Relations with industry

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Many thanks to:
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Disclaimer

- Relations with Industry is a Multi-dimension Universe which is very difficult to concentrate in 15 min of talk
- I will not touch fields like “Services”, “Tooling”, “Big Infrastructure”, try to focus on general aspects and specific detector cases (hope useful cases)
- I’ll give a very partial (and probably biased) point of view
- Not a super expert in some of the subjects touched Apologies to those who know more already

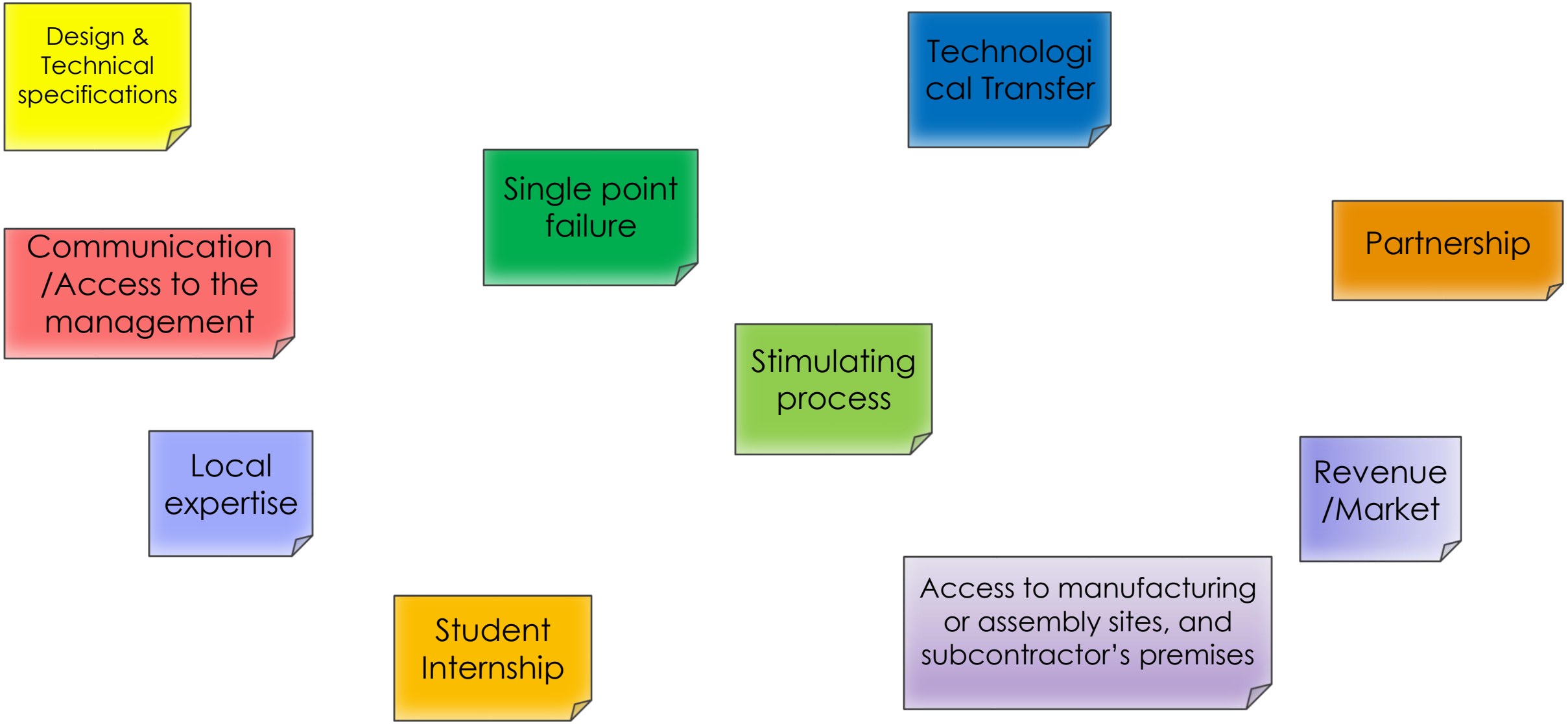
Preamble

- Academic physics researchers usually do not have dedicated training (or in theory are not supposed to have) for interaction with industries, this could lead to multiple unexpected problems when R&D or Mass Production process, which require interaction with company, need to be launched.

