

# **IDEA concept Status Report**

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INFN – Lecce**

**WG11  
CERN, October 4, 2019**

# Disclaimer

- All transparencies are stolen from recent presentations of different authors.
- No software developments.
- No magnet updates.

## Outline

- IDEA detector: a few reminders
- Current activities on
  - Vertex detector
  - Drift Chamber
  - Calorimeter
  - Preshower and Muons

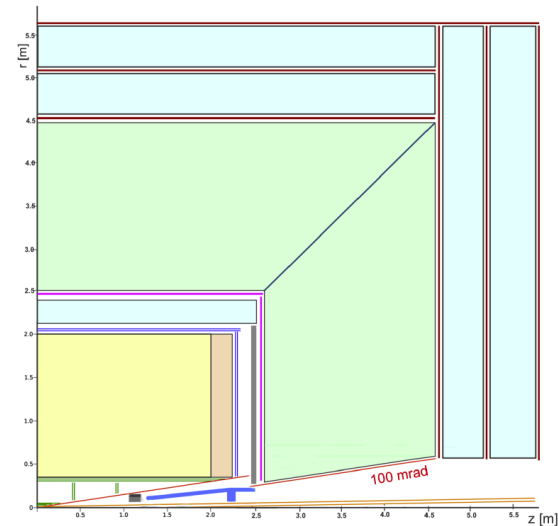
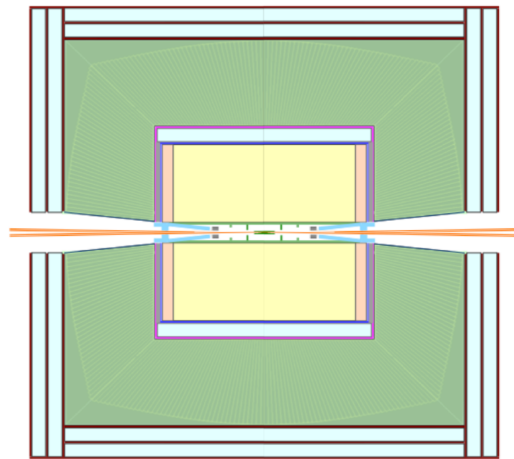
# FCCee IDEA Detector

**Beam pipe:**  $r \sim 1.5$  cm

**Vertex:** 5 MAPS layers  
 $r = 1.7$ -34 cm

**Drift Chamber:** 4 m long,  $r = 35$ -200 cm

**Outer Silicon Layers:** strips



**Superconducting solenoid coil:** 2 T,  $r \sim 2.1$ -2.4 m  
 $0.74 X_0$ ,  $0.16 \lambda @ 90^\circ$

**Preshower:**  $\sim 1 X_0$   $\mu$ -RWELL MPGD

**Dual-Readout Calorimeter:** 2 m /  $8 \lambda_{\text{int}}$

**Yoke + Muon chamber:**  $\mu$ -RWELL MPGD

# Vertex detector

Exploring CMOS technologies, since they have the potential for low cost/high throughput

- **VTX: Depleted Monolithic Active Pixels**
  - Fast signal
  - Possibility for very thin detectors (low material)
  - Small pitches already realized
  - INFN/CSN5 developments: SEED-ARCADIA
    - One AIDA++ EoI submitted
  - INFN/(CSN5+CSN1) developments: HVR\_CCPD-ATLAS
    - One AIDA++ EoI submitted
- **Outer tracker:**
  - Proposing passive CMOS sensor (productions by ATLAS/CMS on going, part of the ATLAS pixel detector market surveys)
    - One AIDA++ EoI submitted

## ARCADIA

(Advanced CMOS Architectures with Depleted Integrated sensor Arrays)  
INFN CSN5 Call Project targeting a full-size system-ready demonstrator of a low-power high density pixel matrix CMOS monolithic sensor featuring:

1. Active sensor thickness in the 50-500  $\mu\text{m}$  range
2. Operating in full depletion fast charge collection by drift
3. Scalable readout architecture with ultra-low power capability  $O(10 \text{ mW/cm}^2)$

# Vertex detector

from  
Attilio  
Andreazza

- Silicon package till now mainly concentrated on application of CMOS technologies
- Assess multi-chip performance of the detectors developed for ATLAS
- Technology of great interest for INFN
- Submitted 5 (3 from IDEA) AIDA++ EoI on CMOS related technologies

Roma, 23 September 2019 RD\_FA: Silicon detectors

### SEED → ARCADIA Sensors

Thinning of sensor

Reduce complexity of backside treatment

Smaller size

MAIN REQUIREMENTS OF MATTISSE	
Technology	CMOS BSI 0.11 μm
Voltage supply	1.2 V
Measurements	Hit position Energy Loss
Number of channels	24 × 24
Input dynamic range	up to 24 ke <sup>-</sup>
Sensor capacitance	~40 fF
CSA input common mode voltage	> 600 mV
Local memories	2 (~70 fF each)
Noise	< 100 e <sup>-</sup>
Shutter type	Snapshot shutter
Readout type	Correlated Double Sampling Double Sampling
Readout speed	up to 5 MHz
Other features	Internal test pulse Mask mode Baseline regulation

Roma, 23 September 2019 RD\_FA: Silicon detectors

### SEED detector characterization

- Microbeam scans at RBI – Zagreb
  - Study charge collection of SEED sensors
  - 2 MeV protons → good charge collection uniformity
  - Pseudomatrices of 10 μm – 50 μm pitch, 100 μm – 400 μm sensor thickness

std dev

mean energy

Metal lines

Matrix edge

Bias Voltage

Roma, 23 September 2019 RD\_FA: Silicon detectors

### ATLAS developments

- Different monolithic devices developed within the ATLAS pixel community
- Front-end electronics **inside** the collecting well
  - uniform charge collection
  - short drift path → less trapping
  - large electrode capacitance ~100 fF, due to parasitic capacitance between the deep wells
  - LFoundry, AMS/TSI technologies
- Front-end electronics **outside** the collecting well
  - non uniform drift field
  - long drift path
  - more sensitive to trapping
  - small electrode capacitance < 10 fF
  - TowerJazz
- CMOS option reviewed in February 2019, in view of the overall ATLAS ITk schedule

From the review report:

- Excellent R&D being done on the monolithic CMOS sensors
  - will be important for the field in the longer term
  - but available evidence suggests it will not converge in time for this iteration of the Pixel Upgrade

Moving developments to RD\_FA

Roma, 23 September 2019 RD\_FA: Silicon detectors

### Completing ATLAS R&D: ATLASPIX3

- AMS 180 nm HV technology now moved to TSI (USA) compatible process
- Sensor radiation hardness verified on several prototypes till  $2 \times 10^{15}$  n/cm<sup>2</sup>

No rad 99.7% efficiency

$10^{15}$  n/cm<sup>2</sup> 99.4% efficiency

- Full size matrix: 20.2mm x 21mm
- Compatible with most ATLAS requirements:
  - 50 × 150 μm<sup>2</sup> pixel size, large fill factor
  - Column drain readout (FE-13 like)
  - Compatible with RD53A serial powering schema and readout protocols
- Submitted to TSI in April, first chips available now

