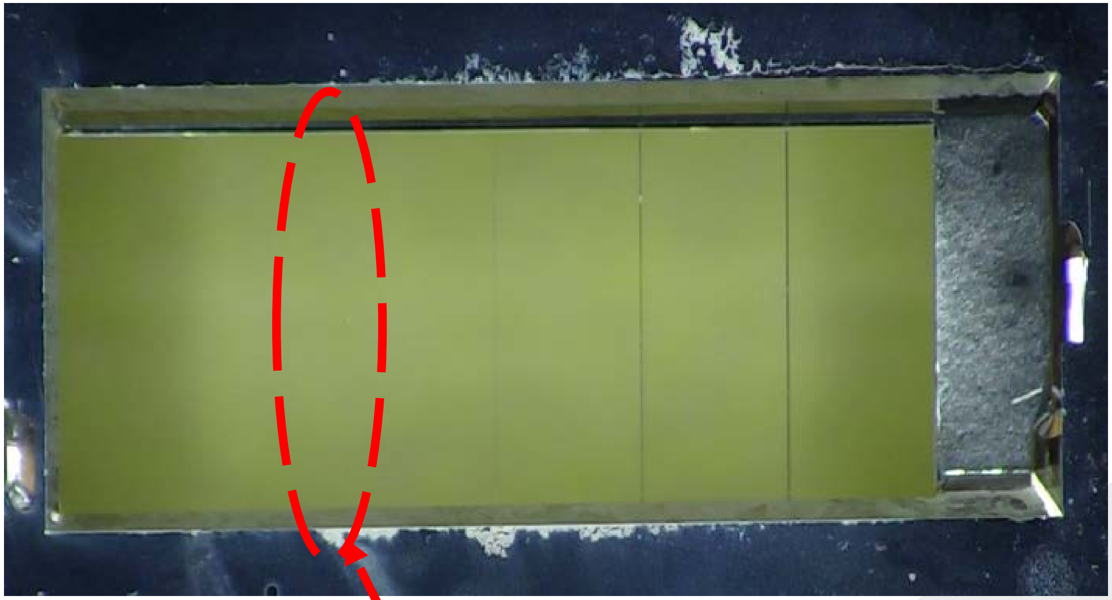
→ Other side → wire pattern

Wet etching→ reproduce patter on Cr thin film used as mask for dry ICP-Reactive ion etching to remove unwanted SiN

Finally remove all Si with KOH wet etchant

aperture:
3 x 9 mm

wires width:
- 20.6 μm
- 13.5 μm
- 6.7 μm
- 4.5 μm



4.5 μm wire not visible in the picture

WIRES vs NF-WIRES

Traditional wires are made of: tungsten, aluminum, carbon (CERN, SLAC/DESY/PSI)

NF wires are made of: Silicon Nitride (SiN)*:

→ Low Z, Low density, hard, high tensile strength

Traditional wires → circular cross section→ resolution= diameter/4

NF wires → rectangular cross section→ width/ √ 12)~width/3.5

Traditional wires minimum diameter ~ 5 μm

NF wires can be made 0.5 μm micron wide (wire robustness limit)

→ σ=0.5/3.5=0.144 μm !!

* Stoichiometry is complex and related to stress level

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NF WIRE STRUCTURE

Our device has 3 layers:

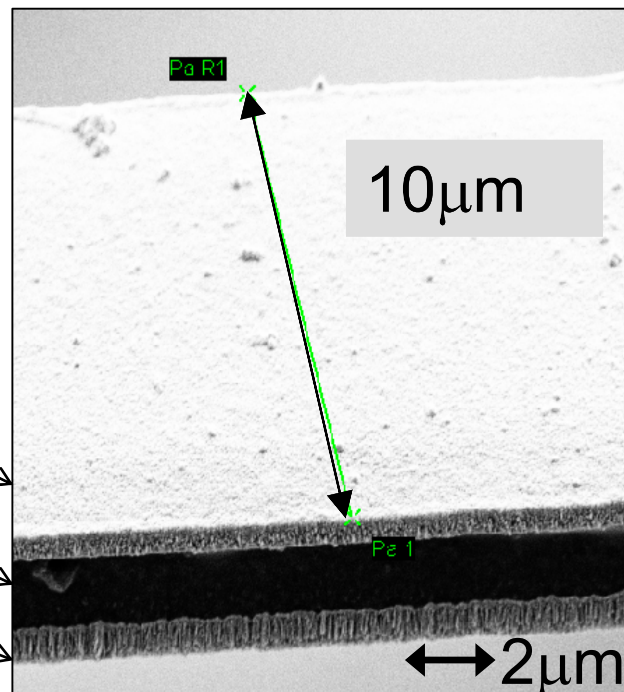
SiN NF wires with size 2μm x10μm (thickness x width) + Ag coating on both sides.

