

DE LA RECHERCHE À L'INDUSTRIE



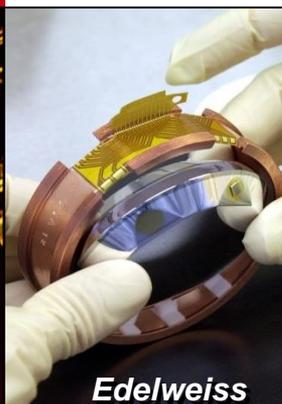
KiCad, a powerful EDA software for MPGD detectors



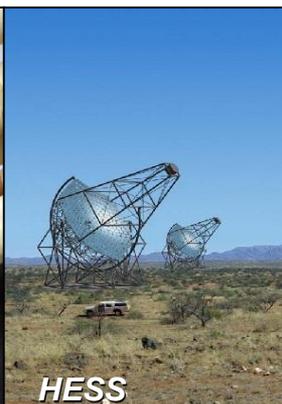
Double Chooz



ALICE



Edelweiss



HESS



Herschel



CMS

Déchiffrer les rayons de l'Univers



Aude GRABAS & Valmir DO NASCIMENTO JÚNIOR

Aude.grabas@cea.fr

Valmir.donascimento@cea.fr

Part 1 – Introduction to KiCad

KiCad, an open source EDA Software

Designing MM detectors with KiCad

The plugins make KiCad very powerful

Part 2 – MM dedicated plugins

Plugin demo

Plugin development

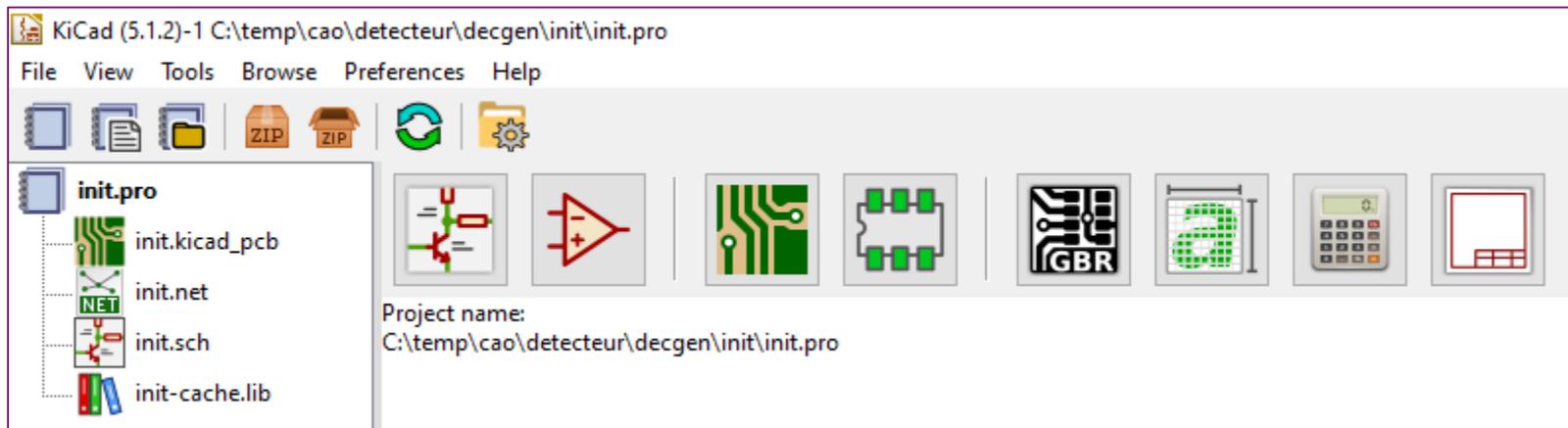
Automated netlist generation

Next steps

Summary

KiCad, a **free** and **open source** EDA software

- created in 1992 by Jean-Pierre Charras from Grenoble University
- multi platform: GNU/Linux, Windows and Apple OS X
- supported by CERN & Society Foundation
<https://cernandsocietyfoundation.cern/projects/kicad-development>
- under continuous development – v6 foreseen for end of 2021



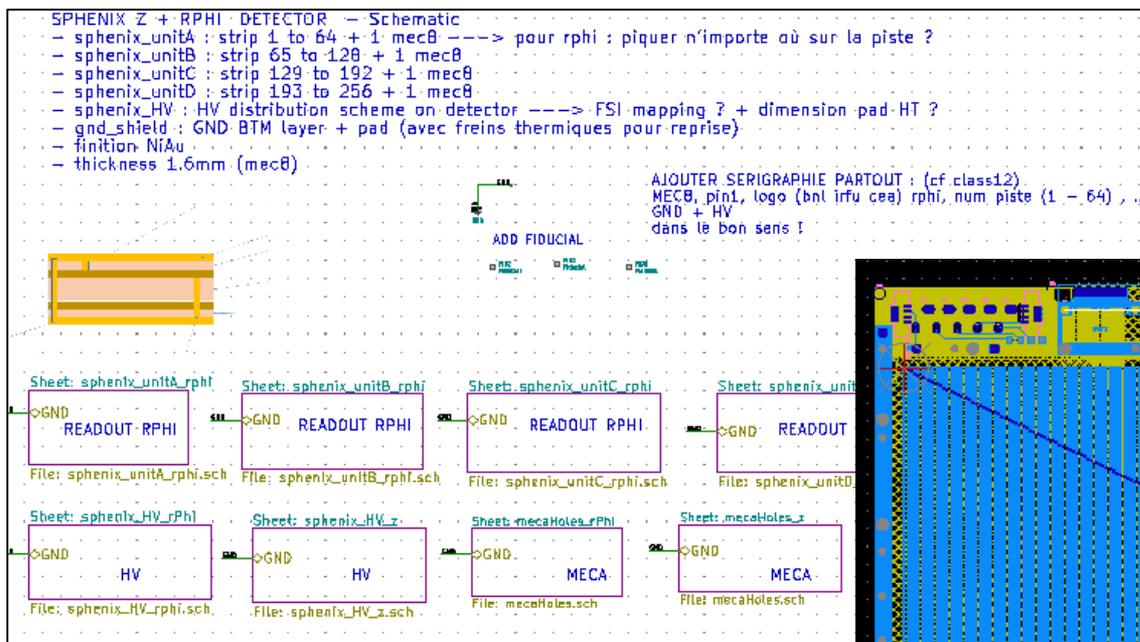
KiCad front panel

TPOT MM prototype and its HV filter board for sPhenix

256 strips – 512mm x 256mm readout zone

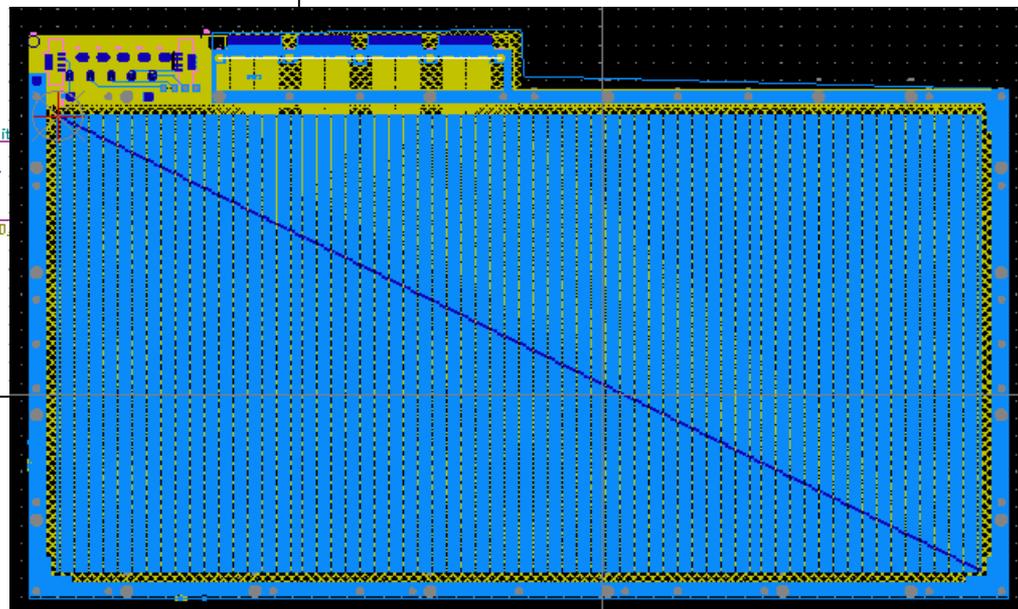
2 inner layers with μ vias, grid GND

HV contacts through FSI connectors – connection to FE through mec8 edge connectors