Roma, 23 September 2019 RD\_FA: Silicon detectors

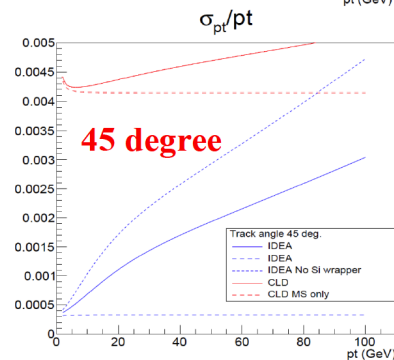
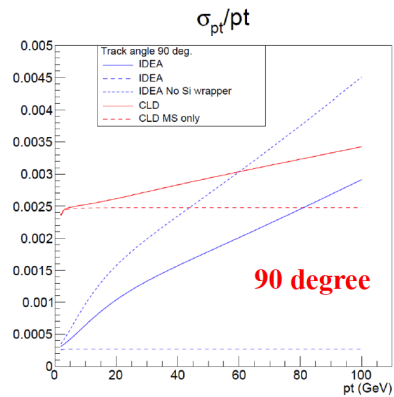
### ATLASPIX3 Modules

- Interest of this new prototype:
  - Readout on full scale matrix
- System aspects:
  - Serial powering
  - Multi-chip module
- Develop a multichip hybrid following a layout similar to the ones for the hybrid ATLAS quad modules
  - Challenges: accurate chip placement + flexibility
  - General agreement: hybrid by Milano, adapter+readout firmware by Lancaster
  - If successful, considering a similar development for the TowerJazz Monopix prototype (small fill factor) to be submitted at the end of the year (see backup).
- Costs depends a lot on geometry and complexity.
  - Our last pseudo-quad from ATLASPIX3 costed 6k + IVA: smaller chip, but more complex layout, integrating also adapters to readout system
  - With simplifications available in ATLASPIX3 and splitting between hybrid and adapter expect to go down to 4k+IVA: funding request of 5k

# Drift Chamber performance

from  
Lorenzo  
Pezzotti

## Full tracking performances (vertex + drift chamber + Si wrapper)



@ 90°, asymptotic behavior

IDEA

$$\sigma_{p_t}/p_t \approx 2.2 \times 10^{-5} p_t$$

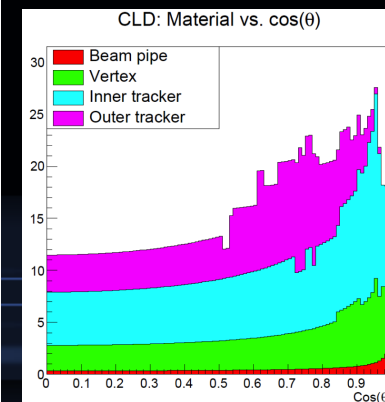
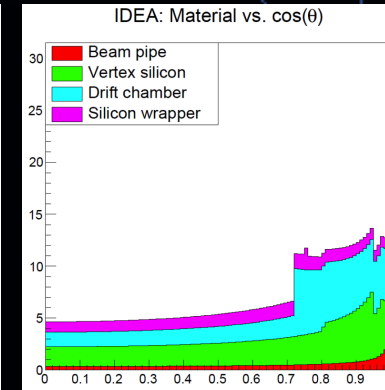
IDEA no Si wrapper

$$\sigma_{p_t}/p_t \approx 5.7 \times 10^{-5} p_t$$

+

Cluster counting  
for improved particle identification:  
 $dN_{cl}/dx \sim 2\%$  vs  $dE/dx \sim 4\%$

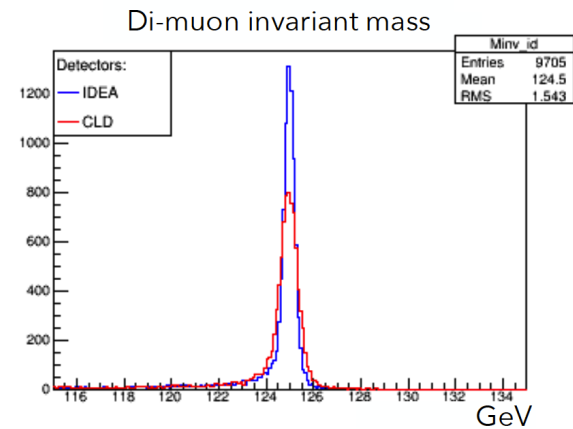
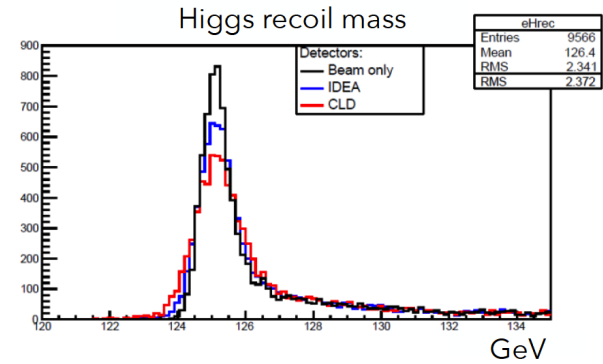
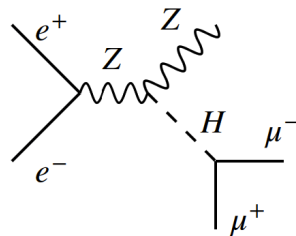
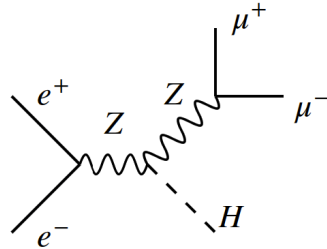
No ion back-flow & short drifting time.



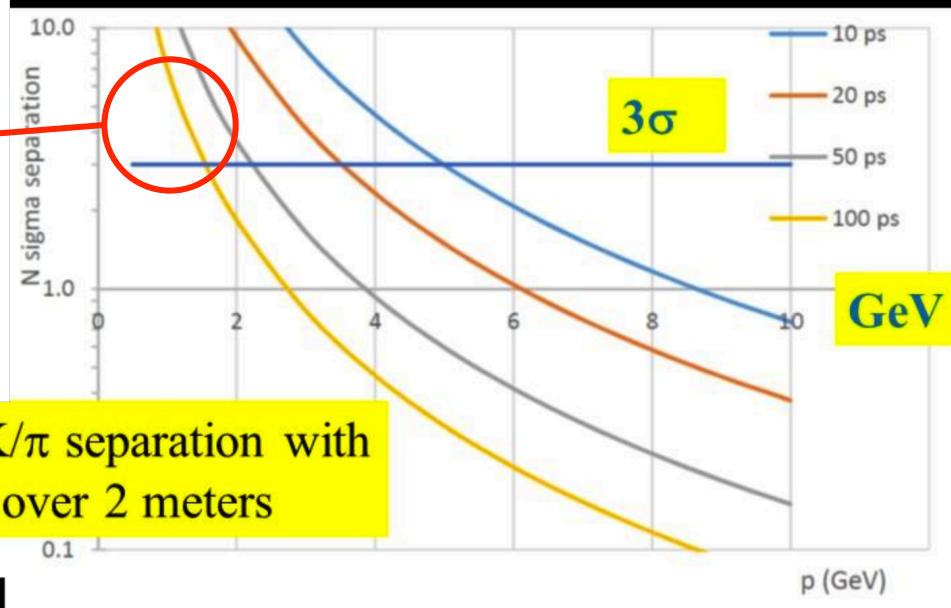
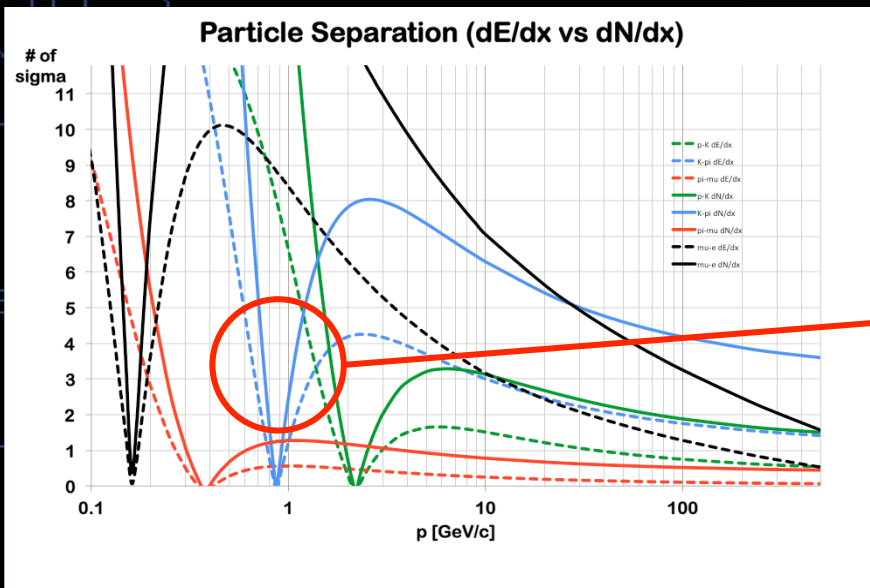
# Drift Chamber performance from Lorenzo Pezzotti