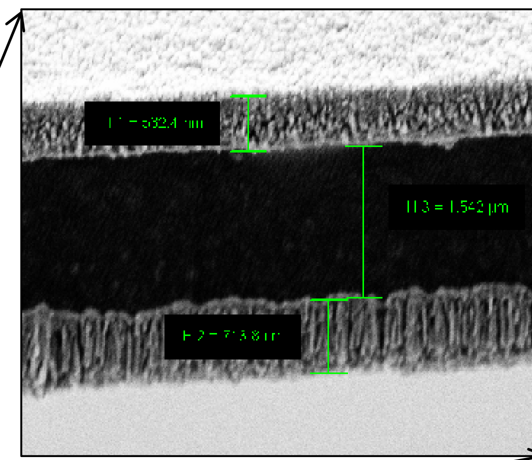
Two side coating balance stress and improve signal.

Layer1 → 0.5μm Ag

Layer 2 → 2μm SiN

Layer 3 →0.5μm Ag





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MATERIALS AND IONIZING DOSE

If we consider only bremsstrahlung

The dose is: proportional to Z^2, proportional to ρ (density)

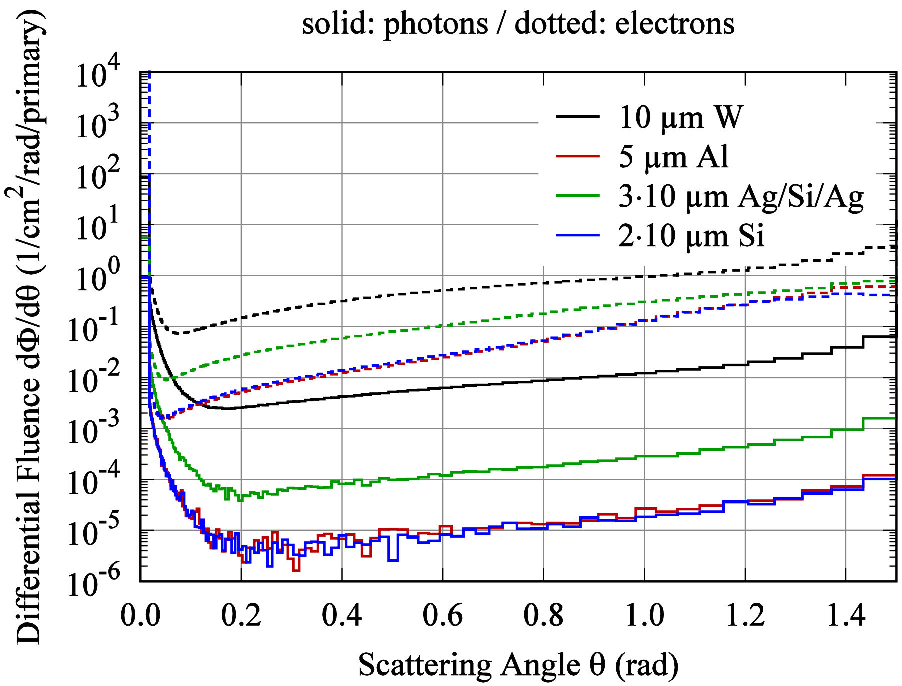
Element	**Z**	**ρ [gcm^{-3}]**
Tungsten	74	19.3
Aluminum	13	2.7
Silicon	14	2.3
SiN	12.5*	3