TPOT Z prototype schematic

TPOT Z prototype layout

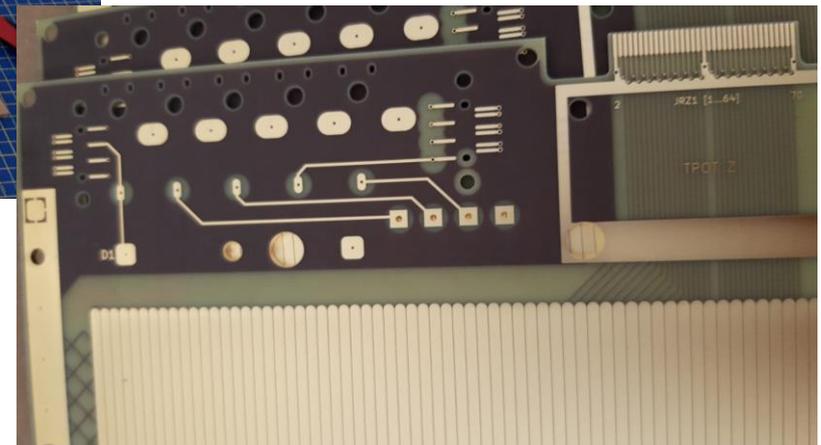
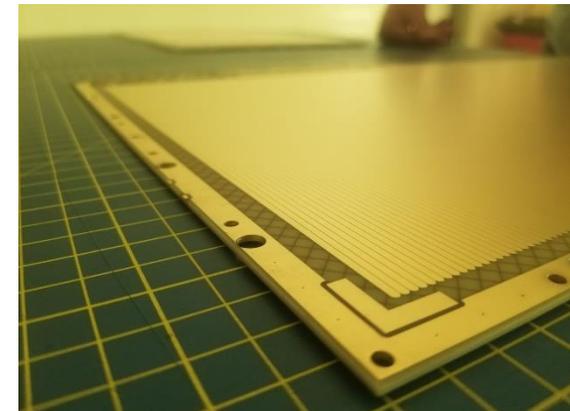
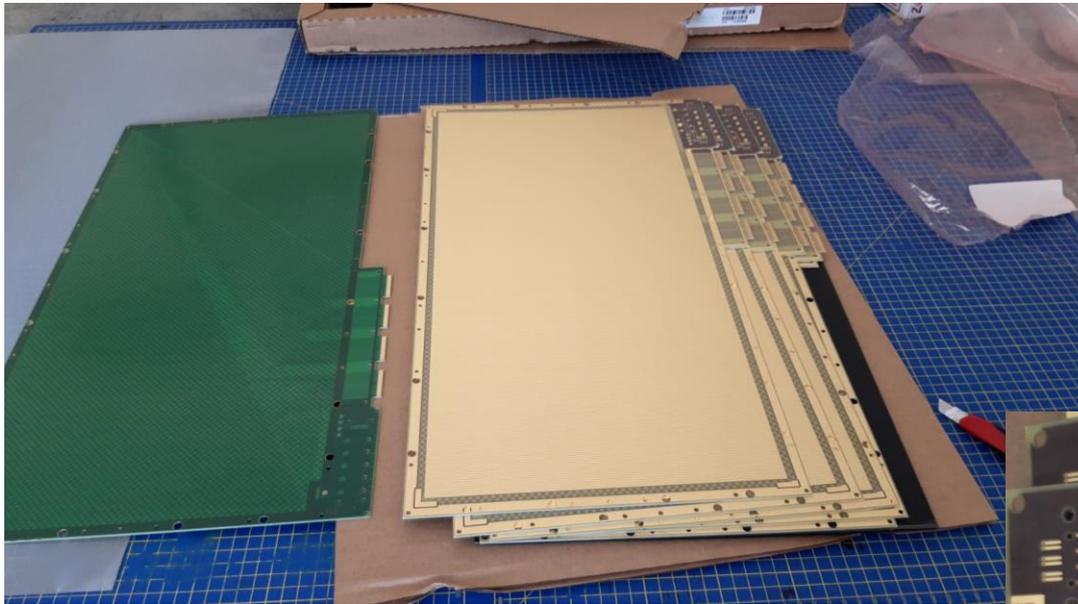


TPOT MM prototype and its HV filter board for sPhenix

256 strips – 512mm x 255mm readout zone

2 inner layers with μ vias, grid GND

HV contacts through FSI connectors – connection to FE through mec8 edge connectors



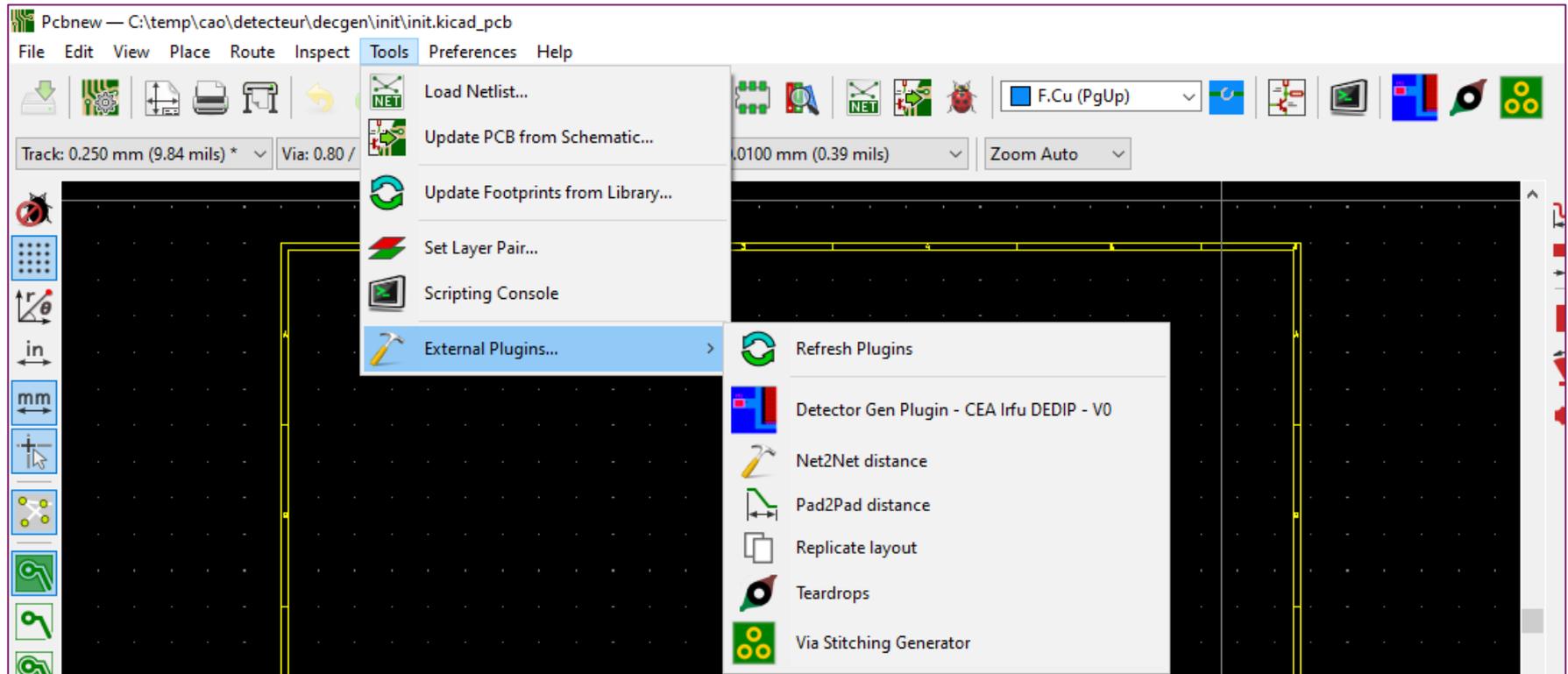
« The objective of [its] development is to **enhance its functionality**, making it an **efficient tool** for PCB design, which people can use to share their design information without compromising productivity.