## IDEA/CLD Comparison

Run @Higgs pole, assuming 0.136% beam spread



# Drift Chamber performance



$N\sigma$   $K/\pi$  separation with TOF over 2 meters



# Drift Chamber R&D: wire length

Electrostatic stability condition

$$T > \frac{C^2 V_0^2 L^2}{4\pi\epsilon w^2}$$

$T$  = wire tension

$C$  = capacitance per unit length

$V_0$  = anode-cathode voltage

$L$  = wire length,  $w$  = cell width

**IDEA Drift Chamber:**  $C = 10$  pF/m,  $V_0 = 1500$  V,  $L = 4.0$  m,  $w = 1.0$  cm

$$T > 0.32 \text{ N}$$

- 20  $\mu\text{m}$  W sense wire (Y.S.  $\approx 1200$  MPa):  $T_{max} = 0.38$  N (marginal)
- 40  $\mu\text{m}$  Al field wire (Y.S.  $\approx 300$  MPa):  $T_{max} = 0.38$  N (marginal)
  - => **shorten chamber** (loss of acceptance)
  - => **widen cell size** (increase occupancy)
  - => **increase wire diameter** (increase multiple scattering and endplate load)

or,

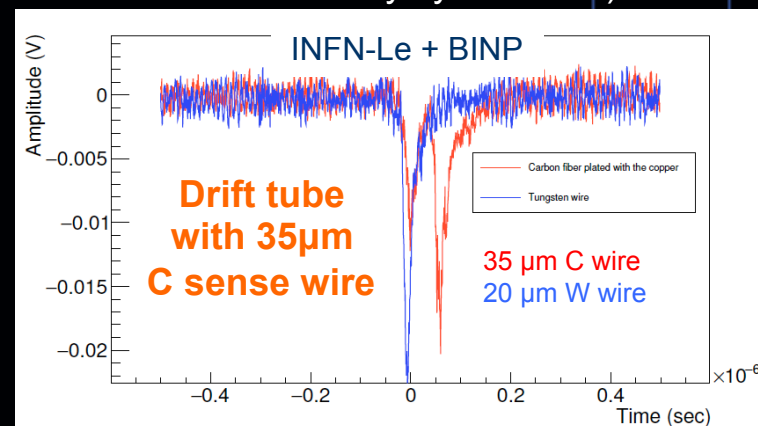
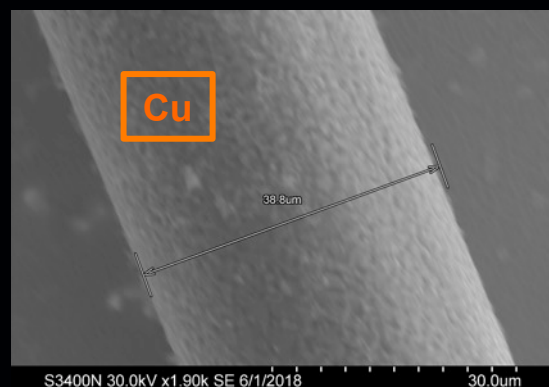
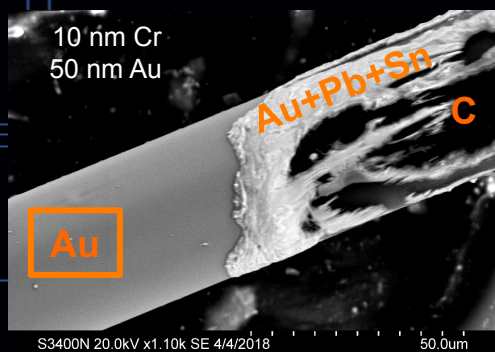
=> replace 40  $\mu\text{m}$  Al with **35  $\mu\text{m}$  Carbon monofilament**  
(Y.S.  $> 860$  MPa):  $T_{max} > 0.83$  N

# Drift Chamber R&D: C wire

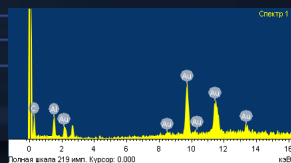
BINP  
A. Popov  
V. Logashenko

## HiPIMS: High-power impulse magnetron sputtering

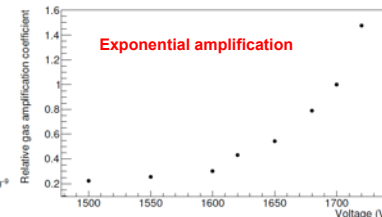
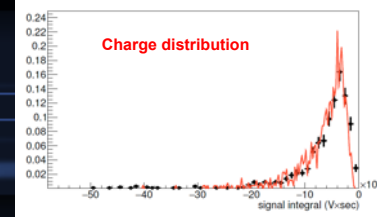
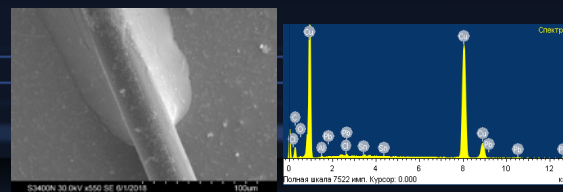
physical vapor deposition (PVD) of thin films based on magnetron sputter deposition (extremely high power densities of the order of kW/cm<sup>2</sup> in short pulses of tens of microseconds at low duty cycle <10%)



**soldering attempt**  
Lead forms intermetallic compound with gold and completely dissolves the 50 nm Au layer.



**good solder wettability on Cu**

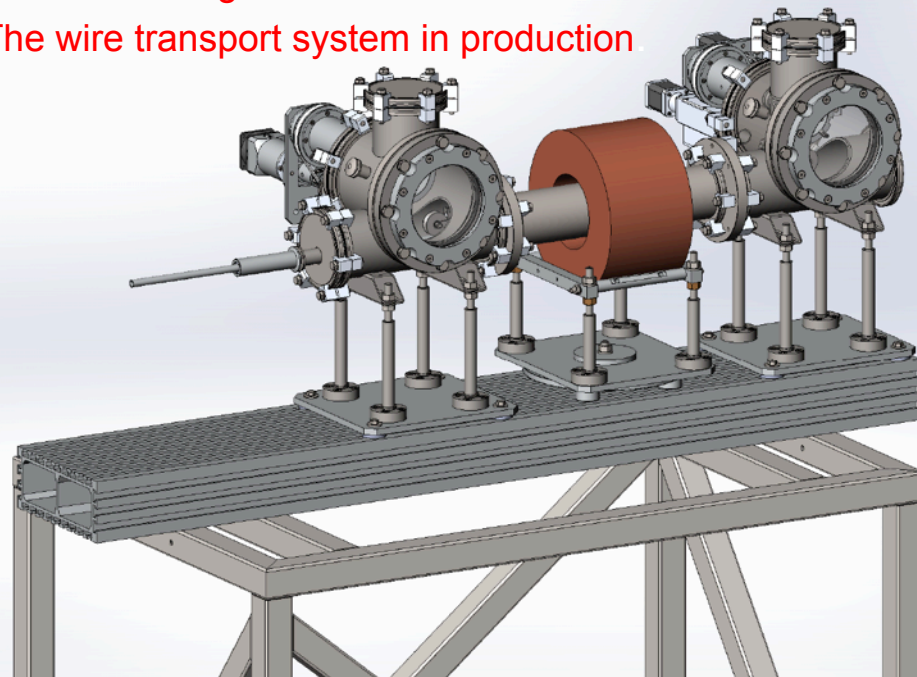


# Drift Chamber R&D: C wire

BINP  
A. Popov  
V. Logashenko

- Cu coating test of 35  $\mu\text{m}$  carbon monofilament very successful on short samples with HiPIMS at BINP, Novosibirsk
- Investigation of magnetron sputtering facilities elsewhere
- Industrialization of process for coating continuous spooled monofilament ongoing
- **Different alternatives?**