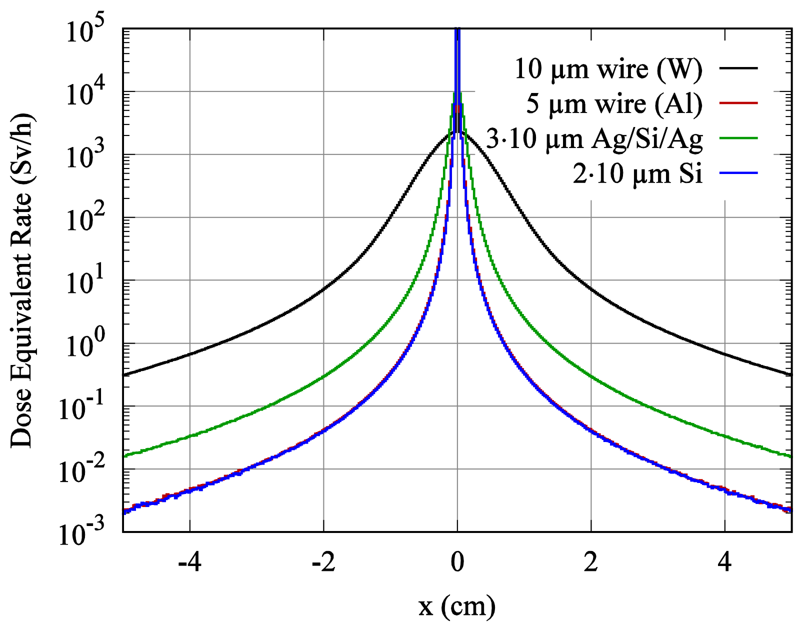
* Effective atomic number

Device	**Normalized dose approximation**	**Normalized dose FLUKA**
Tungsten Wire 10 μm	929	175
Aluminum Wire 5 μm	1	1
NF wire SiN 2 μm x 10 μm	0.8	0.95
NF wire (0.5 μm Ag / 2μm SiN / 0.5μm Ag) x 10μm	26.7	7.5

SIMULATIONS with FLUKA

- Electrons produce main dose (not photons)



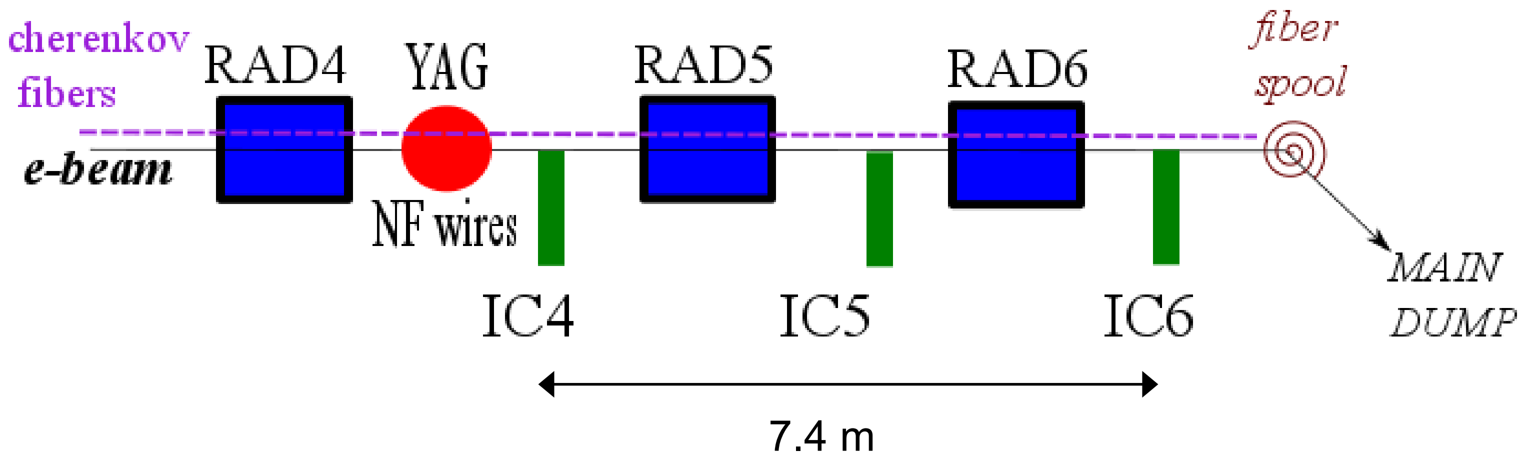


Ultrathin wires → low cross section

Low cross section → low divergence
Low divergence of dose → < 1mrad

→Distance wire / maximum of dose ~10 meters (vacuum chamber diam.)