This will ensure that there are **no artificial barriers** to the sharing of information, so that design and development knowledge can flow more freely »

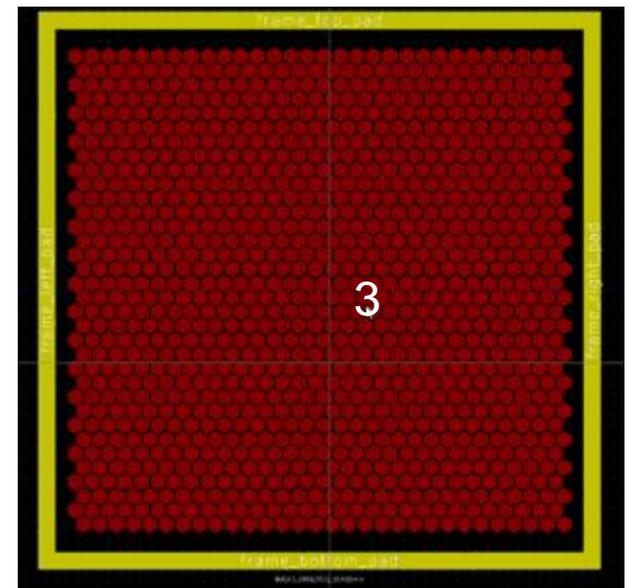
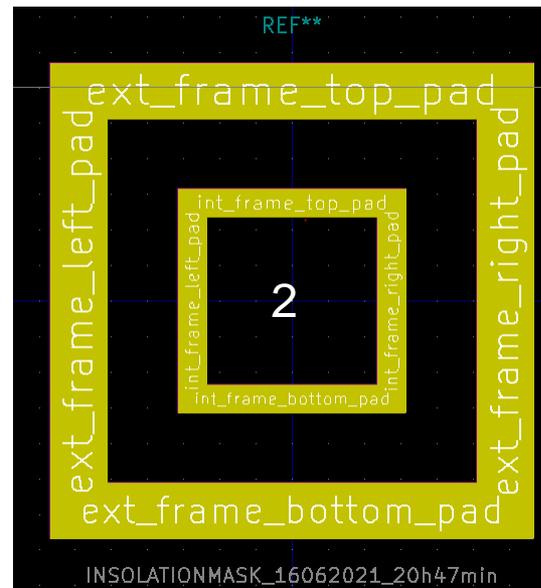
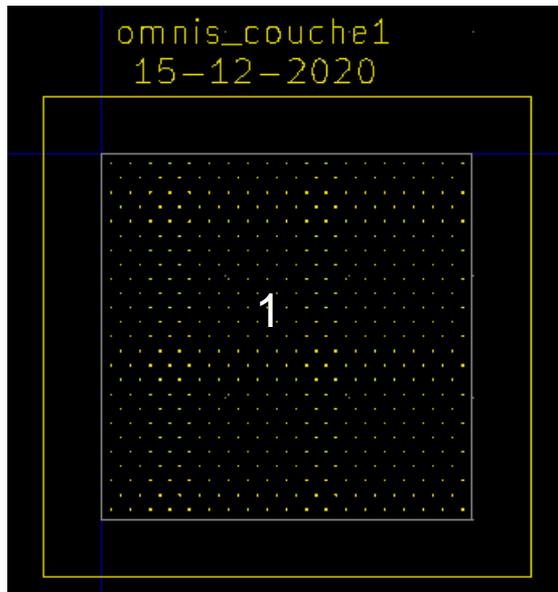
Quote from: <https://cernandsocietyfoundation.cern/projects/kicad-development>

- What does «**enhance its functionality** » mean?

→ Users can **develop third-party tools**, the so called **PLUGINS**, that can interact with KiCad to add custom functionalities



- How can it be an **efficient tool** for detector layout design ?
- Exploit the potential of the « **footprint generator wizard** » to automatically draw
 (1) Mesh mask (pillar) – (2) insulation mask (wall) – (3) readout zone (pixels or strips)



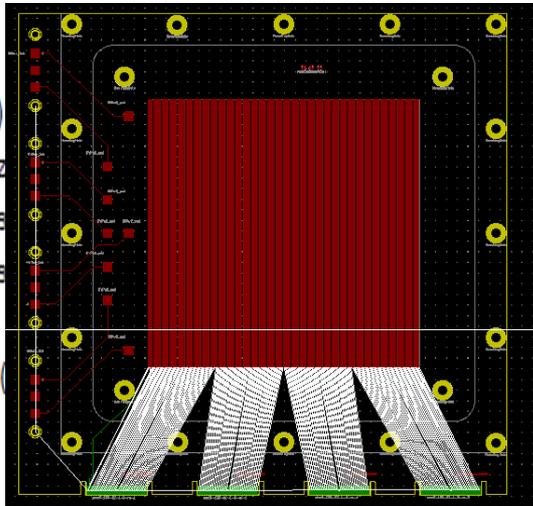
- How can it be an **efficient tool** for detector layout design ?

Exploit the potential of the « **no artificial barriers** » to automatically generate a **KiCad netlist** that is a key element for an **efficient and error – free** routing process.

Other EDA software output files

```
(module test (layer F.Cu) (tedit 60B66628)
  (fp_text reference REF** (at 0 0.5) (layer F.SilkS)
    (effects (font (size 1 1) (thickness 0.15))))
  (fp_text value test (at 0 0.5) (layer F.SilkS)
    (effects (font (size 1 1) (thickness 0.15))))
  (fp_poly (pts (xy -0.6 1.4) (xy -0.6 1.6)) (layer F.SilkS)
    (width 0.1))
  (pad 1 smd rect (at -1.2 3) (size 1.2 1.2) (layers F.Cu F.PcbAn)
    (clearance 0.5) (drill 0.5) (radius 0) (ask))
  (pad 1 smd rect (at -1.2 5.8) (size 1.2 1.2) (layers F.Cu F.PcbAn)
    (clearance 0.5) (drill 0.5) (radius 0) (ask))
  (pad 2 smd custom (at -4.4 1) (size 1.2 1.2) (layers F.Cu F.PcbAn)
    (clearance 0.5) (drill 0.5) (radius 0) (ask))
  (zone_connect 0)
  (options (clearance outline) (clearance 0.5) (radius 0) (ask))
  (end)
```

