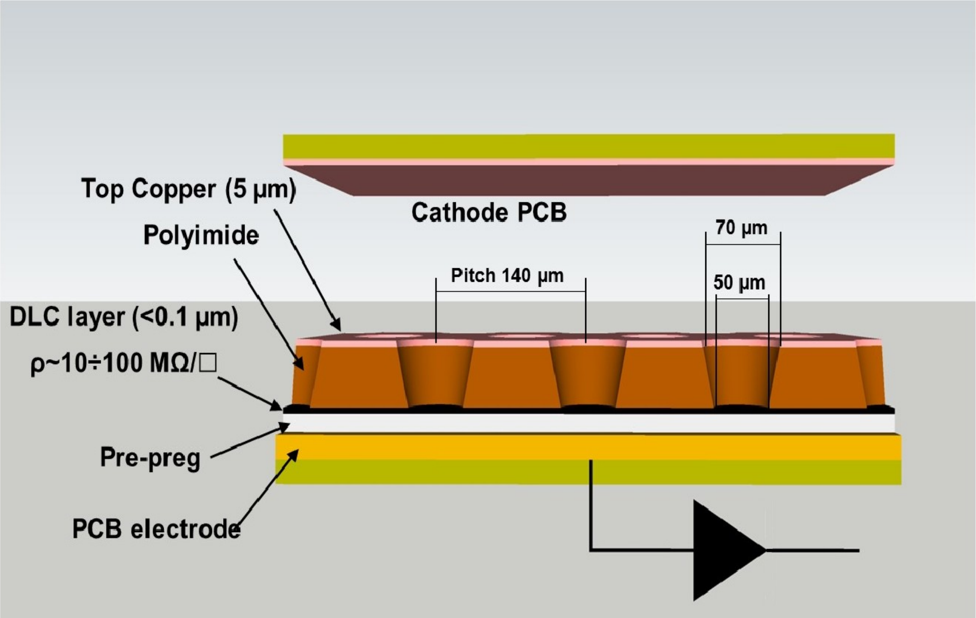
The μ-RWELL technology: overview

G. Bencivenni[1], G. Cibinetto[2], G. Felici[1], P. Giacomelli[3], G. Morello[1], M. Poli Lener[1]

1. Laboratori Nazionali di Frascati dell'INFN
2. INFN - Ferrara
3. INFN - Bologna

The μ-RWELL in a nutshell



The micro-Resistive WELL (μ-RWELL) belongs to the **Micro-Pattern Gaseous Detectors class**.

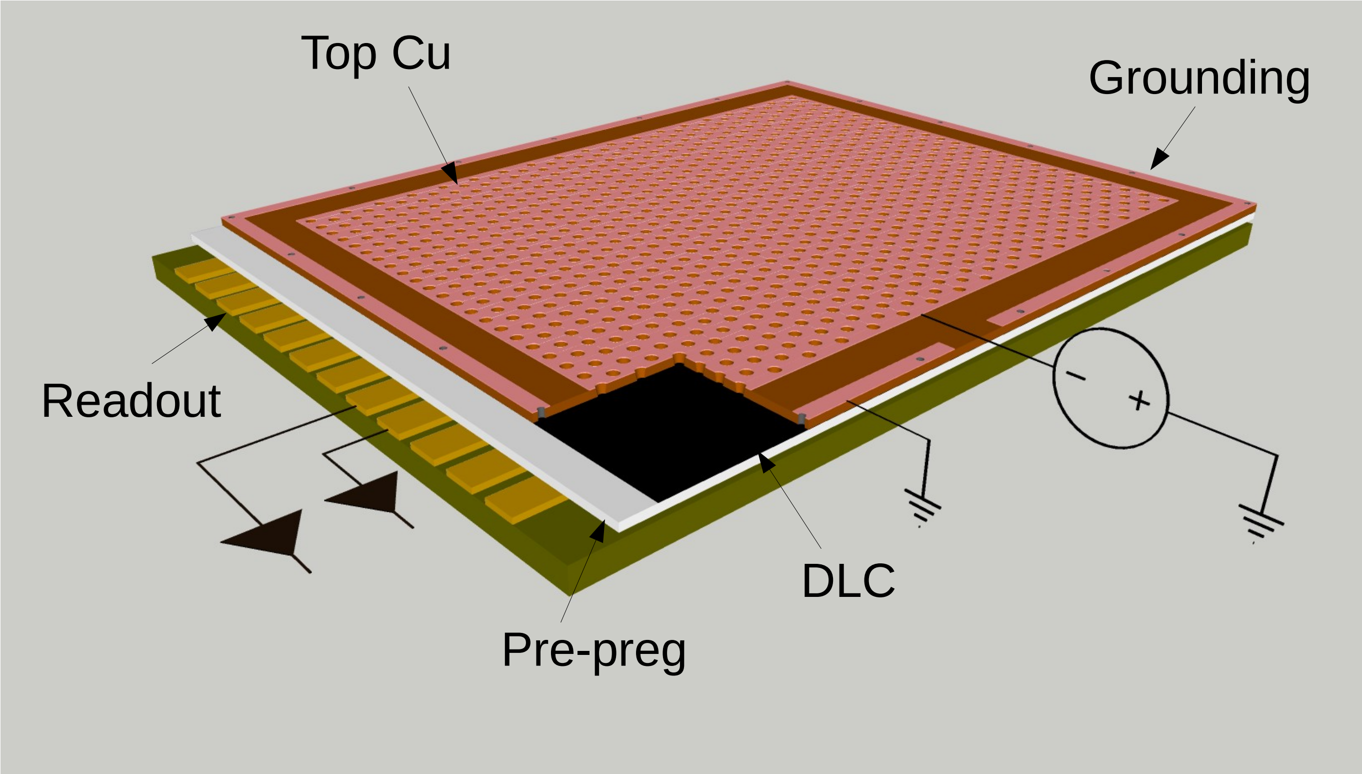
It merges the amplification stage from GEM technology with the resisitive stage (Diamond-Like Carbon) from Micro-Megas.

The result is a detector with a **single amplification stage** and an **intrinsic spark protection**

As the charge, produced in the avalanche, spreads out flowing through the resistive layer towards the ground with a given time constant, the rate capability of the detector requires dedicated studies.

From these tests **different charge evacuation schemes** have been implemented.