Cylindrical magnetron completed at BINP.  
Stable discharge obtained.  
The wire transport system in production.



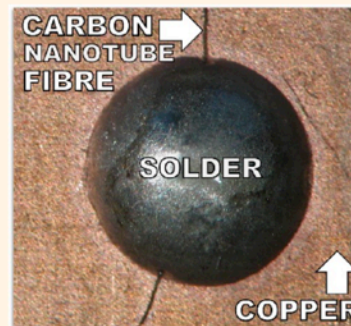
# C wire soldering without metal coating

## Soldering of Carbon Materials Using Transition Metal Rich Alloys

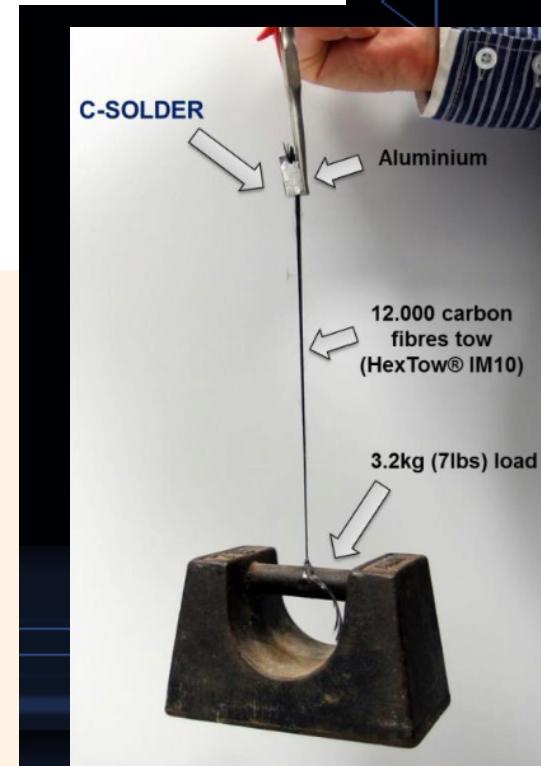
Marek Burda,<sup>\*,†</sup> Agnieszka Lekawa-Raus,<sup>†</sup> Andrzej Gruszczyk,<sup>‡</sup> and Krzysztof K. K. Koziol<sup>\*,†</sup>

<sup>†</sup>Department of Materials Science and Metallurgy, University of Cambridge, 27 Charles Babbage Road, CB3 0FS, Cambridge, U.K. and <sup>‡</sup>Welding Department, Silesian University of Technology, Konarskiego 18a, 44-100 Gliwice, Poland

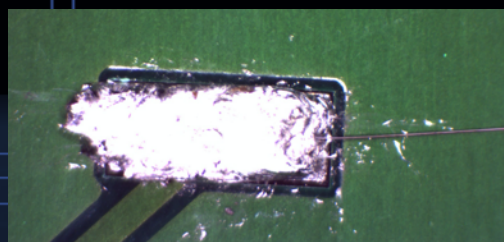
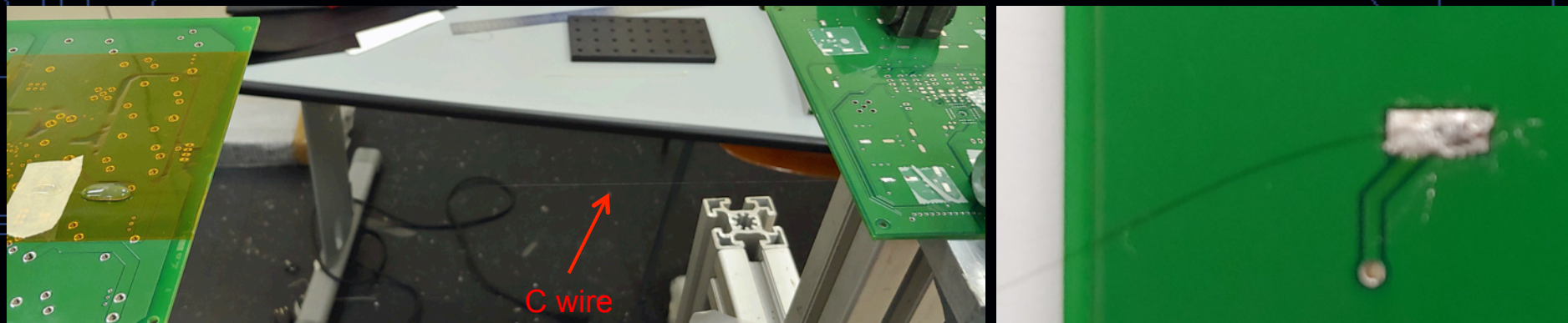
**ABSTRACT** Joining of carbon materials *via* soldering has not been possible up to now due to lack of wetting of carbons by metals at standard soldering temperatures. This issue has been a severely restricting factor for many potential electrical/electronic and mechanical applications of nanostructured and conventional carbon materials. Here we demonstrate the formation of alloys that enable soldering of these structures. By addition of several percent (2.5–5%) of transition metal such as chromium or nickel to a standard lead-free soldering tin based alloy we obtained a solder that can be applied using a commercial soldering iron at typical soldering temperatures of approximately 350 °C and at ambient conditions. The use of this solder enables the formation of mechanically strong and electrically conductive joints between carbon materials and, when supported by a simple two-step technique, can successfully bond carbon structures to any metal terminal. It has been shown using optical and scanning electron microscope images as well as X-ray diffraction patterns and energy dispersive X-ray mapping that the successful formation of carbon–solder bonds is possible, first, thanks to the uniform nonreactive dispersion of transition metals in the tin-based matrix. Further, during the soldering process, these free elements diffuse into the carbon–alloy border with no formation of brazing-like carbides, which would damage the surface of the carbon materials.