KiCad output file
→ No artificial barriers



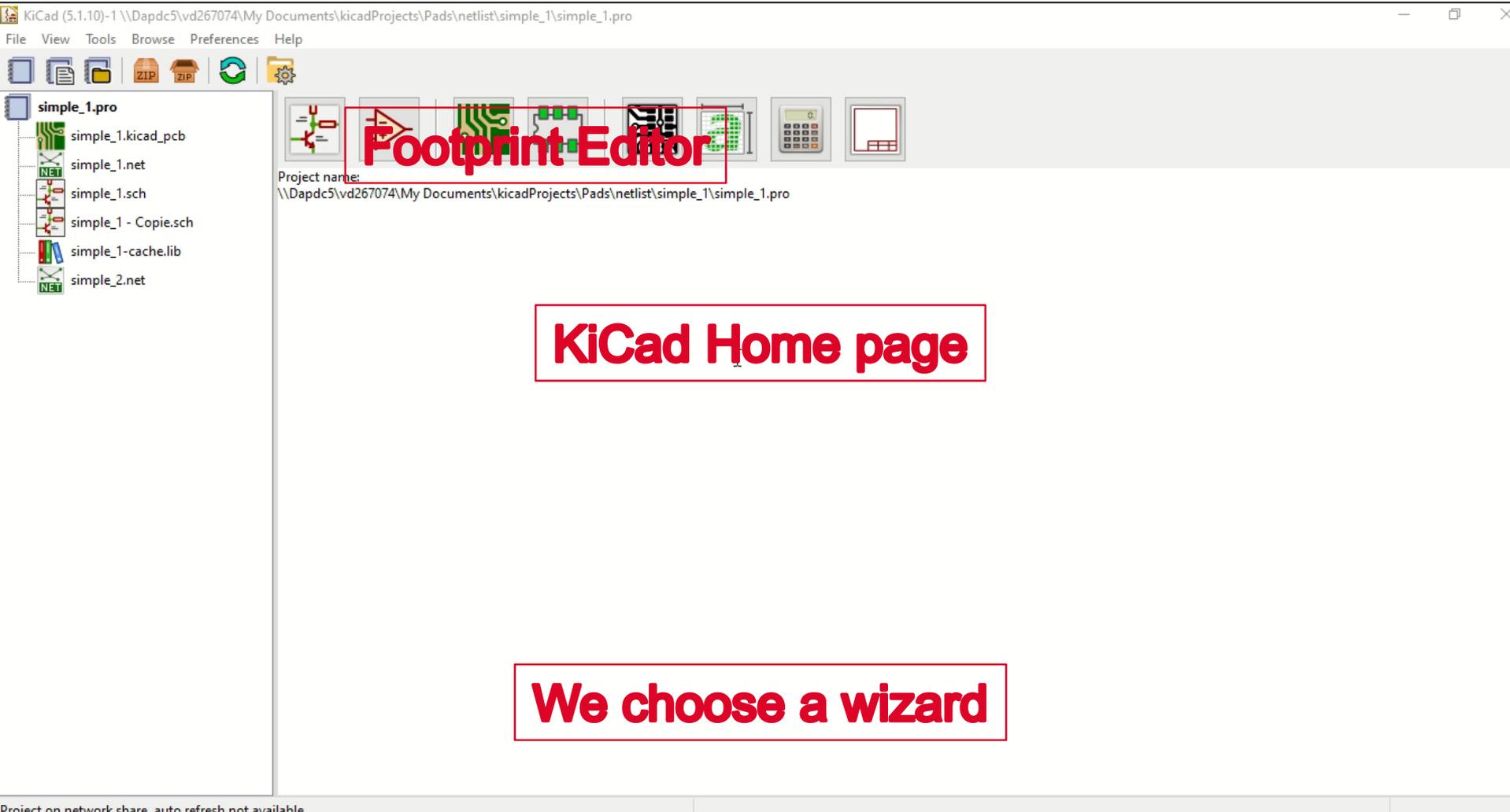
Part 1 in a nutshell

We have decided to develop dedicated KiCad plugins for

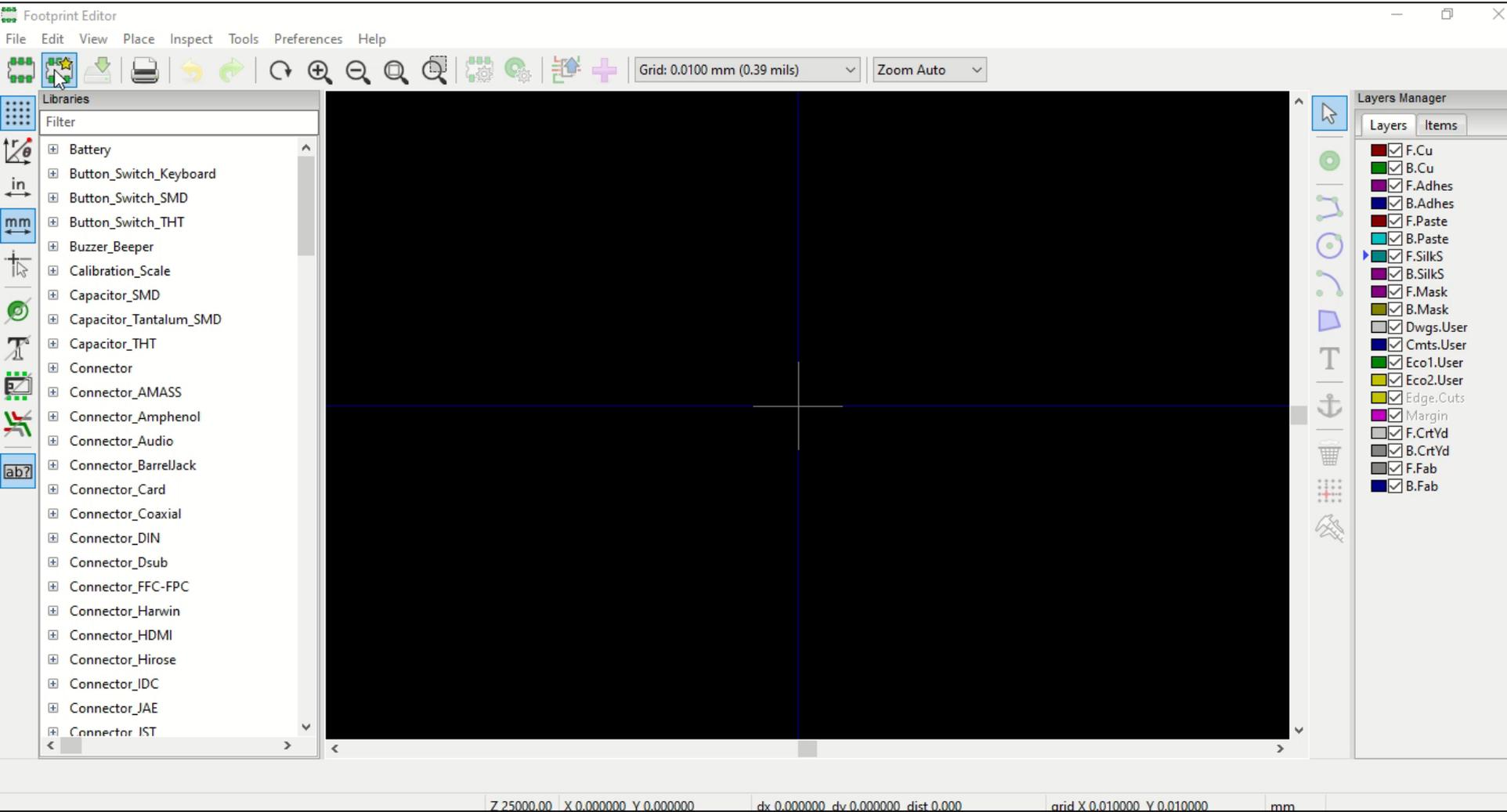
- Mesh mask (pillars) generation
- Insolation mask generation
- Readout zone footprint
- Automated netlist generation

And now, time for demo !

- Creating an insulation mask (movie)



- Meshes with different patterns (movie)



- Readout zones with strips (1D and 2D) (movie)

Footprint Wizard [no wizard selected]

Parameters

Parameter	Value	Units

Footprint Generators

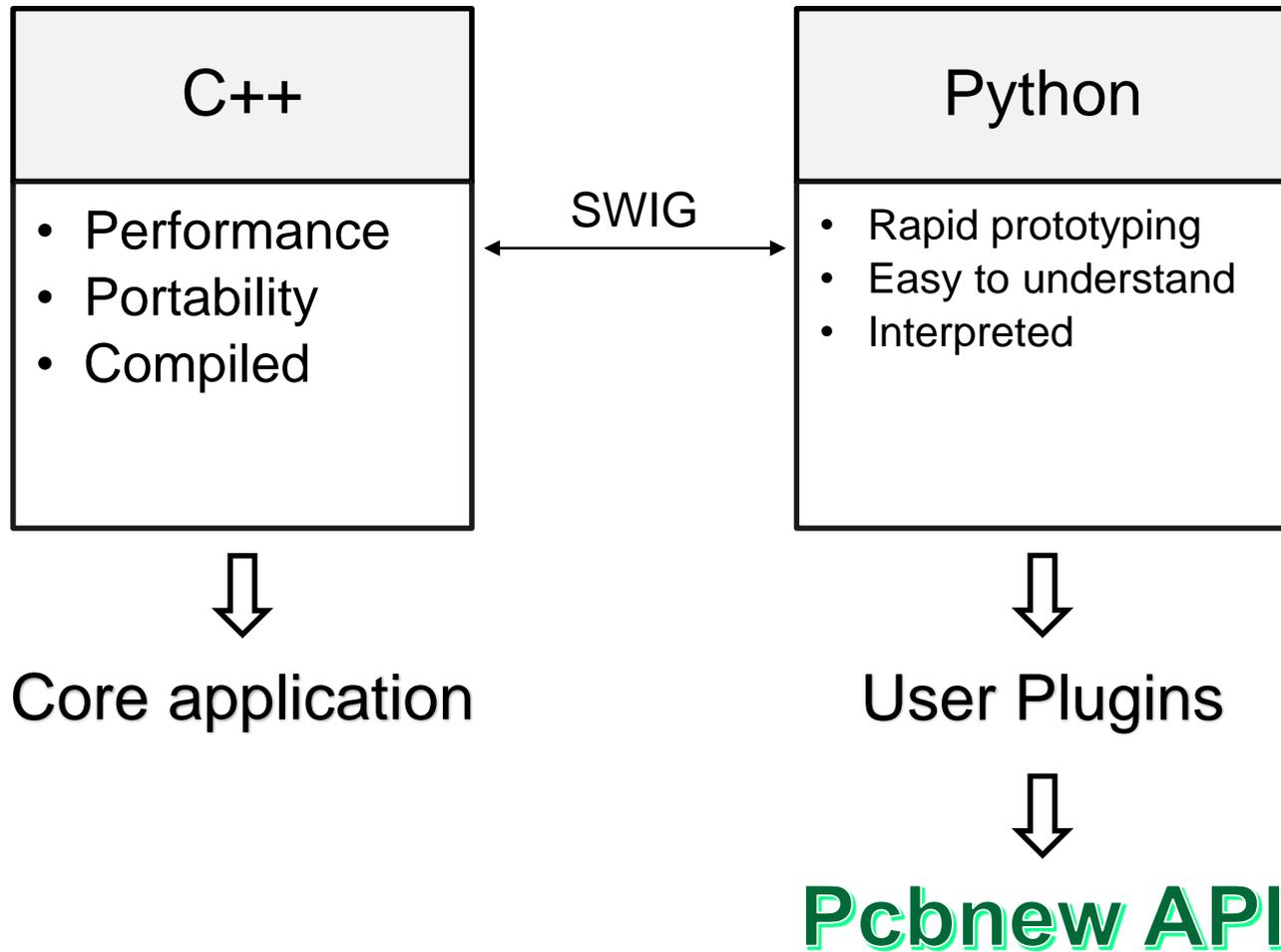
Available Footprint Generators Messages

Name	Description
1 BGA	Ball Grid Array Footprint Wizard
2 Circular Pad Array	Circular array of pads
3 FPC (SMT connector)	FPC (SMT connector) Footprint Wizard
4 Micromatch SMD connectors	Micromatch (with lock and w/o lock), footprint wizard
5 QFN	Quad Flat No-lead (QFN) footprint wizard
6 QFP	Quad Flat Package (QFP) footprint wizard
7 2D Barcode QRCode	QR Code barcode generator
8 S-DIP	Single/Dual Inline Package Footprint Wizard
9 SOIC	SOIC, MSOP, SSOP, TSSOP, etc, footprint wizard
10 Touch Slider	Capacitive Touch Slider wizard
11 BARCODE USS-39	USS-39 Barcode
12 ZIP	N lines Zip Package Footprint Wizard
13 ZOIC	ZOIC, etc, Footprint Wizard
14 Detector Footprint	MICROMEAS mask 2 wizard
15 Insolation Mask	MICROMEAS insolation mask wizard
16 Mesh mask	MICROMEAS mesh mask wizard