Low rate version

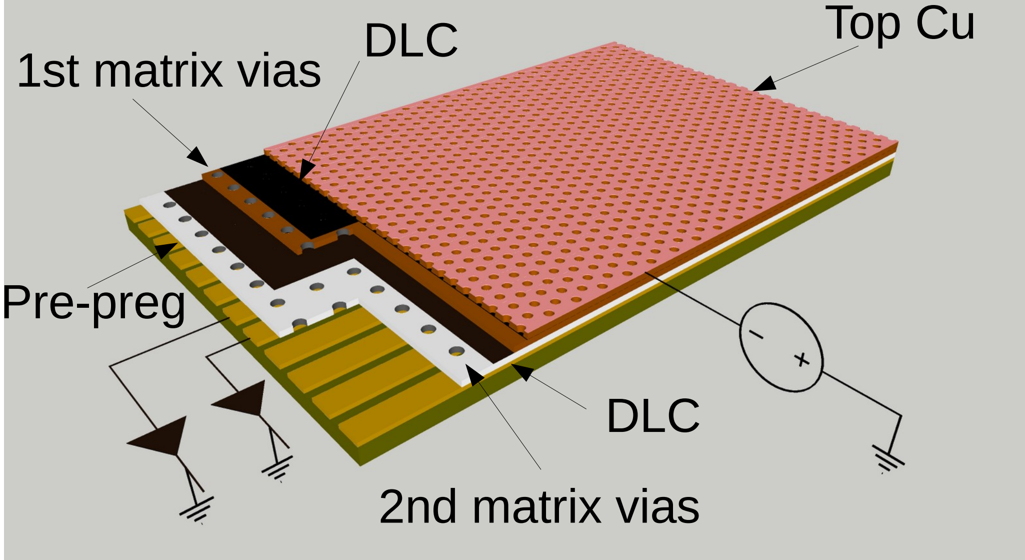


Single Resistive Layer (SRL)

- **2-D current** evacuation scheme based on a single resistive layer
- grounding all around the active area
- **limitation for large area:** the path of the current towards ground connection depends on the particle incidence point **detector response inhomogeneity, limited rate capability – O(10 kHz/cm²)**

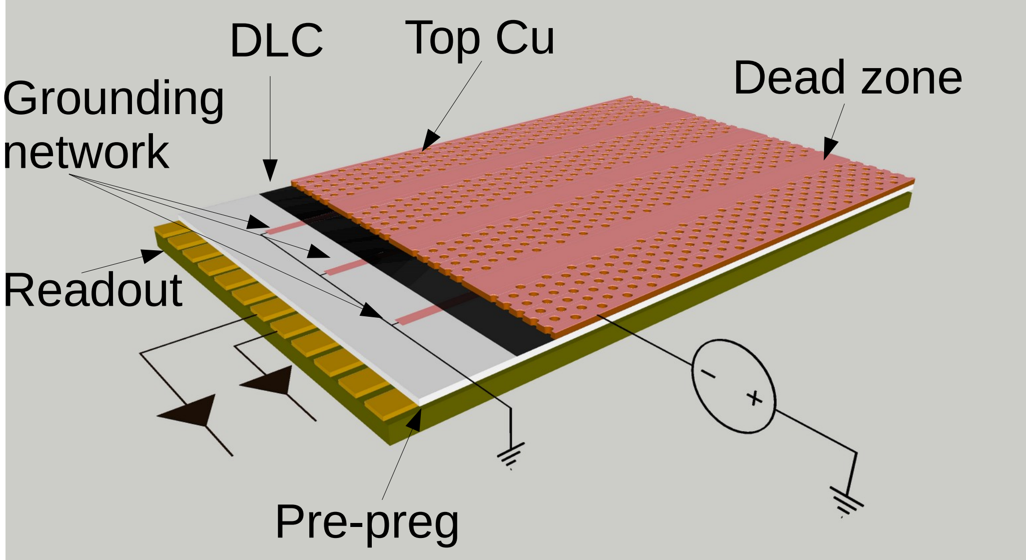
High rate versions

Main purpose of these versions is to reduce the distance to be travelled by the charge towards the ground.



Double-resistive layer (DRL)

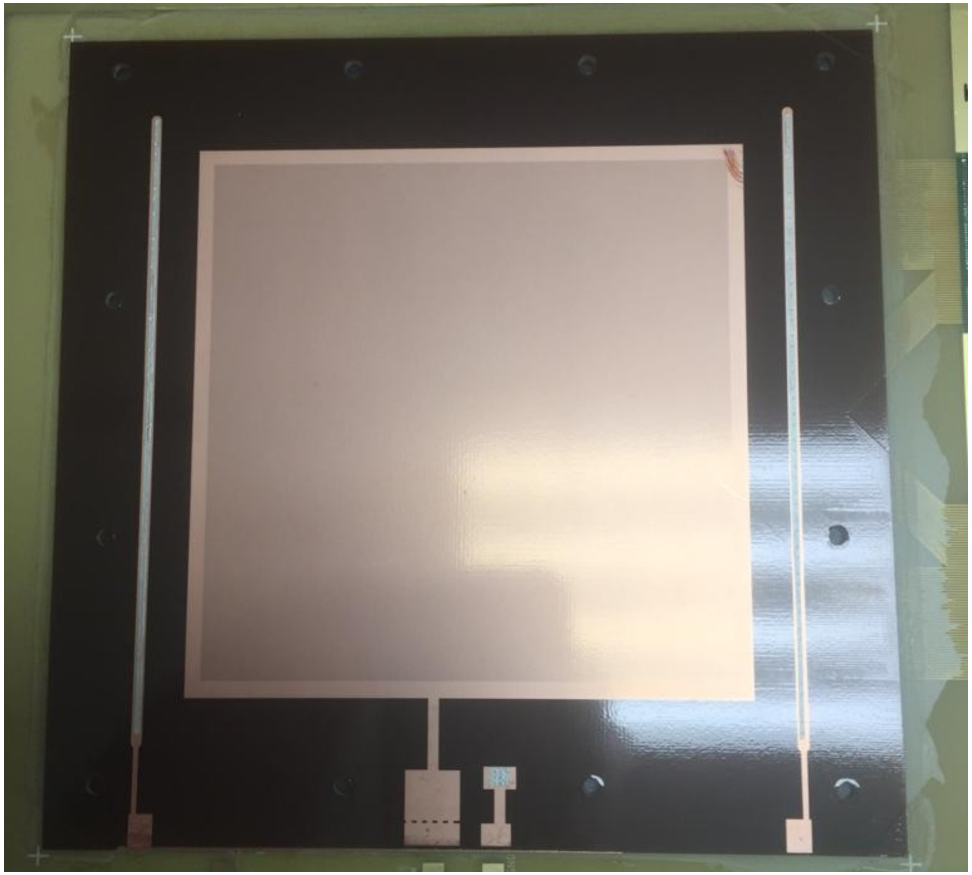
- **3D** charge evacuation scheme
- Two conductive vias matrices (density ~1/cm^2)
- **Grounding through the FEE**
- **Difficult** to be implemented in industrial production