EXPERIMENTAL LAYOUT ON FERMI FEL1

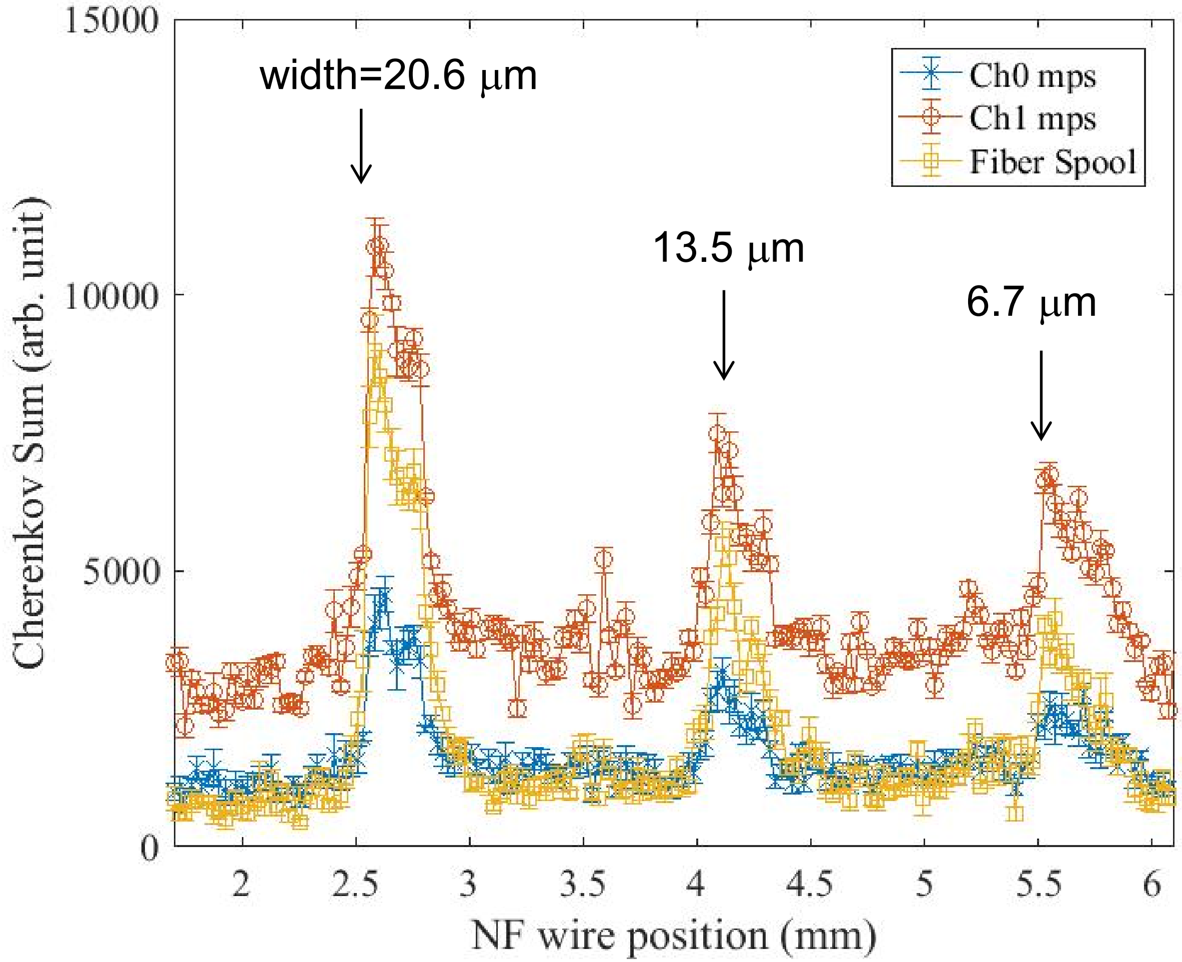


- Dose detectors from MPS:

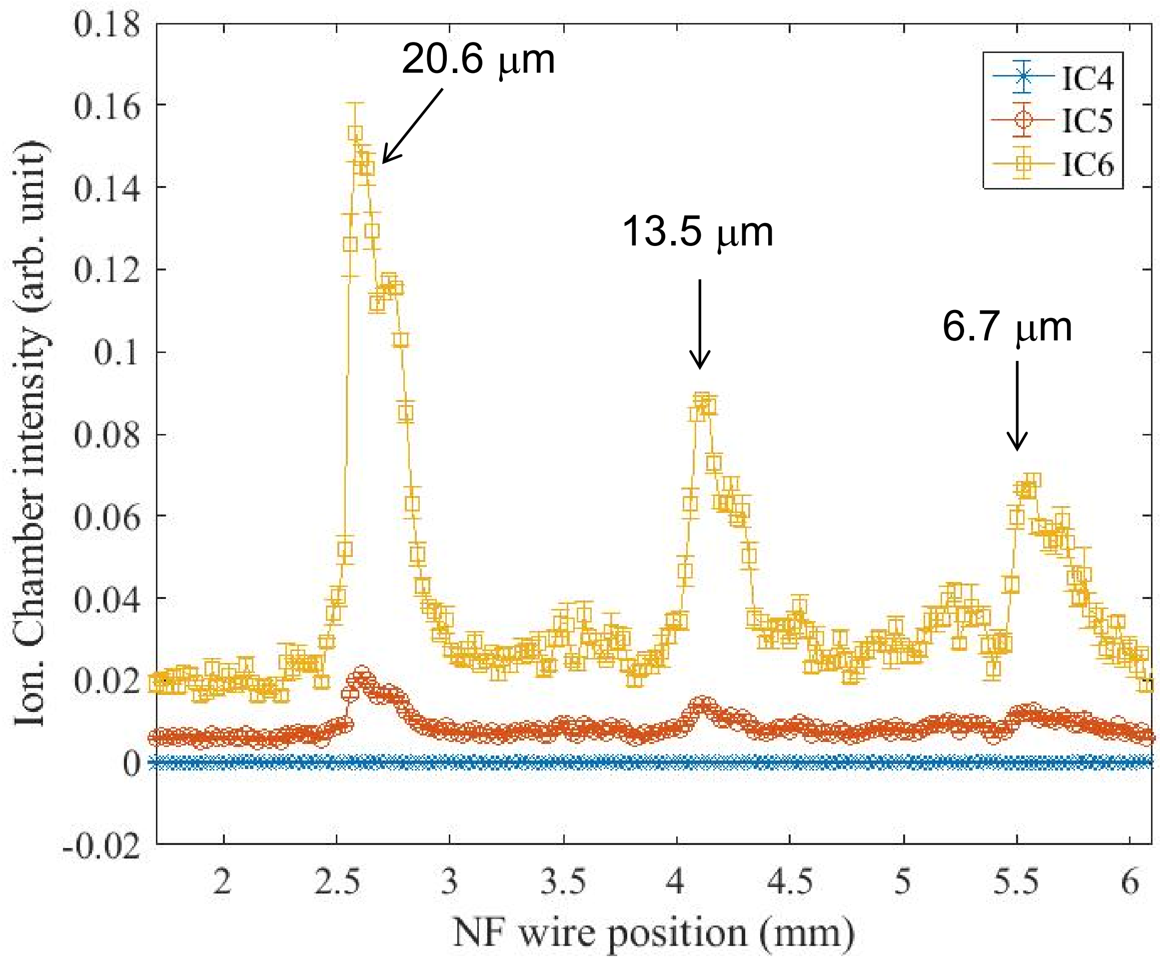
1) Cherenkov fibers + MPPC detector + 250Ms/s 12bit adc
2) Cherenkov fiber spool + MPPC detector + 250Ms/s 12bit adc
3) Ionization chamber + picoammeter