Published online August 09, 2015  
10.1021/acsnano.5b02176



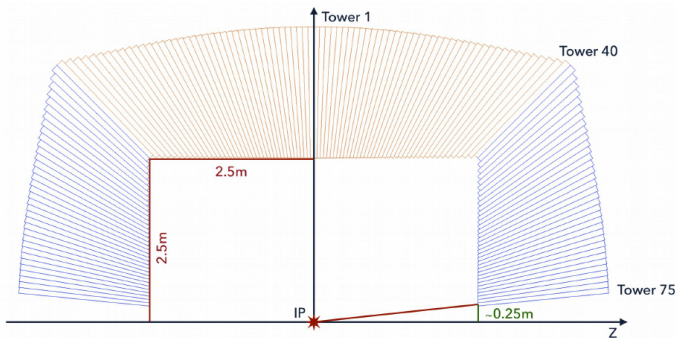
# C wire without metal coating: manual soldering



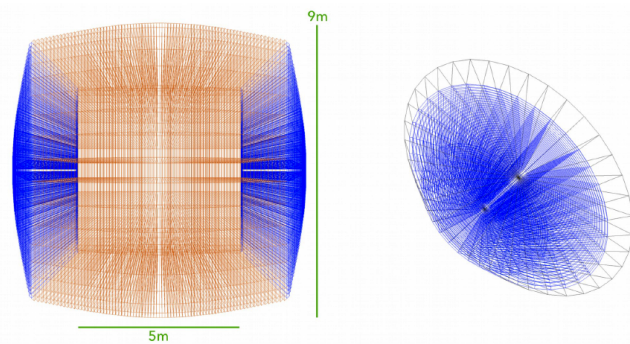
# DR Calorimeter: $4\pi$ simul.

from  
Lorenzo  
Pezzotti

constant sampling fraction



Cu absorber  
1 mm fibres  
1.5 mm pitch

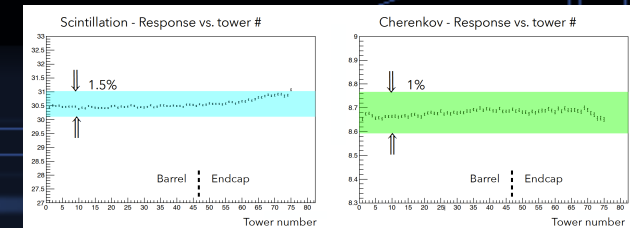
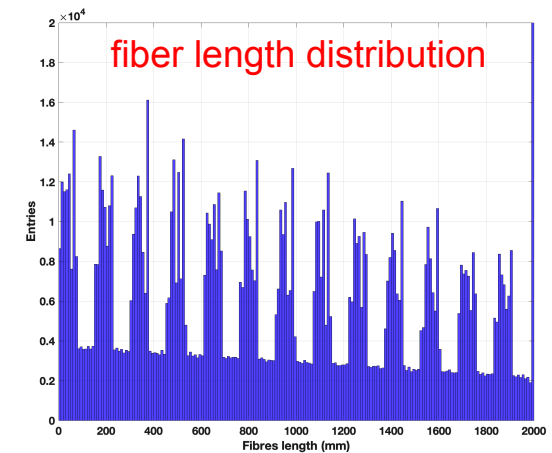


75 projective towers  
× 36 slices

$$\Delta\theta = 1.125^\circ$$

$$\Delta\phi = 10^\circ$$

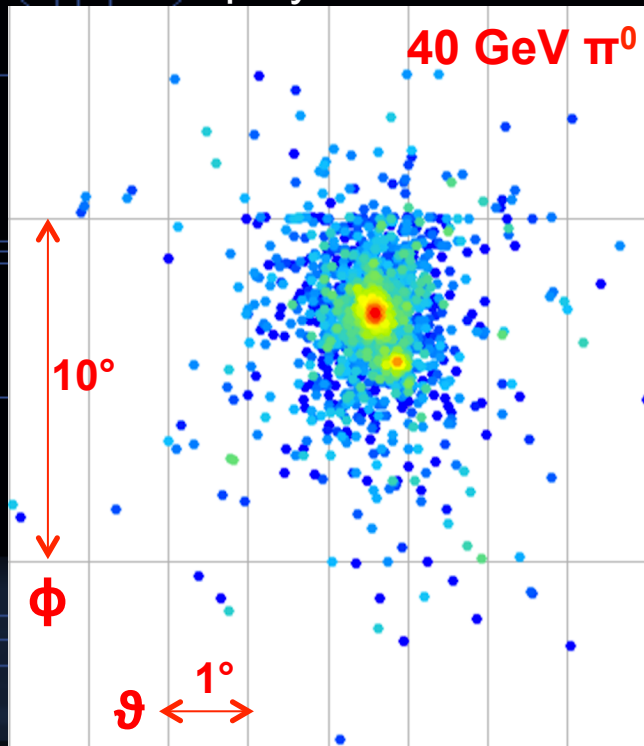
~130 M fibres



# DR Calorimeter: resolutions

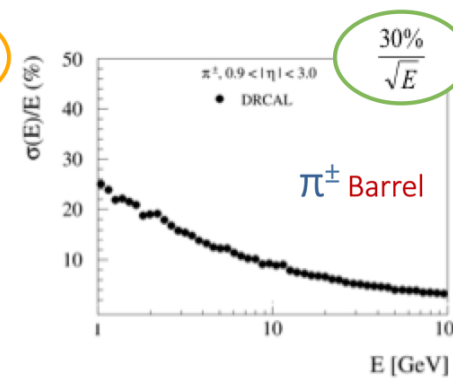
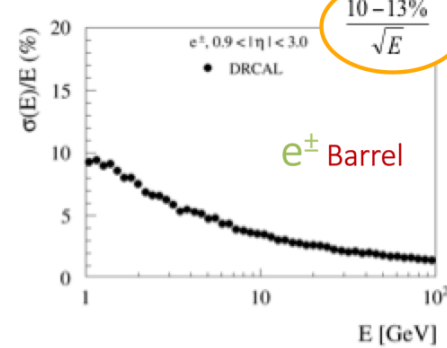
from  
Roberto  
Ferrari

event display

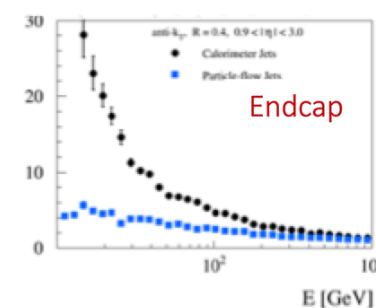
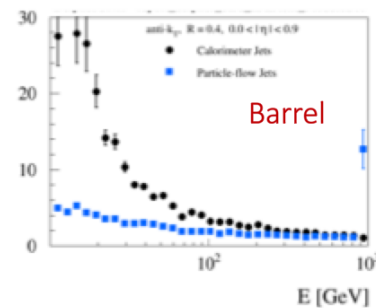