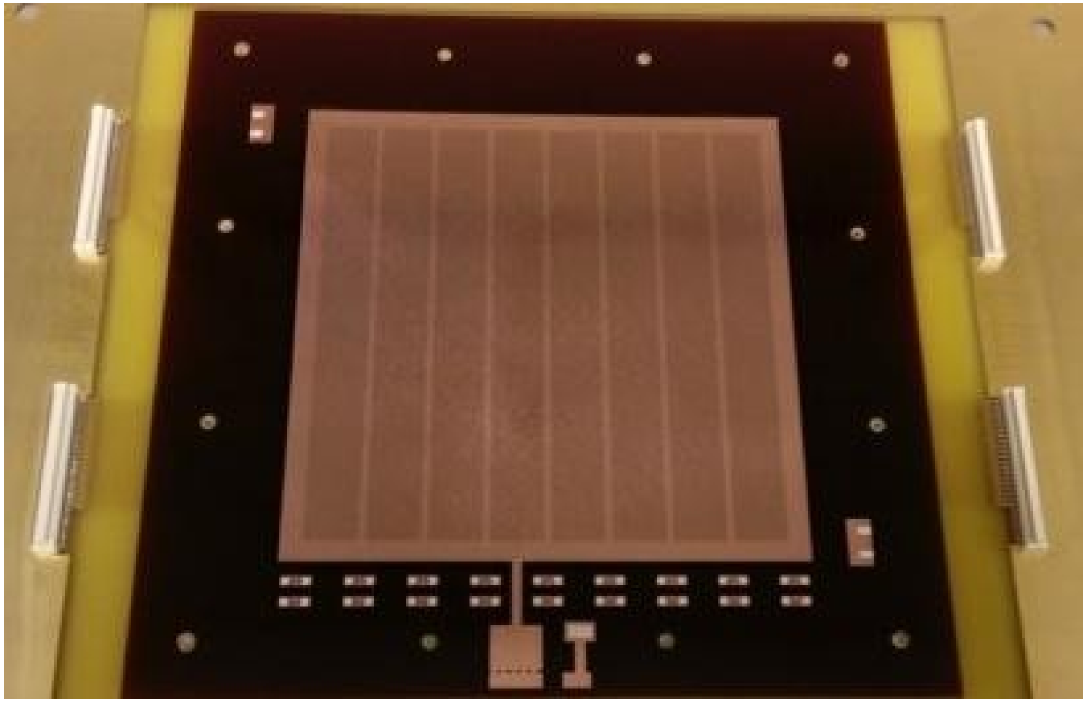
Silver Grid (SG)

- **2D** charge evacuation scheme
- One resistive layer only
- **Grounding through copper lines (screen-printing or photo-litography, pitch ~1/cm)**
- Dead zone above the grounding lines
- **Much easier** to be implemented in industrial production

The µ-RWELL in a nutshell



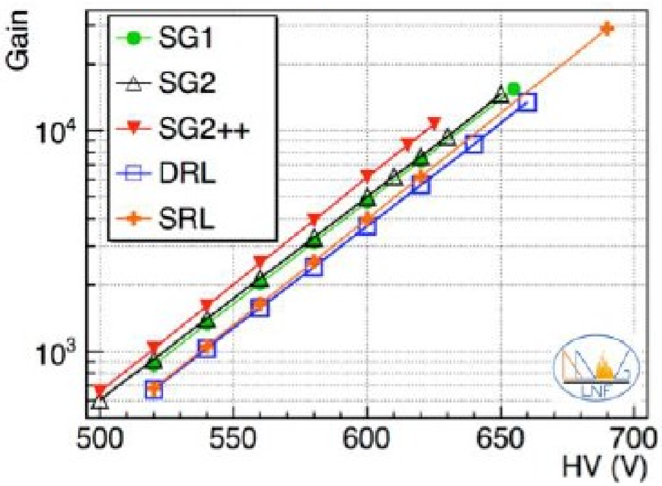
Low rate version with lateral system to measure the surface resistivity



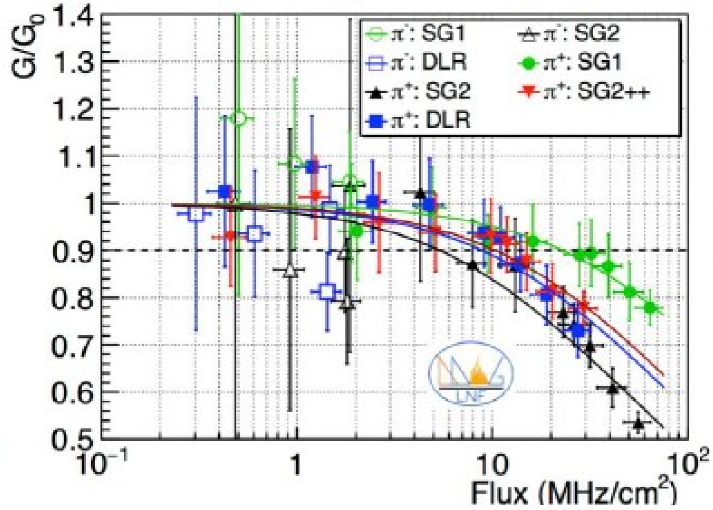
Most recent version of the Silver Grid (pitch 12 mm, ~0.47”)