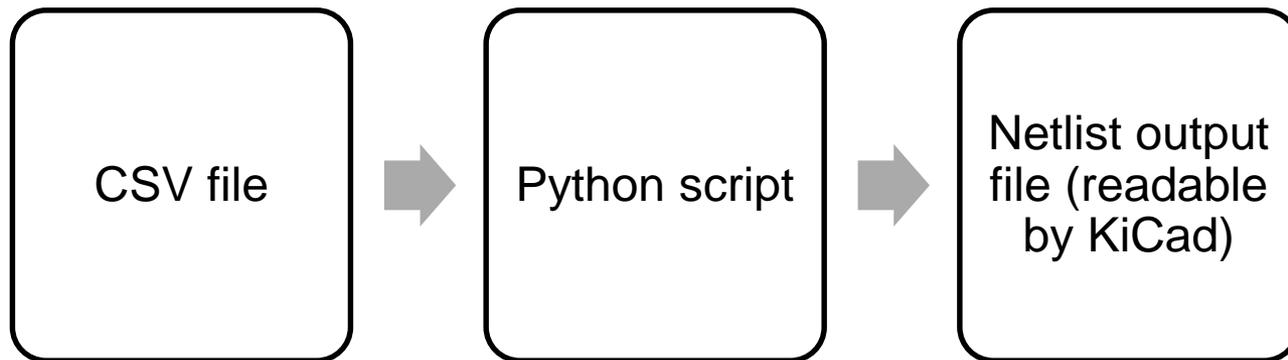
Update Python Modules OK Cancel

Z 25000.00 X 0.000000 Y 0.000000 dx 0.000000 dy 0.000000 dist 0.000 grid X 2.540000 Y 2.540000 mm

- KiCad uses two languages



- The objective: Use a CSV file that describes the **connections** between the detector components and Front End Electronics as an input to KiCad.
- How can we do it ?



AUTOMATED NETLIST GENERATION (DEMO - MOVIE)



File Explorer window showing the directory structure for 'sphenix_z' under 'Documents > kicadProjects > Netlist'. The files listed are:

Nom	Modifié le	Type	Taille
fp-info-cache	17/06/2021 17:54	Fichier	3 015 Ko
sphenix_z.kicad_pcb	17/06/2021 17:54	KiCad Board	1 Ko
sphenix_z.pro	01/05/2021 02:52	KiCad Project	1 Ko
sphenix_z.sch	17/06/2021 17:54	KiCad Schematic	1 Ko

```

Microsoft Windows [version 10.0.18363.1379]
(c) 2019 Microsoft Corporation. Tous droits réservés.

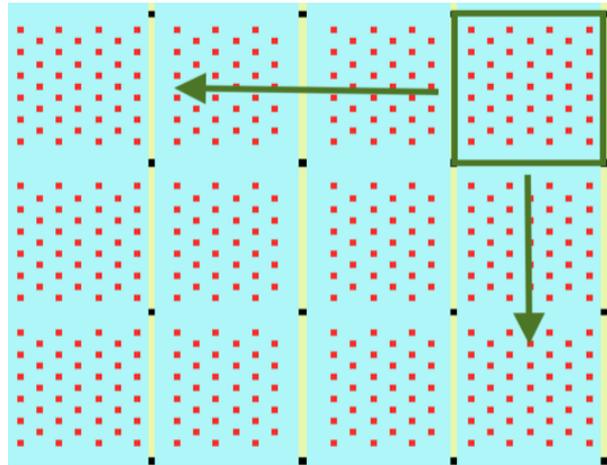
C:\Users\vd267074>python micromegas_netlist.py
    
```

Excel spreadsheet titled 'sphenixMapping_z.csv - Excel' showing a netlist mapping table with columns A through I. The table lists 45 rows of data, each representing a connector and its associated footprint and detector information.

	A	B	C	D	E	F	G	H	I
1	connectorID_A	connectorPartNumber_A	connectorFootprint_A	pinID_A	traceName	detectorStrip	detectorFootprint		
2	connector1	mec8-135-02-L-D-ra-1	mec8_readout	1	gnd				
3	connector1	mec8-135-02-L-D-ra-1	mec8_readout	2	gnd				
4	connector1	mec8-135-02-L-D-ra-1	mec8_readout	3	rd1		1 sphenixZ		
5	connector1	mec8-135-02-L-D-ra-1	mec8_readout	4	rd2		2 sphenixZ		
6	connector1	mec8-135-02-L-D-ra-1	mec8_readout	5	rd3		3 sphenixZ		
7	connector1	mec8-135-02-L-D-ra-1	mec8_readout	6	rd4		4 sphenixZ		
8	connector1	mec8-135-02-L-D-ra-1	mec8_readout	7	rd5		5 sphenixZ		
9	connector1	mec8-135-02-L-D-ra-1	mec8_readout	8	rd6		6 sphenixZ		
10	connector1	mec8-135-02-L-D-ra-1	mec8_readout	9	rd7		7 sphenixZ		
11	connector1	mec8-135-02-L-D-ra-1	mec8_readout	10	rd8		8 sphenixZ		
12	connector1	mec8-135-02-L-D-ra-1	mec8_readout	11	rd9		9 sphenixZ		
13	connector1	mec8-135-02-L-D-ra-1	mec8_readout	12	rd10		10 sphenixZ		
14	connector1	mec8-135-02-L-D-ra-1	mec8_readout	13	rd11		11 sphenixZ		
15	connector1	mec8-135-02-L-D-ra-1	mec8_readout	14	rd12		12 sphenixZ		
16	connector1	mec8-135-02-L-D-ra-1	mec8_readout	15	rd13		13 sphenixZ		
17	connector1	mec8-135-02-L-D-ra-1	mec8_readout	16	rd14		14 sphenixZ		
18	connector1	mec8-135-02-L-D-ra-1	mec8_readout	17	rd15		15 sphenixZ		
19	connector1	mec8-135-02-L-D-ra-1	mec8_readout	18	rd16		16 sphenixZ		
20	connector1	mec8-135-02-L-D-ra-1	mec8_readout	19	rd17		17 sphenixZ		
21	connector1	mec8-135-02-L-D-ra-1	mec8_readout	20	rd18		18 sphenixZ		
22	connector1	mec8-135-02-L-D-ra-1	mec8_readout	21	rd19		19 sphenixZ		
23	connector1	mec8-135-02-L-D-ra-1	mec8_readout	22	rd20		20 sphenixZ		
24	connector1	mec8-135-02-L-D-ra-1	mec8_readout	23	rd21		21 sphenixZ		
25	connector1	mec8-135-02-L-D-ra-1	mec8_readout	24	rd22		22 sphenixZ		
26	connector1	mec8-135-02-L-D-ra-1	mec8_readout	25	rd23		23 sphenixZ		
27	connector1	mec8-135-02-L-D-ra-1	mec8_readout	26	rd24		24 sphenixZ		
28	connector1	mec8-135-02-L-D-ra-1	mec8_readout	27	rd25		25 sphenixZ		
29	connector1	mec8-135-02-L-D-ra-1	mec8_readout	28	rd26		26 sphenixZ		
30	connector1	mec8-135-02-L-D-ra-1	mec8_readout	29	rd27		27 sphenixZ		
31	connector1	mec8-135-02-L-D-ra-1	mec8_readout	30	rd28		28 sphenixZ		
32	connector1	mec8-135-02-L-D-ra-1	mec8_readout	31	rd29		29 sphenixZ		
33	connector1	mec8-135-02-L-D-ra-1	mec8_readout	32	rd30		30 sphenixZ		
34	connector1	mec8-135-02-L-D-ra-1	mec8_readout	33	rd31		31 sphenixZ		
35	connector1	mec8-135-02-L-D-ra-1	mec8_readout	34	rd32		32 sphenixZ		
36	connector1	mec8-135-02-L-D-ra-1	mec8_readout	35	gnd				
37	connector1	mec8-135-02-L-D-ra-1	mec8_readout	36	gnd				
38	connector1	mec8-135-02-L-D-ra-1	mec8_readout	37	rd33		33 sphenixZ		
39	connector1	mec8-135-02-L-D-ra-1	mec8_readout	38	rd34		34 sphenixZ		
40	connector1	mec8-135-02-L-D-ra-1	mec8_readout	39	rd35		35 sphenixZ		
41	connector1	mec8-135-02-L-D-ra-1	mec8_readout	40	rd36		36 sphenixZ		
42	connector1	mec8-135-02-L-D-ra-1	mec8_readout	41	rd37		37 sphenixZ		
43	connector1	mec8-135-02-L-D-ra-1	mec8_readout	42	rd38		38 sphenixZ		
44	connector1	mec8-135-02-L-D-ra-1	mec8_readout	43	rd39		39 sphenixZ		
45	connector1	mec8-135-02-L-D-ra-1	mec8_readout	44	rd40		40 sphenixZ		