Delphes simulation

Cell size: 6 cm x 6 cm



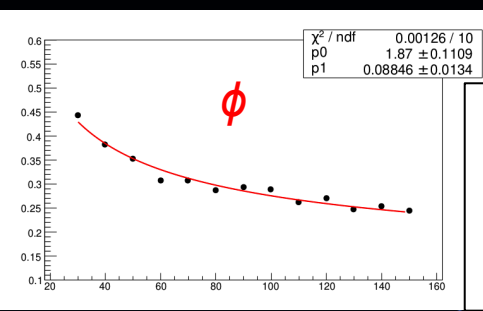
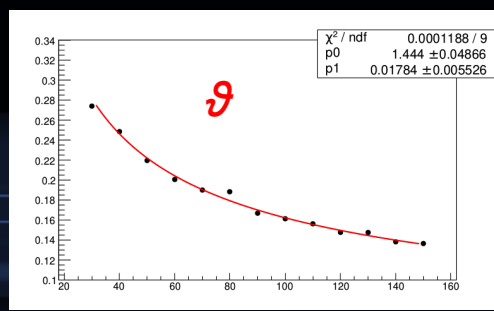
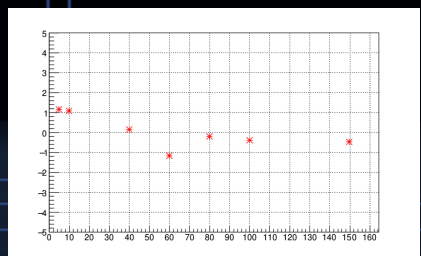
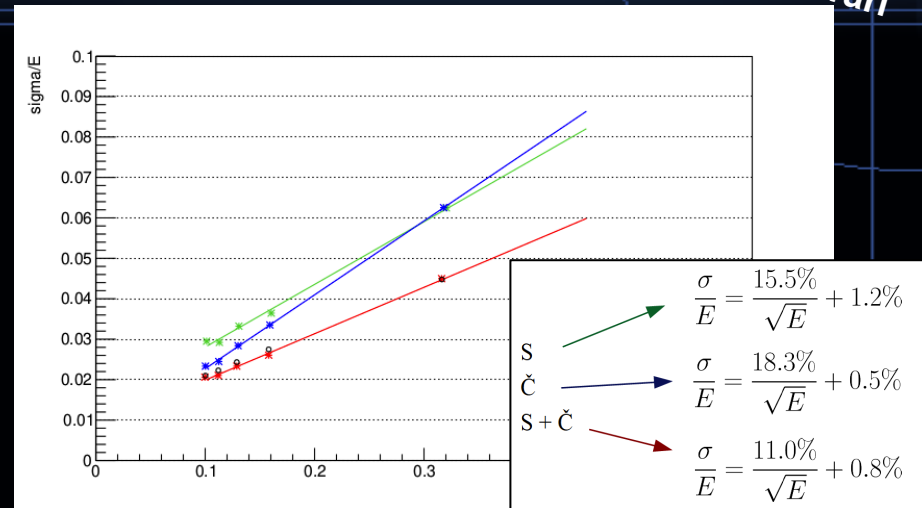
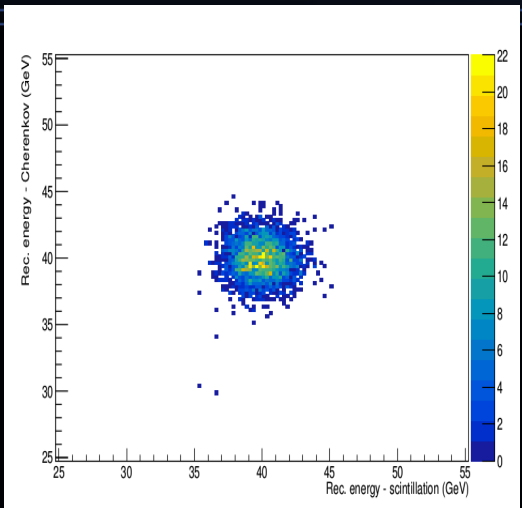
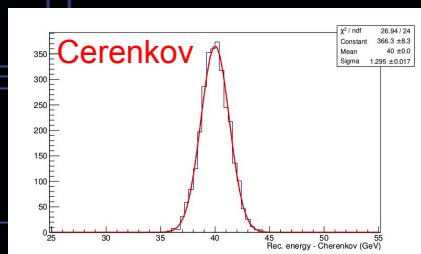
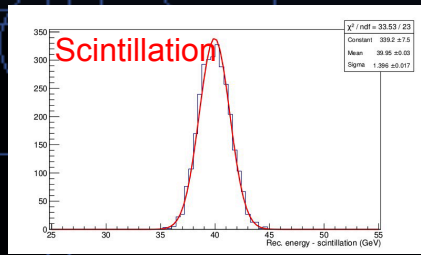
Energy resolution for reconstructed objects (both had and em particles) considering two different regions of pseudorapidity ( $\eta$ ) with particle gun events (electrons and pions)



Jet Energy resolution using PF reconstruction

# DR Calorimeter: resolutions

from  
Roberto  
Ferrari



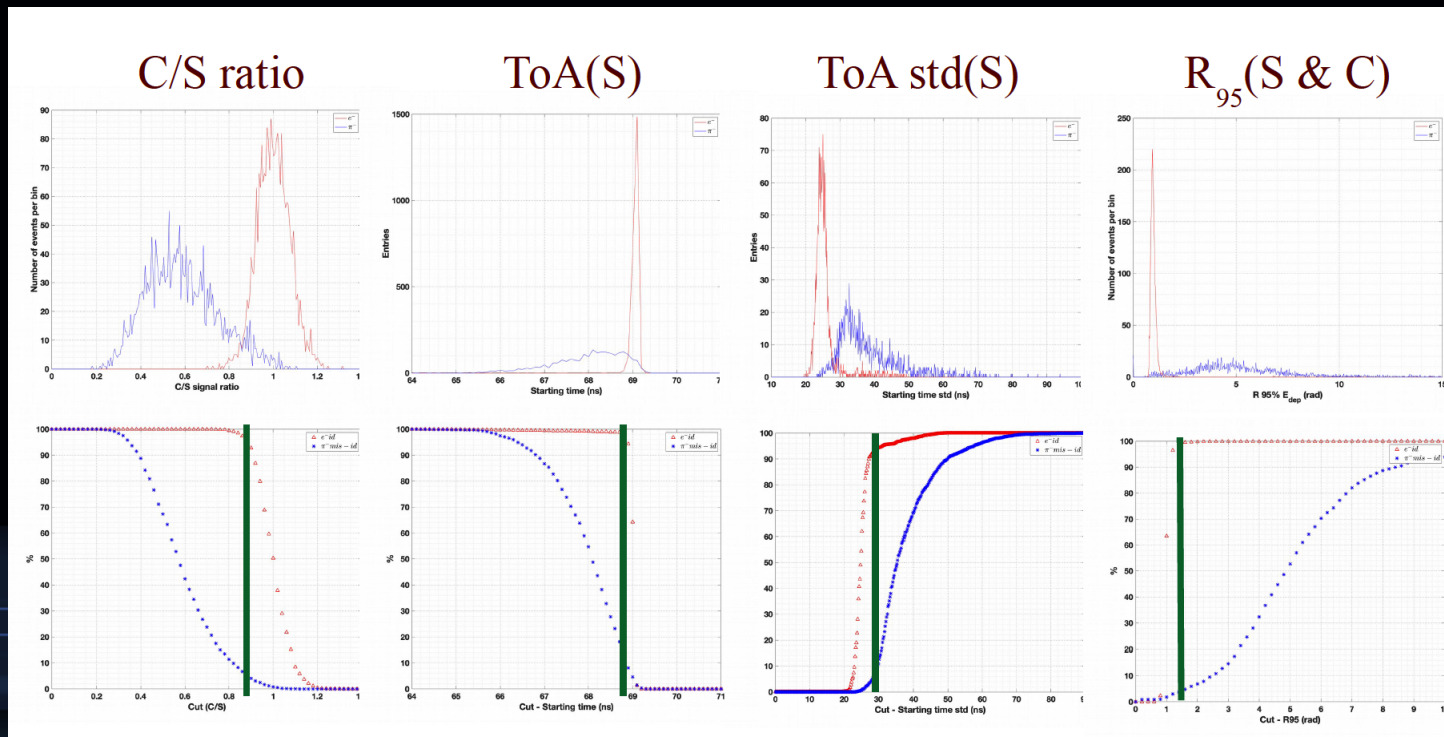
$\sigma_{\theta} = \frac{1.4\%}{\sqrt{E}} + 0.02 \quad (\text{mrad})$   
 $\sigma_{\phi} = \frac{1.8\%}{\sqrt{E}} + 0.09 \quad (\text{mrad})$