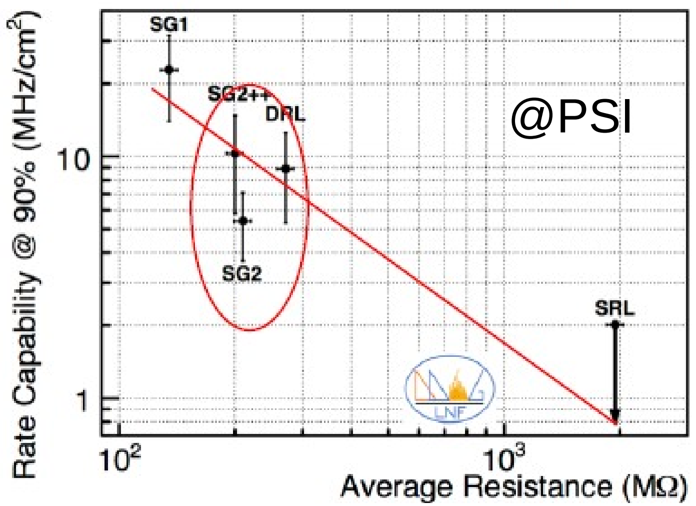
Measurements: hall of fame

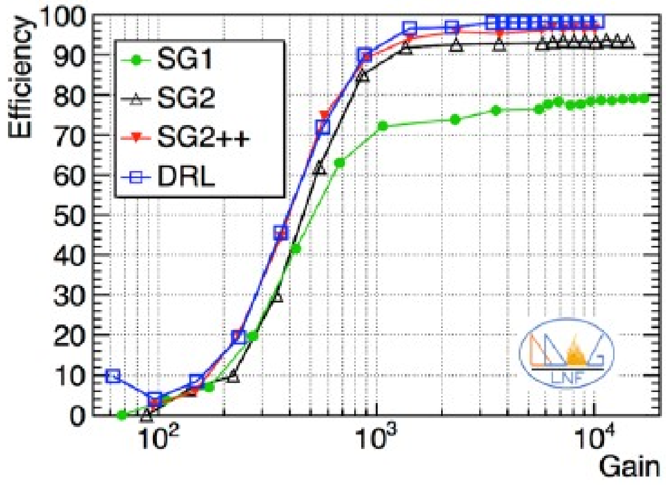
Gain up to ~ 10^4



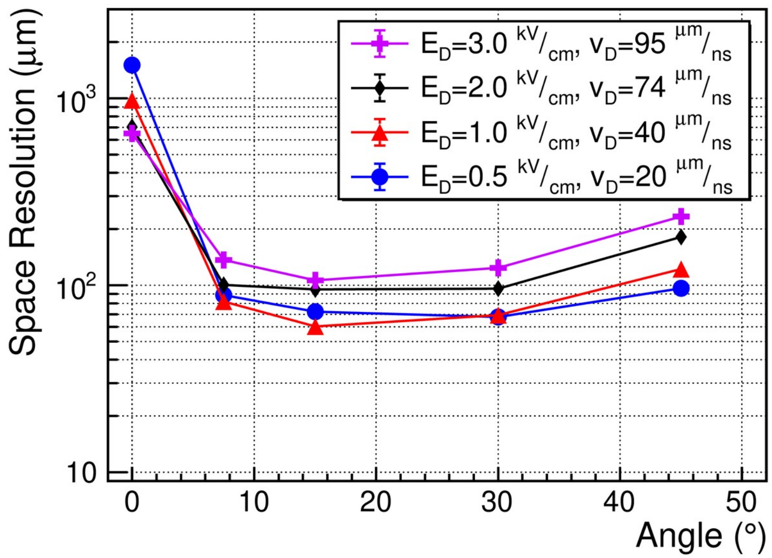
Rate capability (@ G = 5000) ~ 5-10 MHz/cm^2