- High resolution Imaging scintillating screen:
  YAG:Ce with COTR immune geometry

SIGNALS FROM CHERENKOV FIBERS ON FERMI FEL1

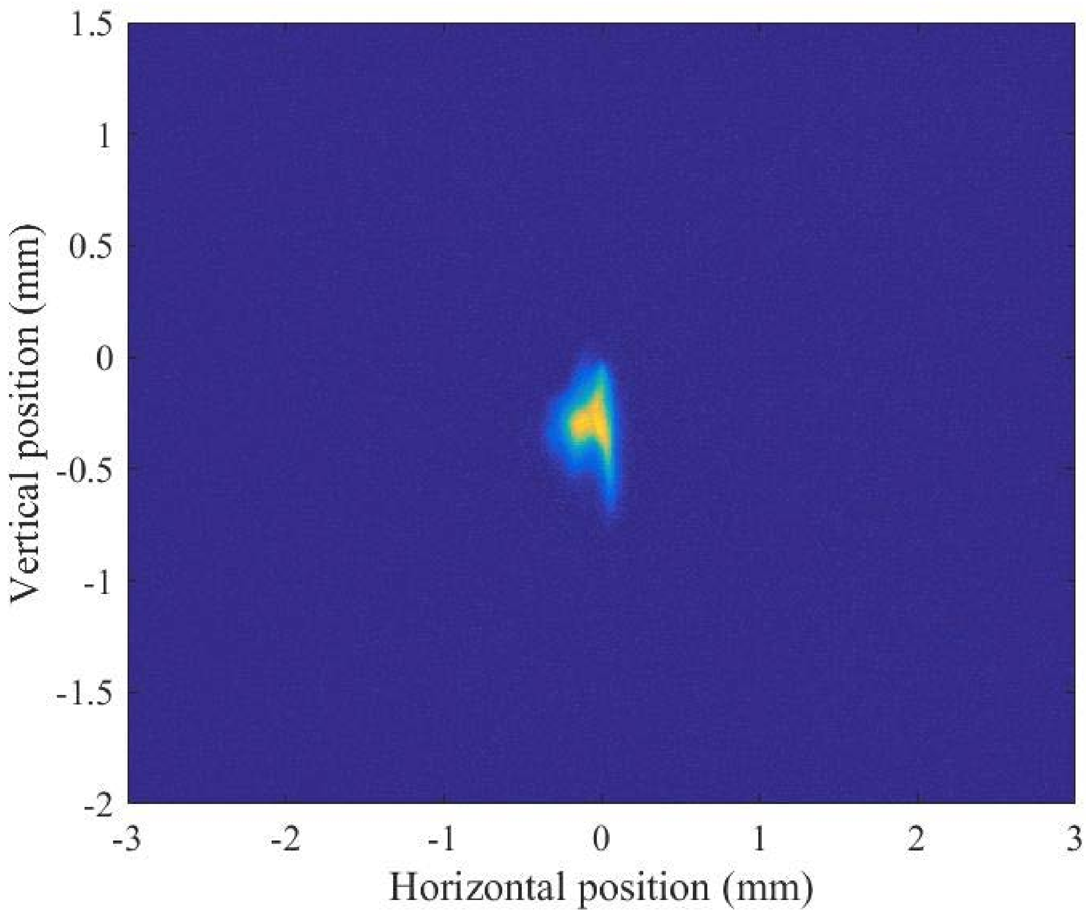


SIGNALS FROM IONIZATION CHAMBERS ON FERMI FEL1

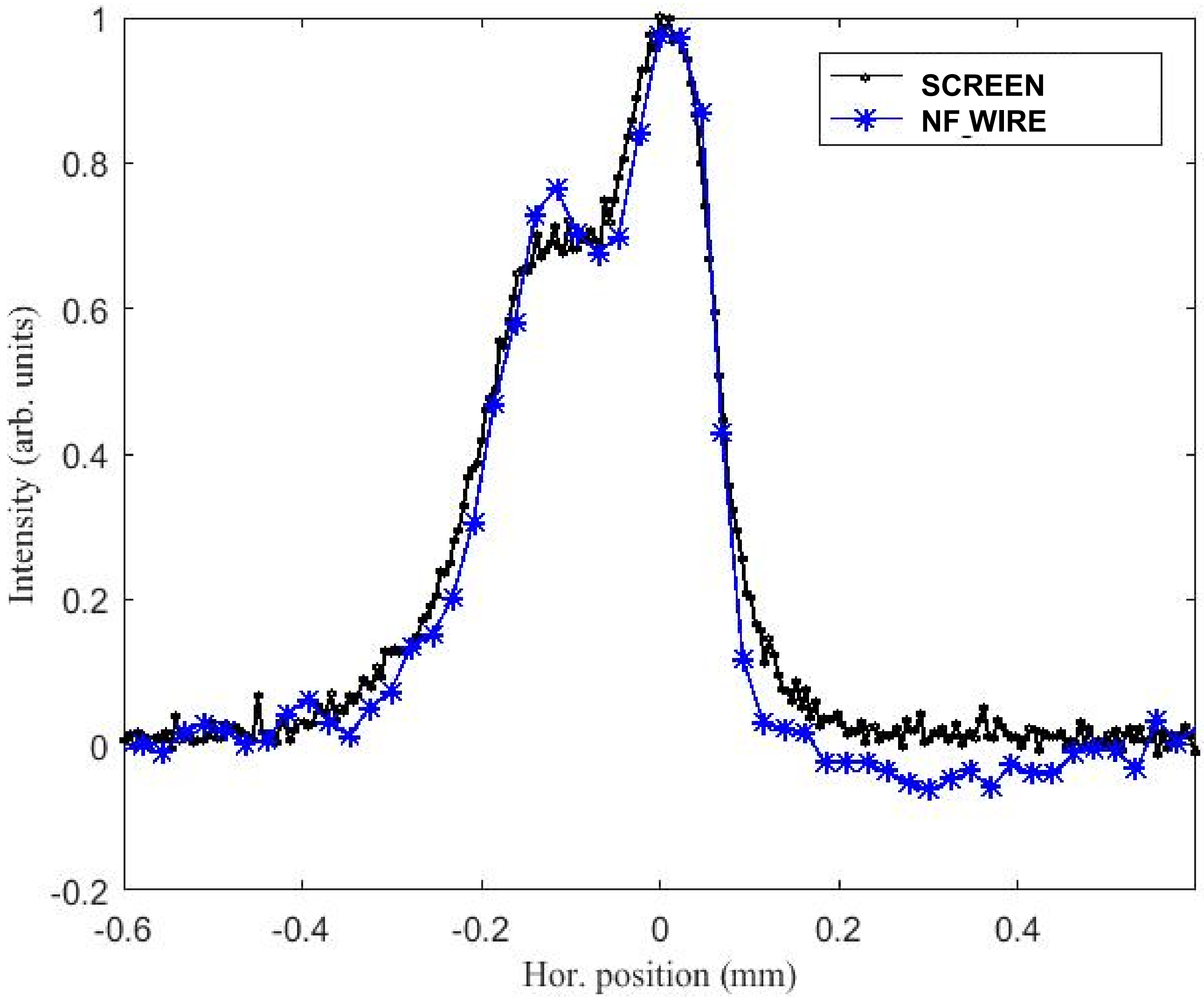


IC6 shows higher signal →closer to dose maximum position

HIGH RESOLUTION SCREEN



NF WIRE vs HIGH RESOLUTION SCREEN



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CONCLUSIONS & PERSPECTIVES

NF wires successfully built & tested with beam on FERMI

Lessons Learned:

- Metallic coating should be done both sides to avoid stresses and wire breaking
- Best suited for small beam sizes <100 μm → high brightness and E>~100MeV
- Main technological limit is the vertical aperture <= 5mm
- Halos or wakefields may affect SNR

FUTURE GOALS:

To fabricated a new device for both X and Y measurements

To improve SNR (bulk scintillator, PMT) to better operate with thin wires

To test resolution limits with much smaller beams

Thank you for your attention!