# DR Calorimeter: resolutions

from  
Roberto  
Ferrari

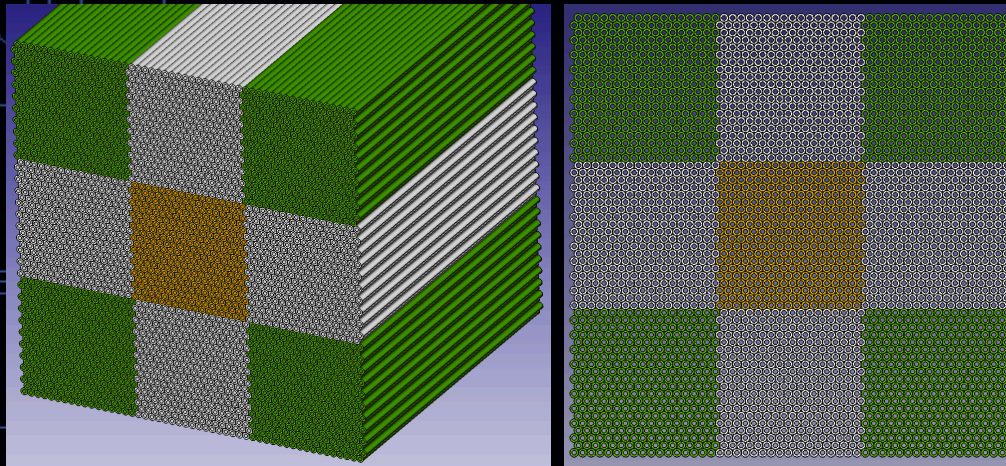
PID for single particles with timing



# DR Calorimeter: tubelets

from  
Roberto  
Ferrari

Zagreb RBI proposal



2.0 mm OD, 1.1 mm ID and 1000 mm Length  
ID tolerance: + 0.1 mm and - 0.0 mm  
Material: CuZn37, 170 VPN Hardness

**RBI Zagreb** : select, test and assembly tubelets study fibre insertion

**INFN Pavia** : study and produce mechanics for fibre gathering and distribution, study fibre insertion

**U. of Sussex** : select and qualify S and Č fibres attenuation length, light yield, numerical aperture

**INFN Milano (Insubria)** : SiPM selection and readout chain

# Muon detector

from  
Paolo  
Giacomelli

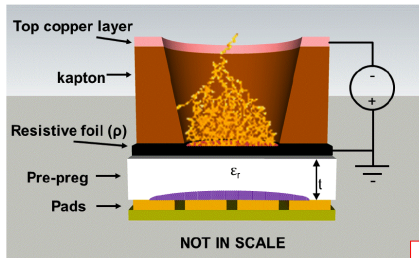
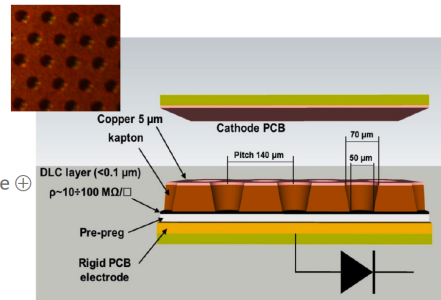


## The $\mu$ -RWELL architecture

The  $\mu$ -RWELL is composed of only two elements:

- $\mu$ -RWELL\_PCB
- drift/cathode PCB defining the gas gap

$\mu$ -RWELL\_PCB = amplification-stage  $\oplus$  resistive stage  $\oplus$  readout PCB



- The "WELL" acts as a multiplication channel for the ionization produced in the gas of the drift gap
- The charge induced on the resistive layer is spread with a time constant,  $\tau \sim \rho \times C$

$$C = \epsilon_0 \times \epsilon_r \times \frac{S}{t} \cong 50 \text{ pF/m (pitch-width 0,4 mm)}$$

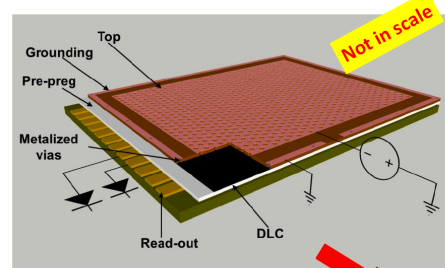
G. Bencivenni e P. Giacomelli, RD\_FA WP7:  $\mu$ -RWELL R&D

3

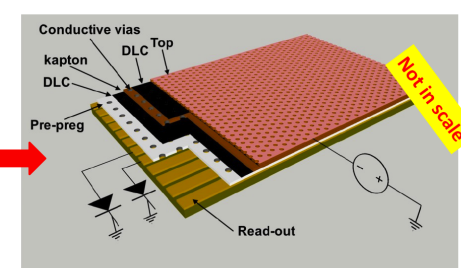


## Detector Layouts

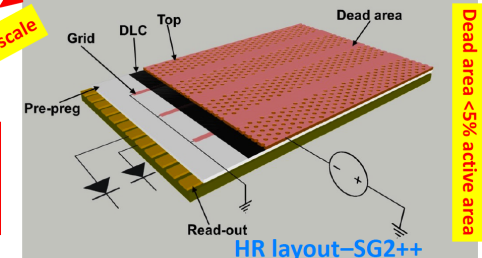
Single resistive layer – LOW RATE



Double resistive layer – HIGH RATE



Not in scale



Detailed description in:  
*The micro-RWELL layouts for high particle rate*, G. Bencivenni et al., 2019\_JINST\_14\_P05014.

HR layout-SG2++

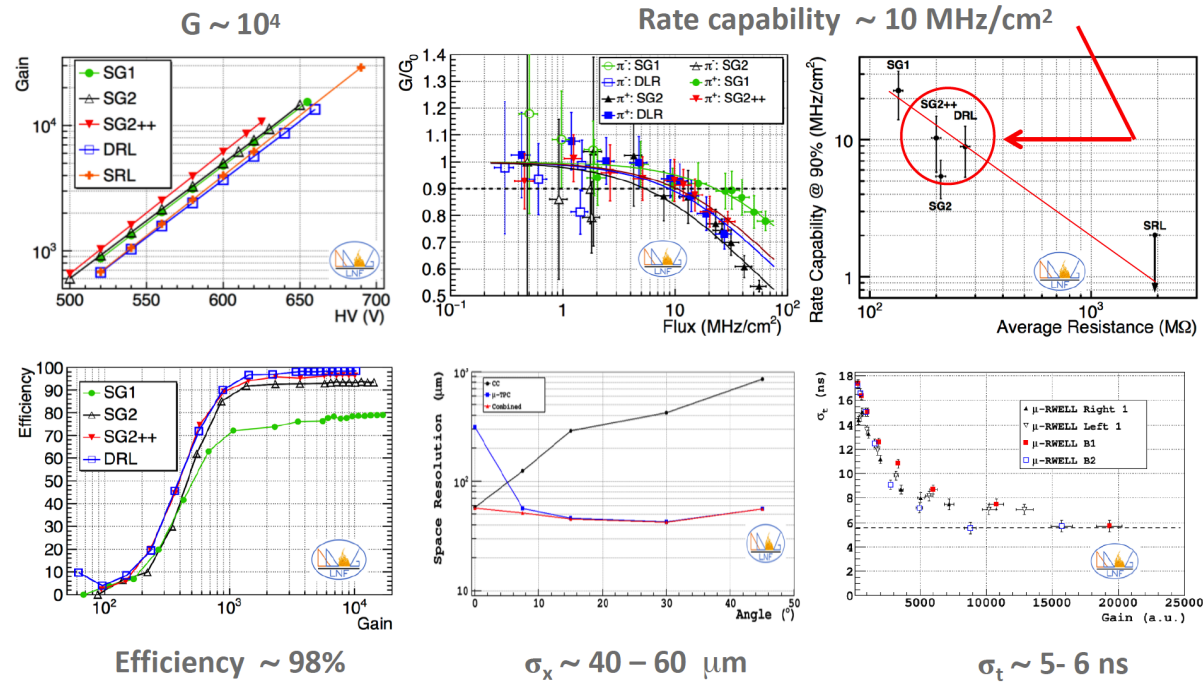
Single resistive layer with dense grid grounding – SIMPLIFIED HIGH RATE