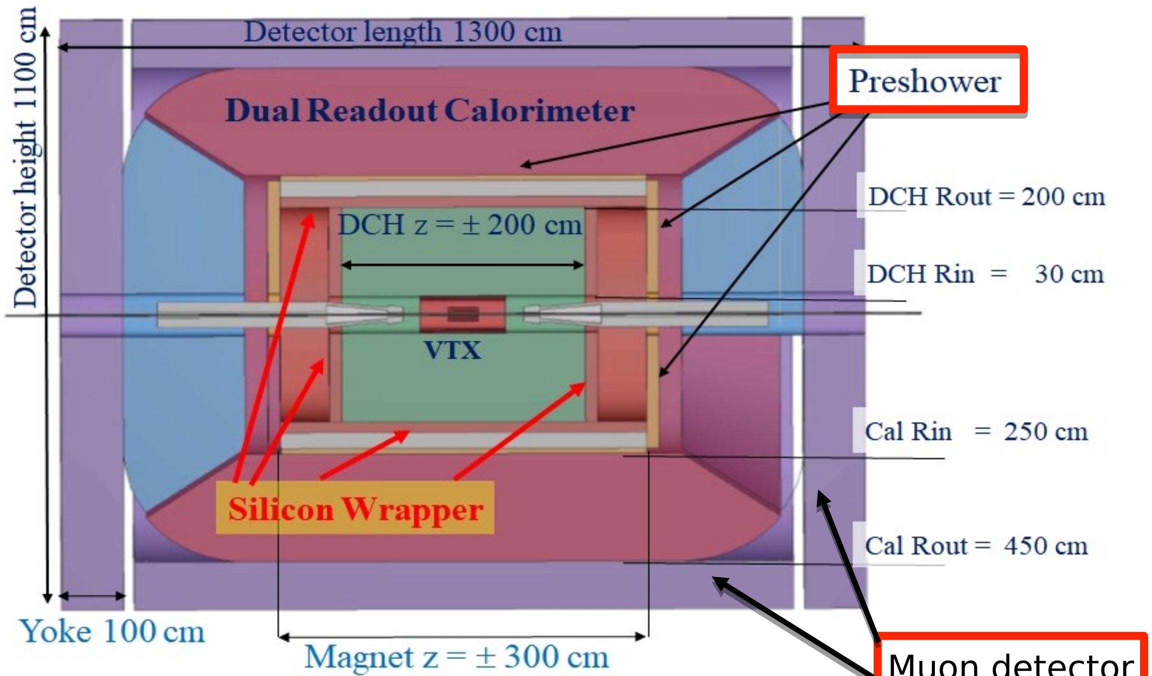


Efficiency ~ 98%

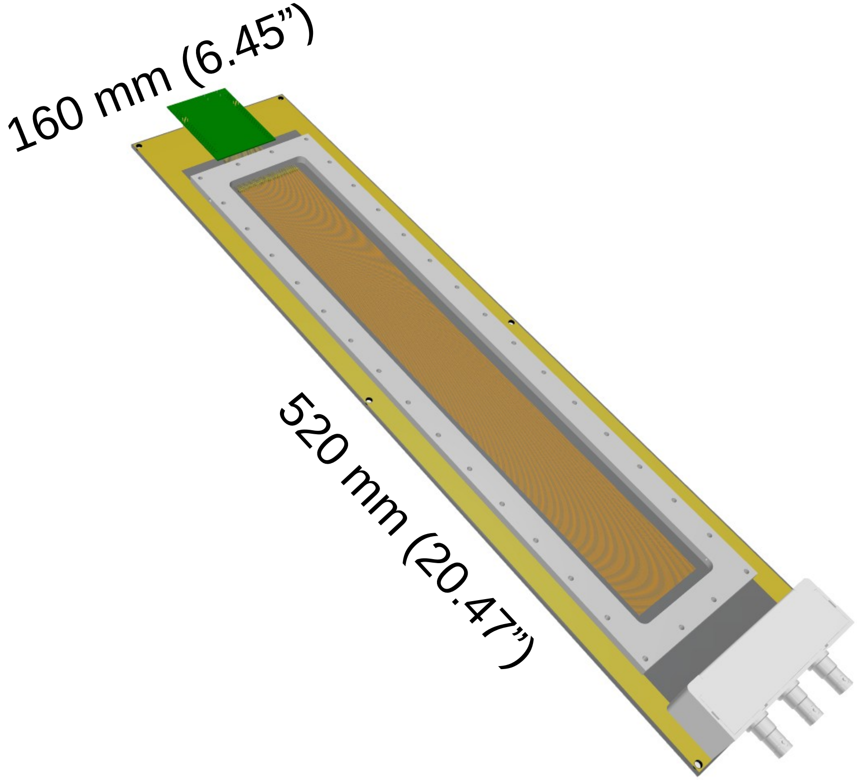


Space resolution < 100 µm with the µ-TPC reconstruction algorithm

Low-rate applications: IDEA apparatus @ FCC-ee/CepC



Test beam planned in October at H8-CERN North Area for cluster size vs resistivity studies with scaled prototypes



Expected rate: 10 kHz/cm^2

Low-rate applications: IDEA apparatus @ FCC-ee/CepC

Pre-shower

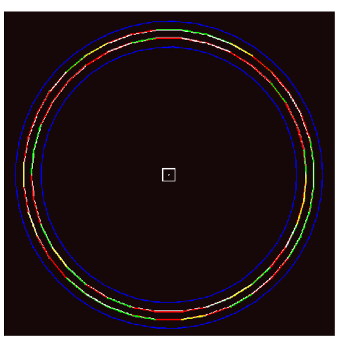
Barrel

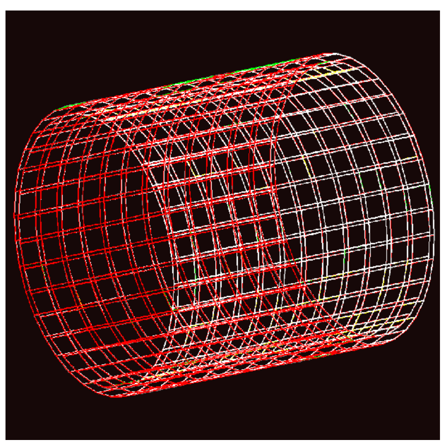
R [mm]	Length [mm]	Thickness [mm]	pixel size [mm]	area [cm^2]	# of channels
2460	±2480	20	0.4×500	768K	384K

Endcap

R_{in} [mm]	R_{out} [mm]	z [mm]	Thickness [mm]	pixel size [mm]	area [cm^2]	# of channels
248	2440	±2460	20	0.4×500	370K	185K

Tiles: 50x50 cm^2 with X-Y readout
Strip Length: 50 cm
Strip pitch: 0.4 mm



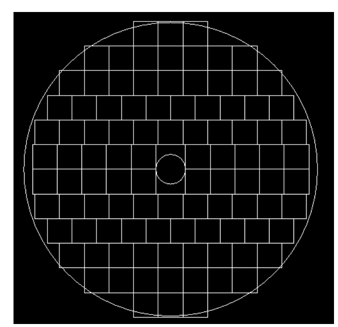


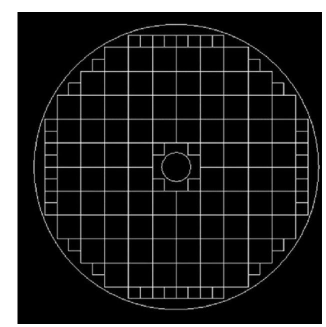
Muon

Layer	R [mm]	Length [mm]	Thickness [mm]	int. length	pixel size [mm]	area [cm^2]	# of channels
µRwell	4520	±4500	20		1.5×500	2.6M	341K
iron	4560	±4500	300	1.5			
µRwell	4880	±4500	20		1.5×500	2.8M	368K
iron	4920	±4500	300	1.5			
µRwell	5240	±5260	20		1.5×500	3.5M	462K