Footprint wizards:

- Include a feature to generate segmented meshes
 - The pattern is repeated every X and Y



- Optimization: export mesh footprint directly as a Gerber File
 - Saves time when creating meshes with millions of pads

Netlist Generator Script:

- Add a User Interface Plugin embedded into KiCad to simplify its usage

KiCad is a (very) powerful and flexible EDA software for Detector Design.
It can cover all steps of detector design flow.

- 2 keywords:
 - **Efficiency**
 - Saclay Bulk Lab staff starting to design the masks required for the bulk process using dedicated Footprint wizard
 - Micromegas Designers can draw (exotic 😊) readout zone using the dedicated Footprint wizard
 - Automated netlist generation is a precious help for CAD Designer
 - **Flexibility**
 - Free, open source, multi platform software

Thank you for your attention

aude.grabas@cea.fr
valmir.donascimento@cea.fr

Commissariat à l'énergie atomique et aux énergies alternatives
Centre de Saclay | 91191 Gif-sur-Yvette Cedex

Etablissement public à caractère industriel et commercial | R.C.S Paris B 775 685 019

Tel : +33 1 69 08 xx xx – Fax : +33 1 69 08 xx xx



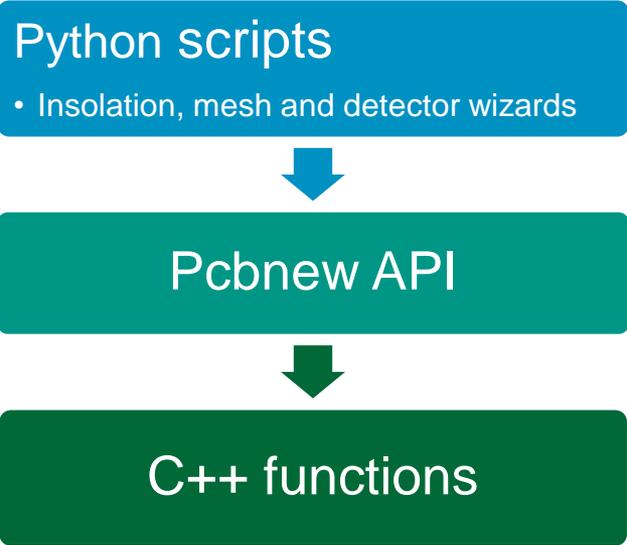
Direction de la Recherche Fondamentale
Institut de recherche
sur les lois fondamentales de l'Univers
Service



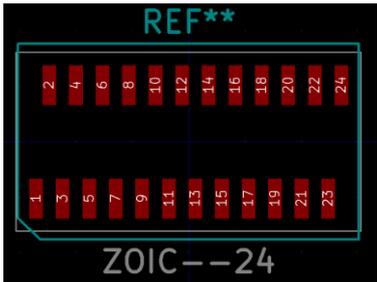
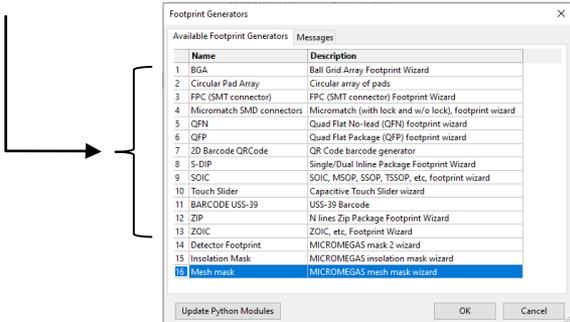
BACK UP SLIDES



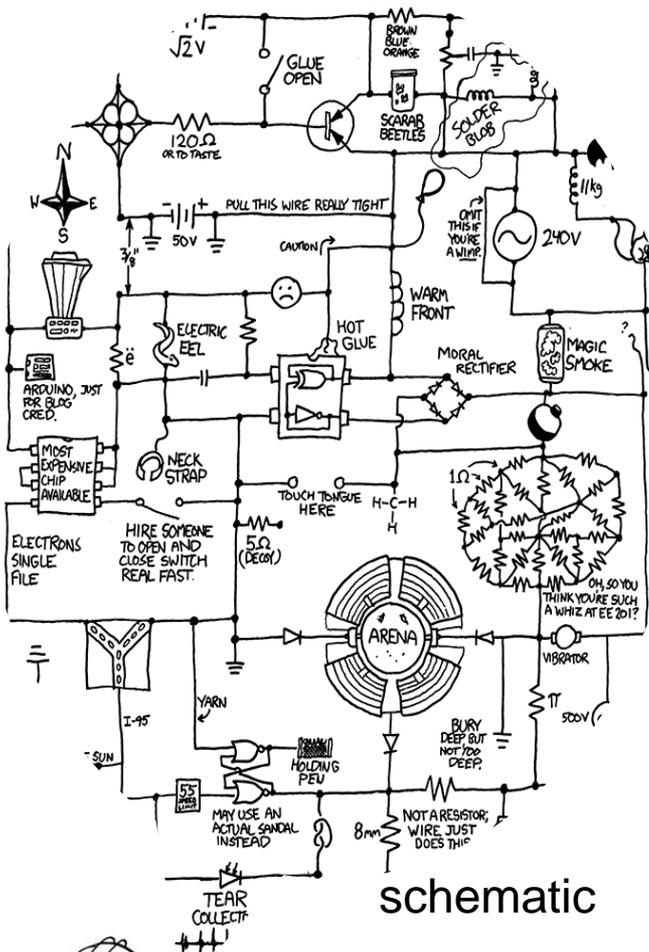
- Extensive use of the Pcbnew API



- Use of existing plugins



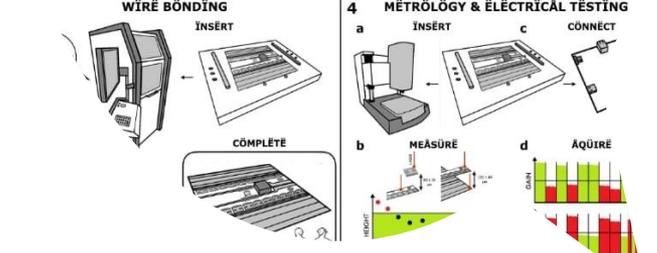
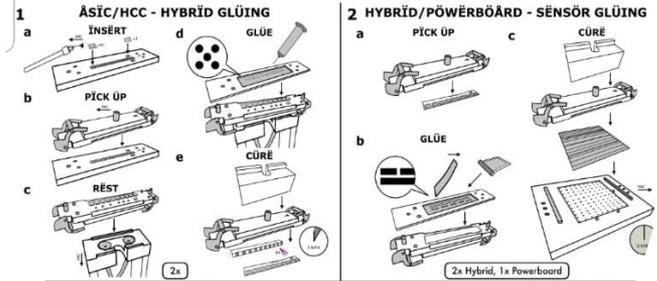
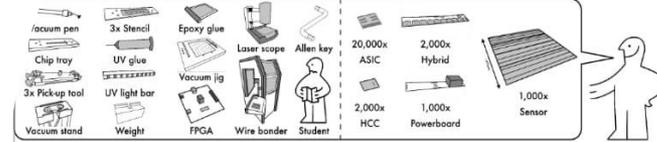
WHEN ELECTRONICS DESIGNERS MEET DETECTOR DESIGNERS