# Muon detector

from  
Paolo  
Giacomelli



## Detector performance

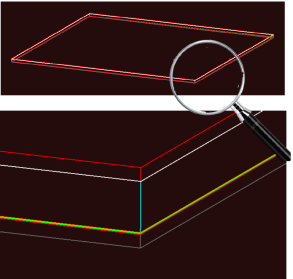


# Preshower detector

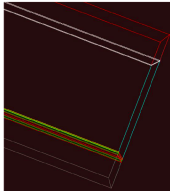
from  
Paolo  
Giacomelli

two options  
for endcap

**INFN** Full simulation of IDEA's Preshower



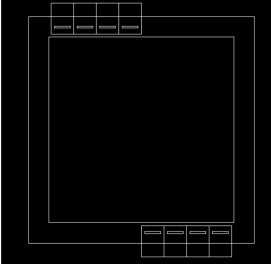
Chamber thickness: 9.4601mm  
 > Cathode thickness: 1.635mm  
 > Driftgap: 6mm  
 >  $\mu$ -RWELL+readout thickness: 1.8251mm  
 The cathode points to the IP



All the materials and dimensions of a HR  $\mu$ -RWELL HR-SG2++ have been considered

**INFN** Full simulation of IDEA's Preshower

First considered chamber size:  
500 mm x 500 mm

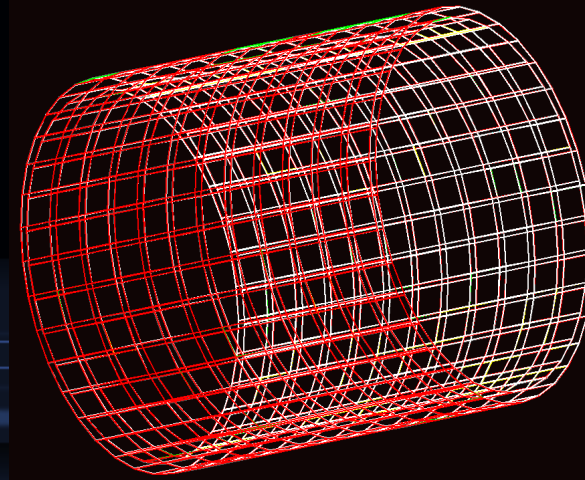
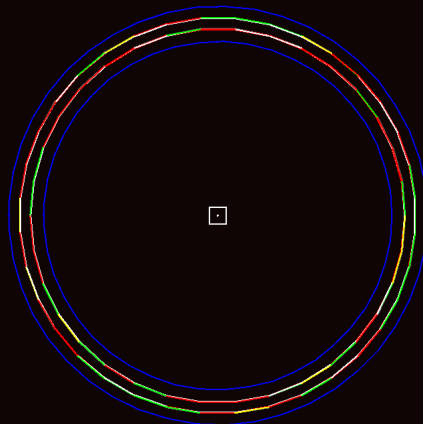
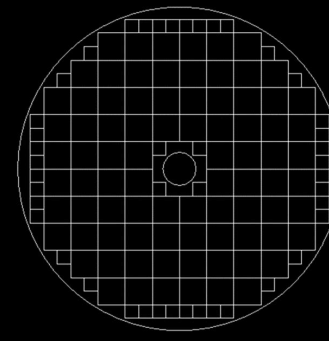
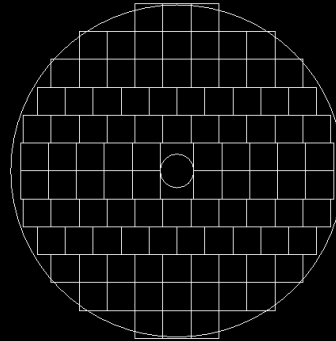


Need to evaluate the realistic ACTIVE AREA of the detector:

- HV cables
- 8 APV25 (128 channels): 50 mm x 68 mm x 1.6 mm
- Panasonic connectors (perpendicular to strips): 35 mm x 4.2 mm x 7mm

ACTIVE AREA = 410 mm x 410 mm  
 Pitch: 400  $\mu$ m  $\Rightarrow$  1025 strip  
 (they will be reduced to 1024, so that they can be read by 8 APV25 (128 channels))

Description of a  $\mu$ -RWELL (HR layout-SG2++) detector implemented



# IDEA EoI's

## ➤ Dual readout calorimeter

- **Detector design and construction (Pi, Pv, Mi, Sussex, Korea, USA, Zagreb)**
  - Choice of materials (absorber and fibres)
  - Production of the elements
  - Assembly, Quality control
- **Light sensors and Readout (Pv, Mi, Sussex, USA)**
  - SiPM, ASIC, FPGA, signal processing and feature extraction

## ➤ Drift Chamber

- **Cluster Counting/Timing (Le, Ba, BINP)**
  - Data reduction and pre-processing of drift chamber signals sampled at high rates
- **A prototype of an ultra-light drift chamber (Le, Ba, BINP)**
  - With new materials for the next generation of lepton colliders

# IDEA EoI's

## ➤ Preshower and Muon detector

- Innovative ML-based algorithms for tracking in MPGDs (Bo, Fe, LNF)
  - Improve particle tracking (for any incident angle) in modern MPGDs ( $\mu$ RWELL, GEM, MicroMegas, etc.)
- Industrial engineering of high-rate  $\mu$ RWELL detectors with bi-dimensional readout (Bo, Fe, LNF, CERN, Eltos)
- Development and characterisation of integrated electronics for the readout of pixellated  $\mu$ RWELL detectors (Bo, Fe, To, LNF)

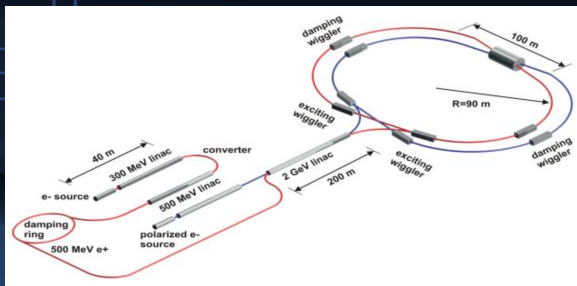
## ➤ Vertex detector

- Sensor development, ARCADIA-based solution (To, Mi, Tn, Pd, Pv, Bo, Pg)
- Senior development HV-CMOS (Mi, Pv, Pi, Bonn, Strasbourg)
- Optimisation of detector mechanics and cooling (Mi, To, Pd, Tn)

# An ultra-low mass Tracking Chamber with Particle Identification capabilities for SCTF at BINP

presented at "Joint Workshop on future tau-charm factory" LAL, Orsay, Dec. 2018

## CREMLIN+ Proposal



F. Grancagnolo  
INFN – Lecce



Istituto Nazionale di Fisica Nucleare

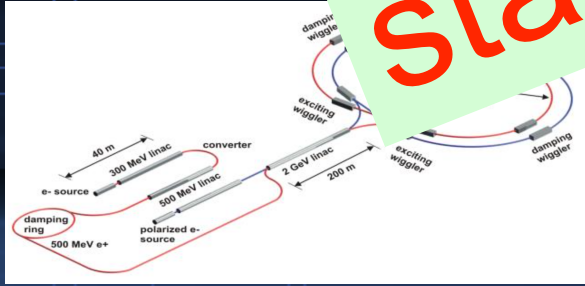


# An ultra-low mass Tracking Chamber with Particle Identification

Approved  
starts Feb. 1, 2020

presented at "Jet Physics and Heavy Ion Physics", Orsay, Dec. 2018

## Proposal



F. Grancagnolo  
INFN – Lecce