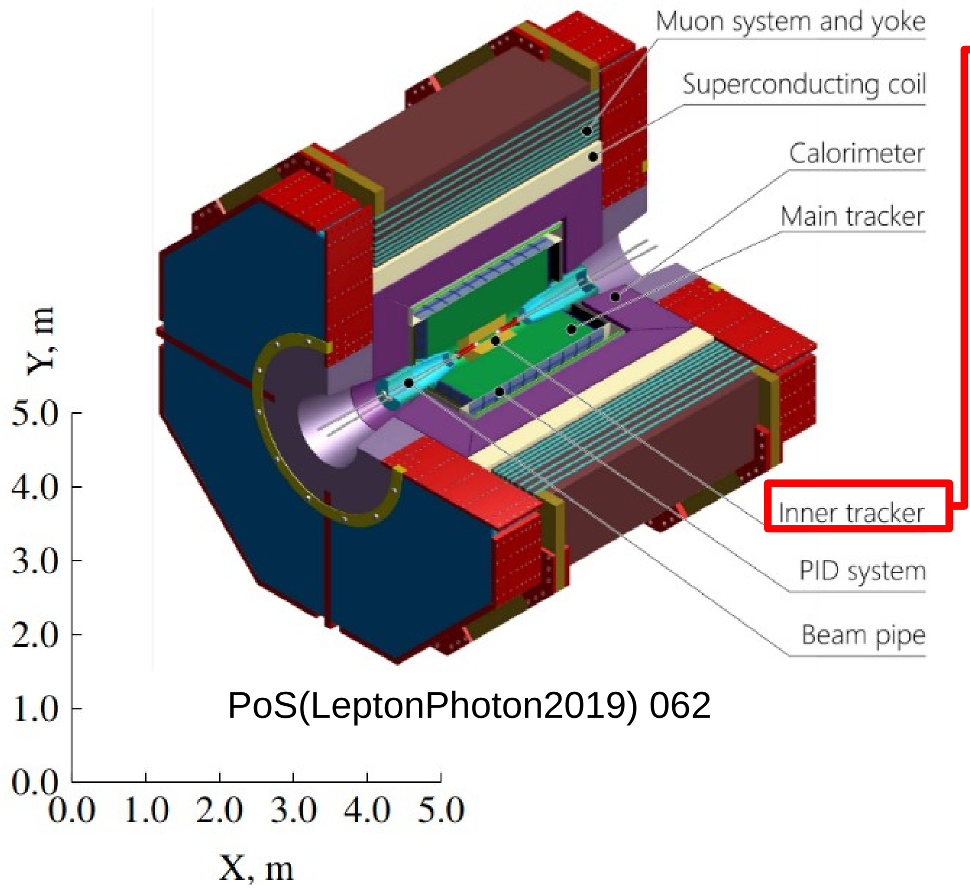
Disk	R_{in} [mm]	R_{out} [mm]	z [mm]	Thickness [mm]	int. length	pixel size [mm]	area [cm^2]	# of channels
µRwell	454	5220	±4520	20		1.5×500	1.7M	227K
iron	454	5220	±4560	300	1.5			
µRwell	454	5220	±4880	20		1.5×500	1.7M	227K
iron	454	5220	±4920	300	1.5			
µRwell	454	5220	±5240	20		1.5×500	1.7M	227K

Tiles: 50x50 cm^2 with X-Y readout
Strip Length: 50 cm
Strip pitch: 1.5 mm





Low-rate applications: apparatus for SCT (BINP, RUS), CREMLIN PLUS joint RUS-ITA project



PoS(LeptonPhoton2019) 062

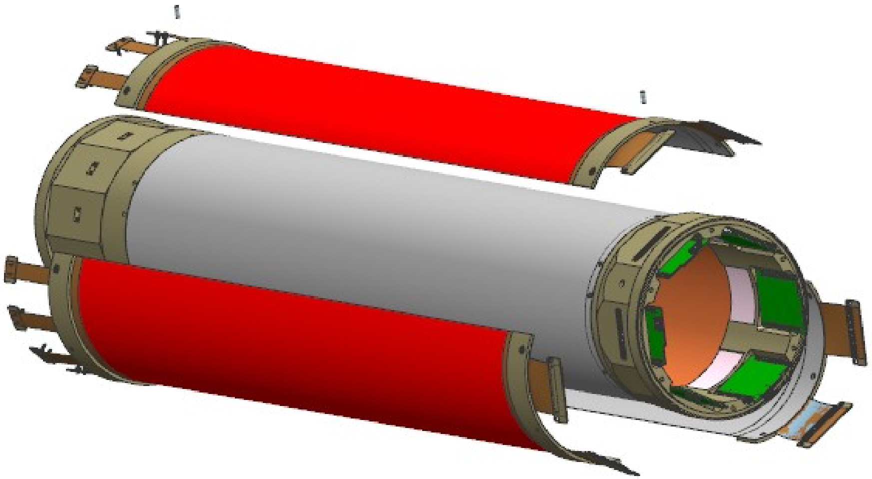
Competition ongoing between two technologies: TPC and μ-RWELL

The core of the project is to exploit the flexibility of the substrate (®kapton) to produce roof tiles.

The detector will be composed of two or four coaxial cylindrical μ-RWELL. Each μ-RWELL will be composed of three removable roof tiles, in order to substitute one in case of problems

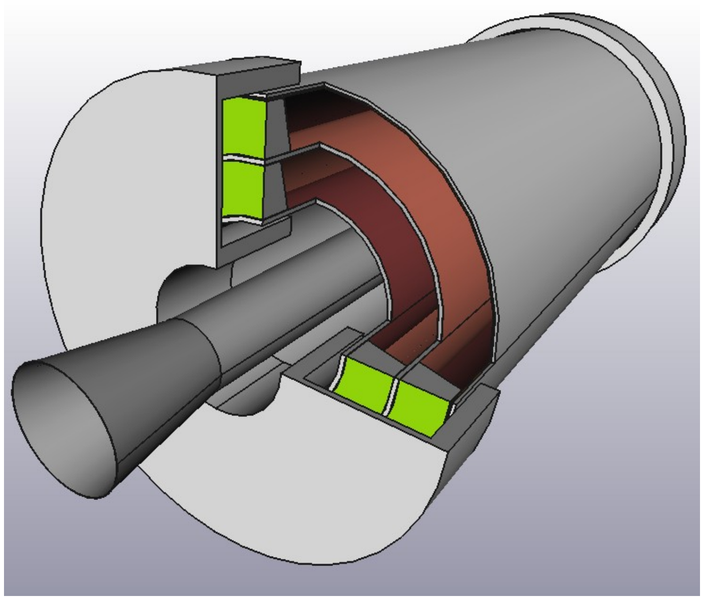
Dimensions of the inner tracker: 1011 mm x 210 mm