schematic

netlist

Footprint library



drawing

step

masks

mapping

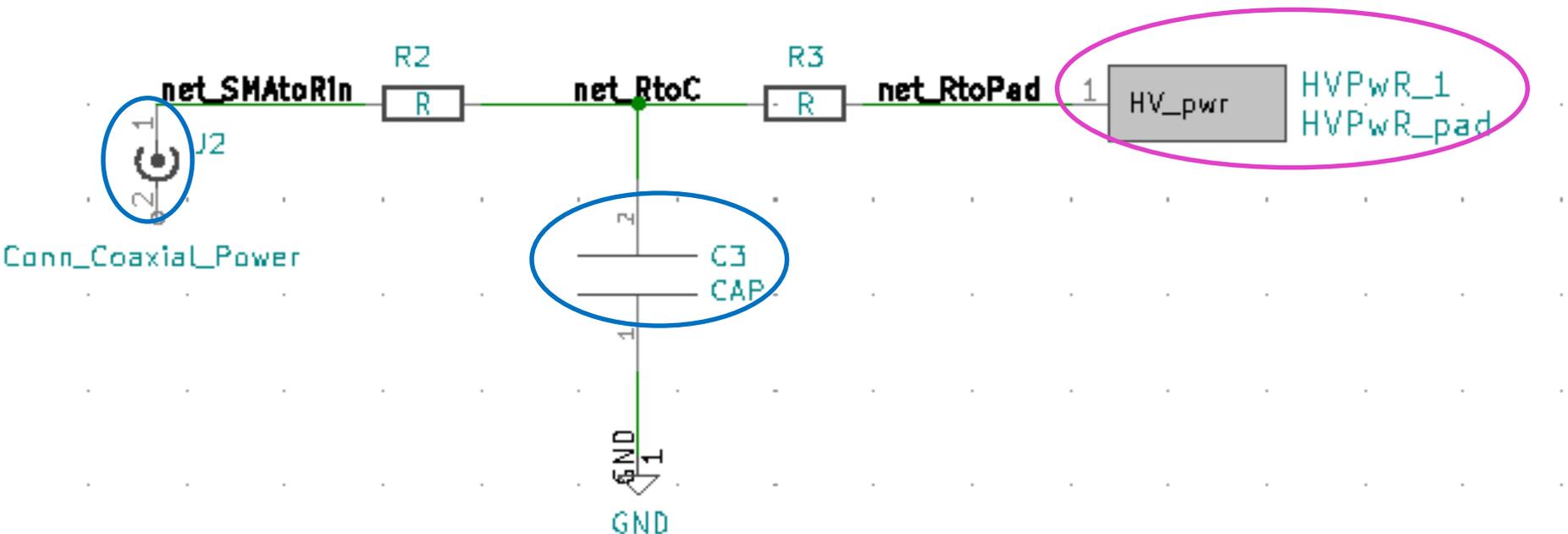


Freely inspired from <https://xkcd.com/730/> and from Theodore Zorbas Poster

Definition: a **symbolic** representation of the **physical connection** between different electrical **components** of a system »

Physical connections == **green line** with a name (**net name**)

Electrical component == **standardized drawing** or 'box'

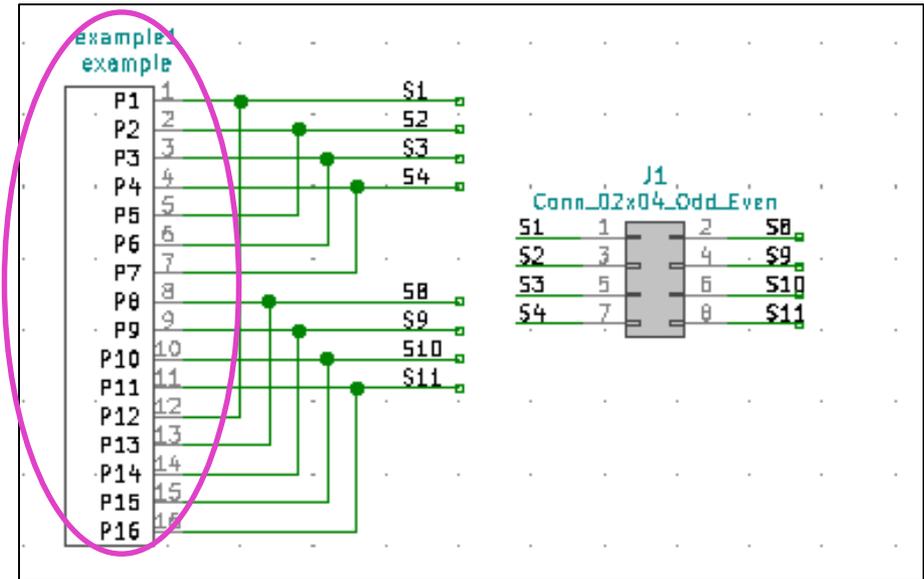
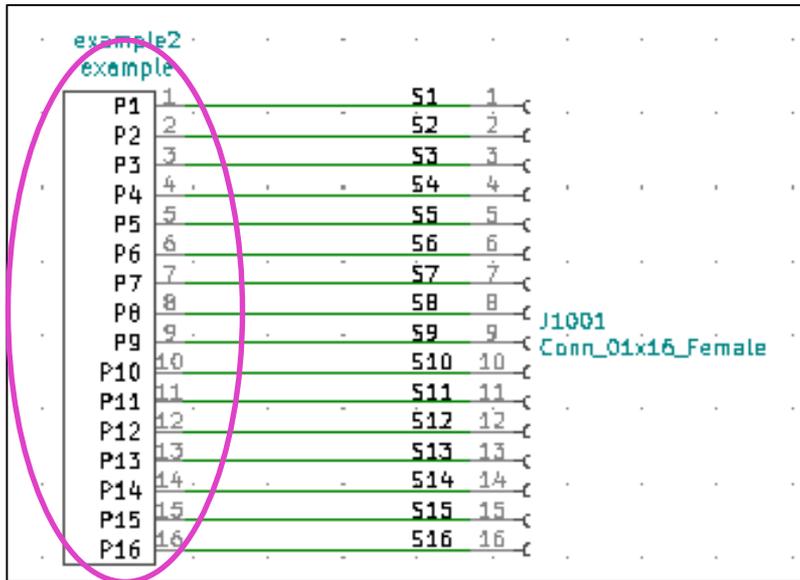


Example in the electronic world: RC filter for HV supply

MPGD Definition: « a **symbolic** representation of the **physical connection** between the **readout zone** and the **FE board connectors** and the HV elements

Physical connections == **green line** with a name (**net name**)

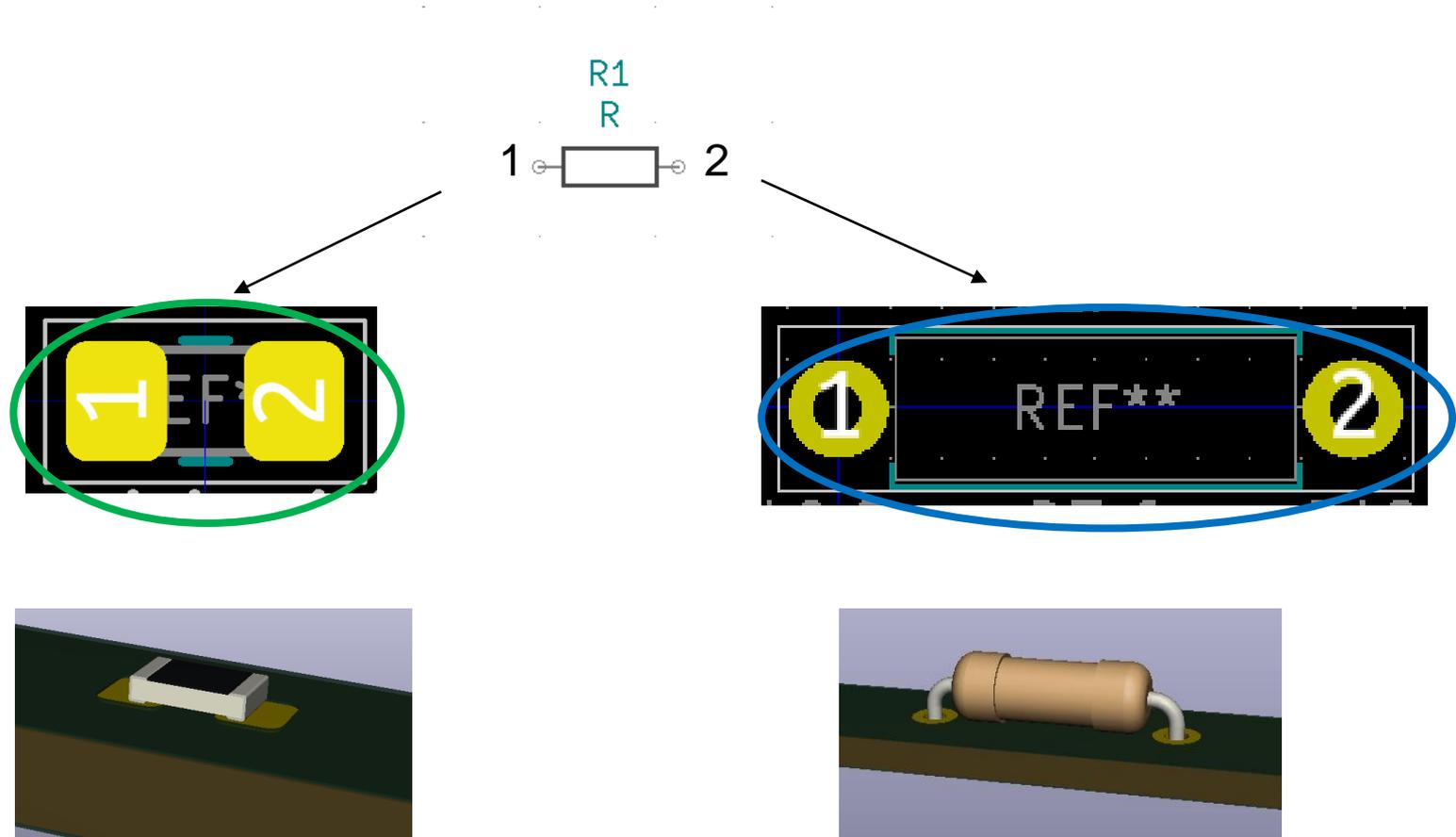
Component == **'box'** (no standard component for detector readout zone)