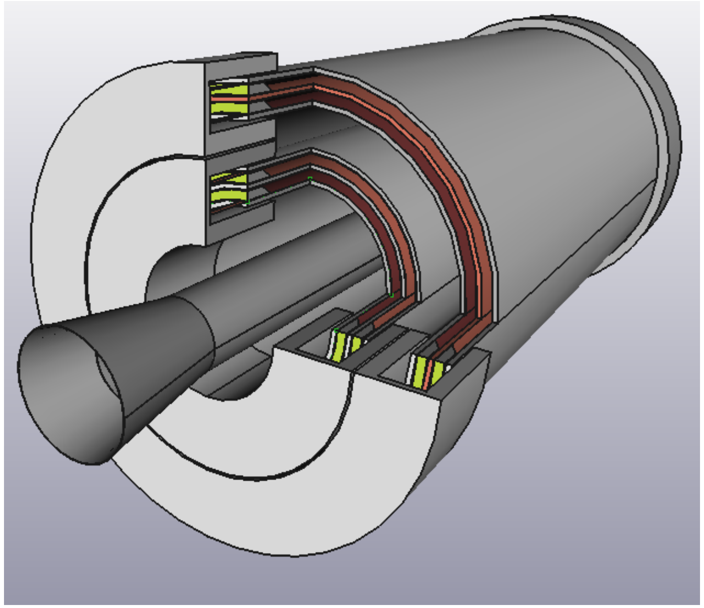
Expected rate: 50 kHz/cm^2



Low-rate applications: apparatus for SCT (BINP, RUS), CREMLIN PLUS joint RUS-ITA project

Two ideas on the table:





- N.1 large gap back-to-back layers **0.86 - 0.96% X_0**
- 2 x 1 cm thick gas gap/B2B device
- 10 cm global sampling gas, readout in μ-TPC mode

- N.2 small gap back-to-back layers **1.72 - 1.92% X_0**
- 2 x 1 cm gas gap/B2B device
- 4 cm global sampling gas, readout in μ-TPC mode

Low-rate applications: neutron detection, ATTRACT-URANIA EU project

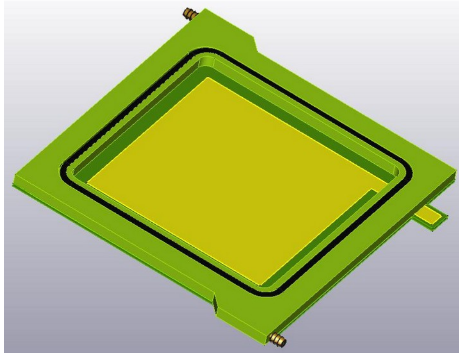
Beyond high energy physics, particle detectors find room for social life application (ex. homeland security).

In particular neutron detection is:

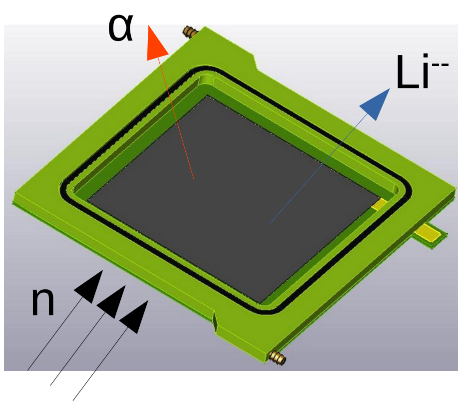
- Basic to fight against radioactive material smuggling
- Strictly necessary for radioactive waste monitoring
- Complementary to X-ray materials radiography

These activities needs detectors *simple* to be scaled up to large areas (low rate, ~1m^2), *flexible* to be adapted to different geometries (cylindrical) and using a *converter* not interfering with the readout (es. $^{10}B_4C$ converter, strip- or pad-segmented readout)

μ-RWELL cathode



+ $^{10}B_4C$ sputtering =



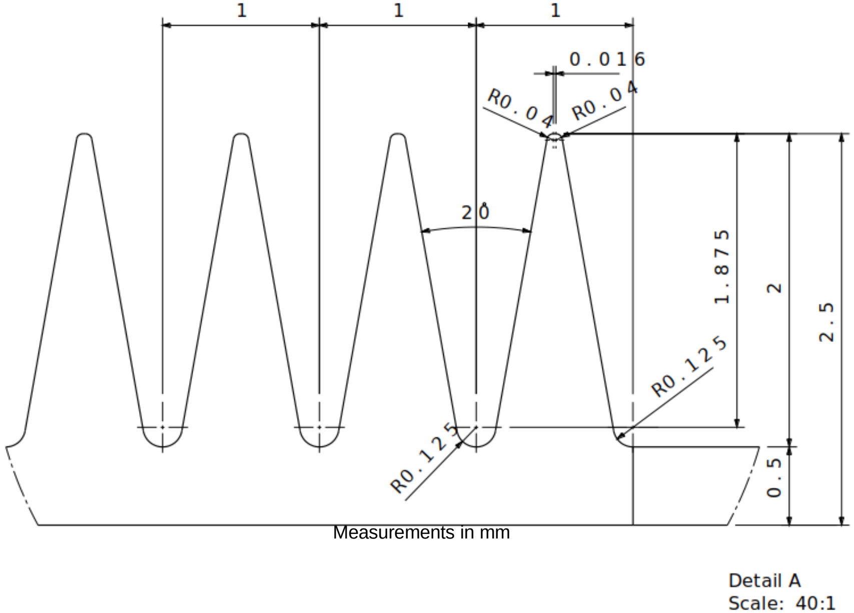
From the reactions:

$$n+{}^{10}B \rightarrow {}^{7}Li^{*}(0.84\text{ MeV}) + \alpha(1.47\text{ MeV}) + \gamma(0.48\text{ MeV}) \qquad 93\%,\ Q=2.3\text{ MeV}$$
$$n+{}^{10}B \rightarrow {}^{7}Li(1.16\text{ MeV}) + \alpha(1.78\text{ MeV}) \qquad 7\%,\ Q=2.79\text{ MeV}$$

at least one slow charged particle is released inside the gas with a huge amount of primary ionization electrons.

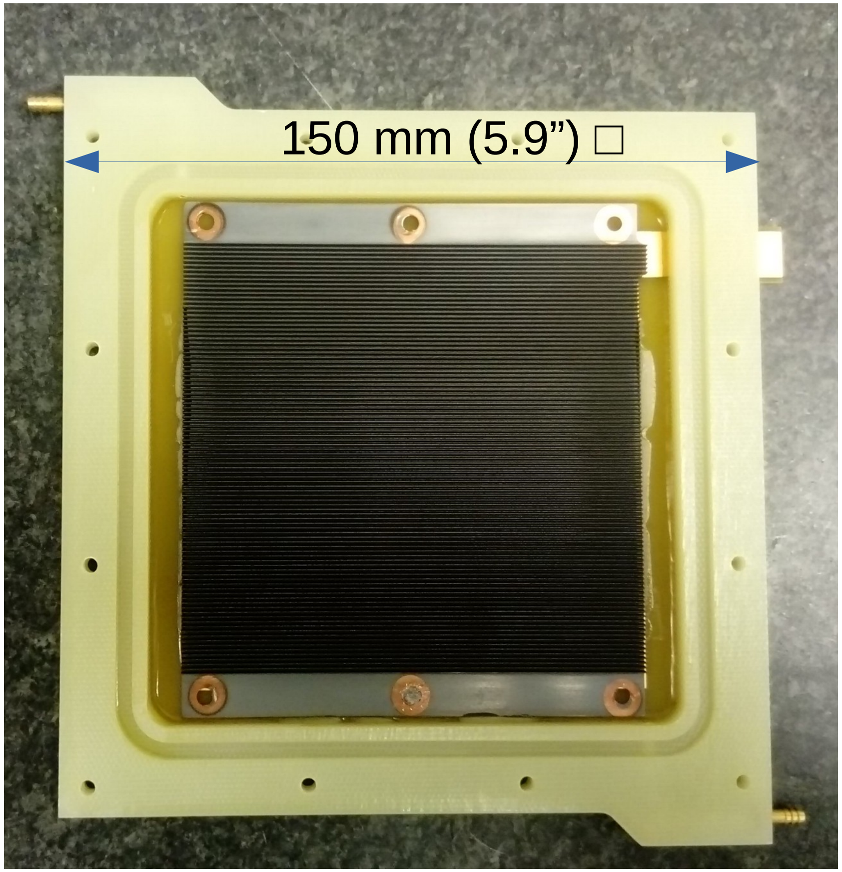
Low-rate applications: neutron detection, ATTRACT-URANIA EU project

GEANT4 simulations indicate a conversion efficiency of ~2% for planar cathodes.
The neutron conversion efficiency DOES NOT depend on the amplification stage; it can be improved introducing different geometries of the cathode



Test at HOTNESS-ENEA Frascati (RM) planned in May at 241Am-Be source (750 Hz/cm^2 neutron flux estimated)

Simulations with GEANT4 suggested a neutron conversion efficiency up to 5.6% (emission of α or Li in the detector active volume)



High-rate applications: LHCb @ HL-LHC

The muon stations of LHCb are subject to very different rates. For their upgrade we plan to involve both layouts.

Max particle flux (single GAP) for U2 (@ L= **$2x10^{34}$** $cm^{-2}s^{-1}$) is obtained by scaling x10 the particle flux during phase-1, and considering the attenuation factor due to the Iron shielding in front of M1

(*)	kHz/ cm^2		kHz/ cm^2		kHz/ cm^2		kHz/ cm^2
M2R1	998	M3R1	575	M4R1	211	M5R1	179
M2R2	97	M3R2	72	M4R2	30	M5R2	20
M2R3	13	M3R3	8	M4R3	5	M5R3	4
M2R4	10	M3R4	3	M4R5	2	M5R4	2

(*) average rates are approximately 1/2 max values

HR RWELL – 600 detectors

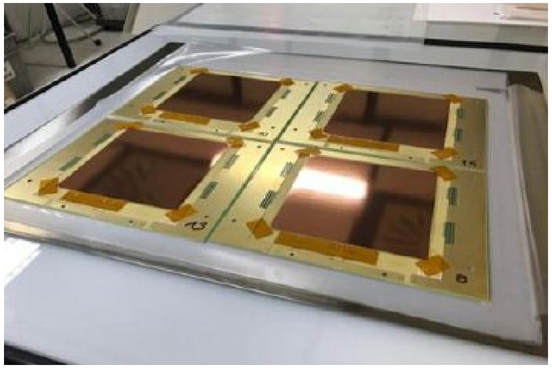
Technology transfer

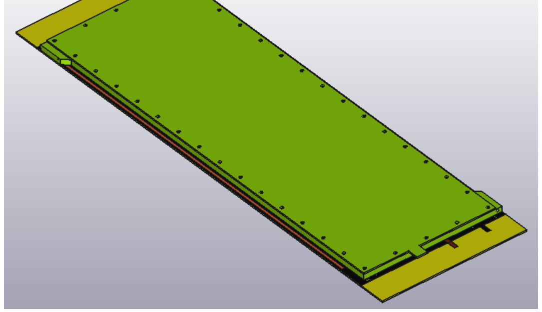
We established through the years a strong collaboration with **ELTOS SpA**, a company producing PCB

Several small size prototypes realized by this company.

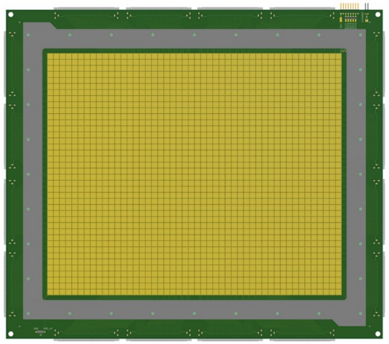
For the phase-2 upgrade of the CMS muon stations we proposed the u-RWELL technology.
The R&D lead us to the construction of 0.5x0.5 m^2 flat tiles to be spliced together to cover ~2 m^2 area

Nowadays the collaboration looks at the construction of the PCB for IDEA and LHCb



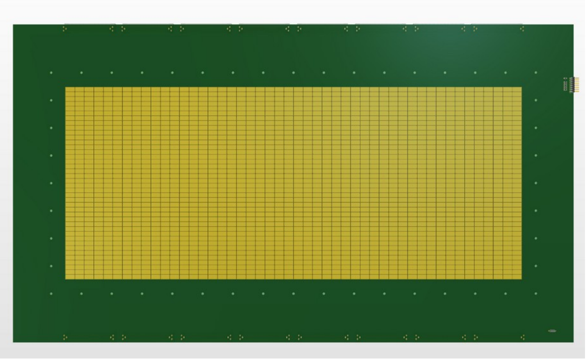


IDEA



LHCb M2R1

LHCb M2R2



Conclusions

- The u-RWELL technology is quite promising for many applications in high energy physics and beyond
- The simplicity and modularity of the detector makes it suitable to cover large areas
- The flexibility of the substrate of the amplification stage can be exploited to build cylindrical detectors
- No matter how the readout is segmented, the detector becomes sensitive to neutrons with a properly sputtered cathode
- The technology is considered in many in different projects
- The collaboration with industry is well established: soon they will produce medium size detectors (0.5 x 0.5 m^2)

PRESENT PLANS
Development of further high rate versions with an easier manufacturing technique