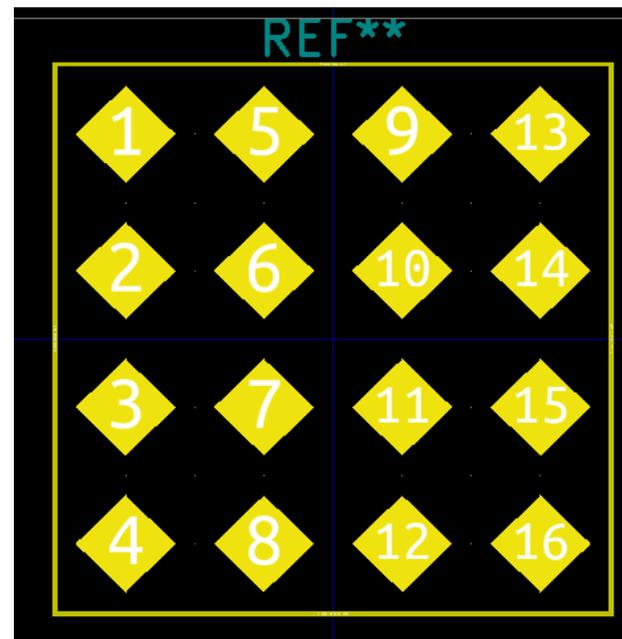
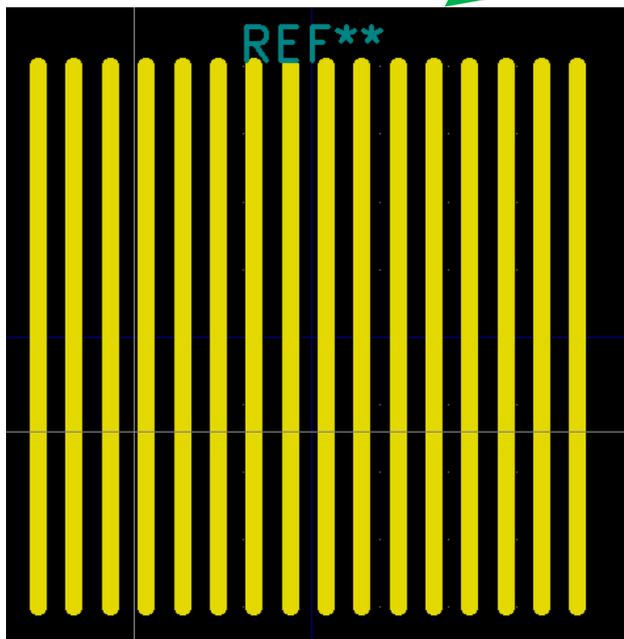
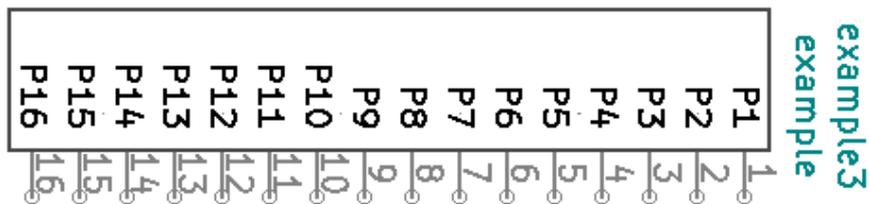
2 Examples in the detector world:

- 16 pixels / strip readout zone connected to 1 FE connector
- 16 pixels / strip multiplexed signals connected to 1 FE connector

Wikipedia Definition: A footprint or land pattern is the arrangement of **pads** or **through holes** used to physically attach and electrically connect a component to a PCB.

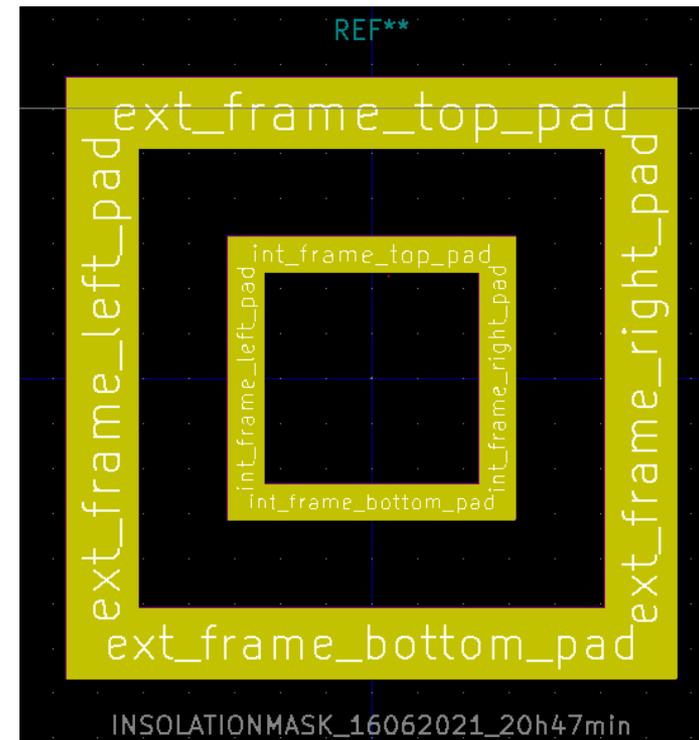
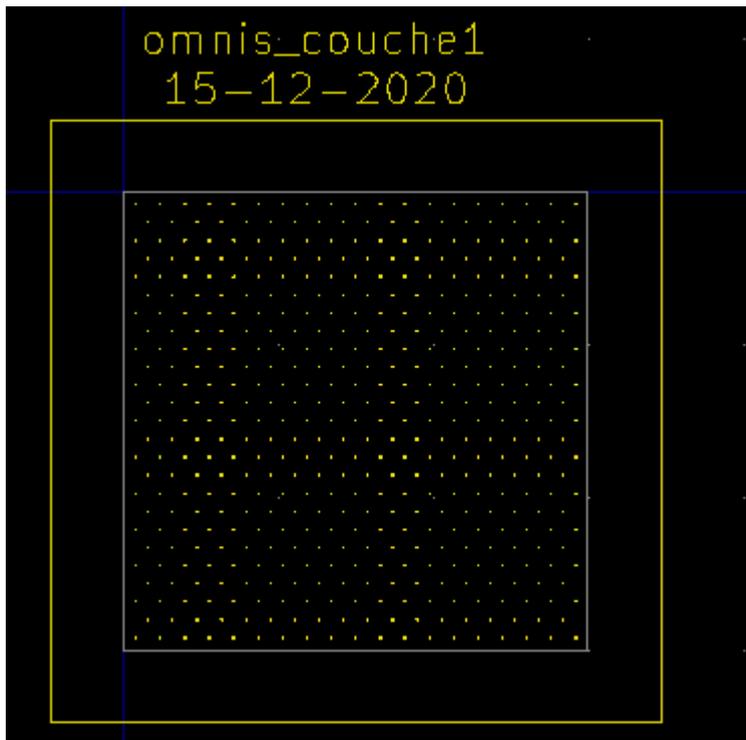


MPGD Definition: A detector footprint is the arrangement of **pixels** or **strips** of a **read out zone** to physically attach and electrically connect it to a detector PCB



MPGD Definition : (1) A detector footprint is the arrangement of **pixels** or **strips** of a **read out zone** to physically attach and electrically connect it to a detector PCB

(2) A **mask footprint** is a pattern designed for the bulk process machine : insulation mask for the mesh plots, silkscreen mask for resistive paste, insulation protection wall,...



Definition: A **netlist** is a list of components in a circuit and a list of the nodes that connect the components to each other.