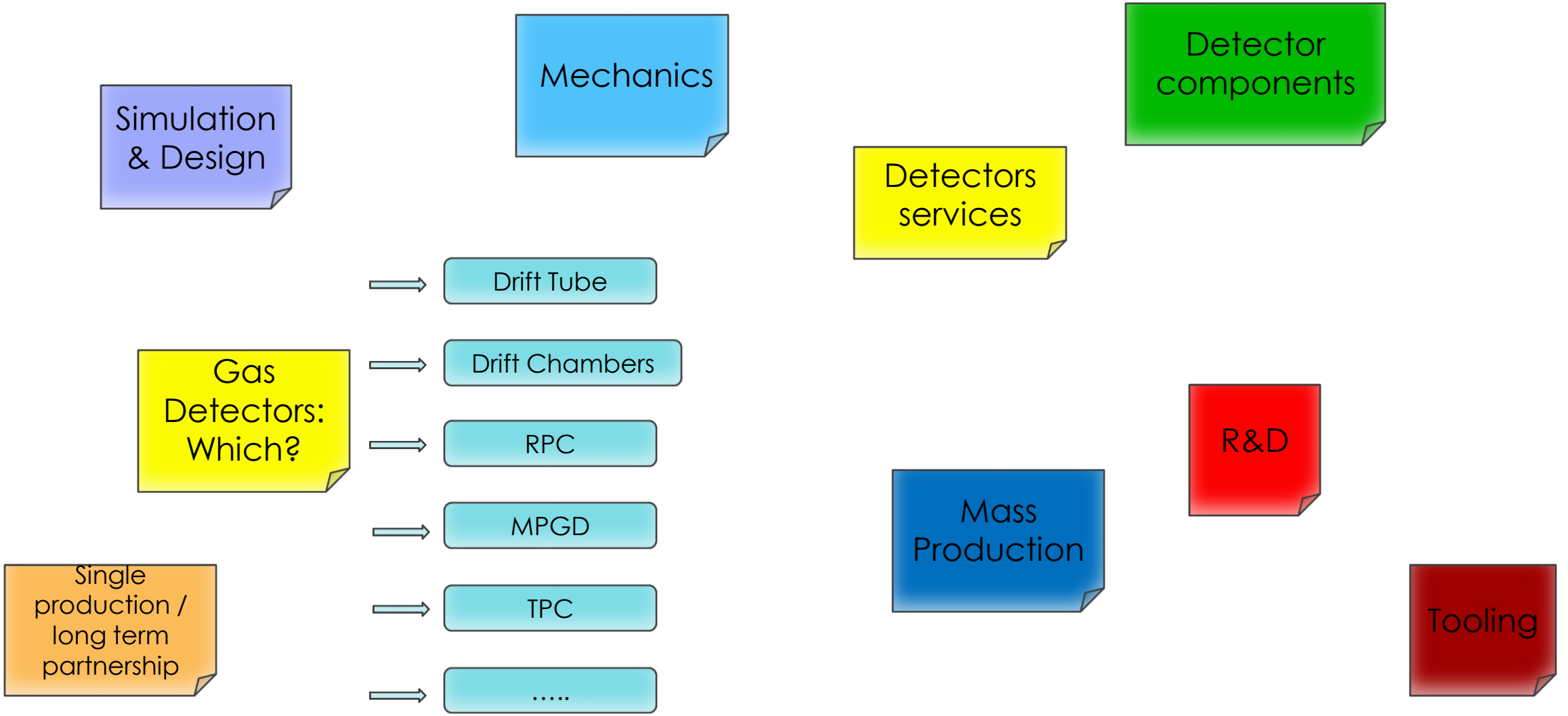
- While the technical/bureaucratic aspects could be effectively improved by appropriate training, knowledge of the market which could support development and production of Gas Detectors is often the result of previous experiences and interaction with collaborators

The following slides do not want to make a list of good/bad companies (the assessment could be the results of particular lucky or not well-prepared collaboration) rather than hint and tips for process preparation and interactions with the companies, plus feedbacks from recent experiences in Industry collaborations

Key Words


Design & Technical specifications
Technologi cal Transfer
Single point failure
Partnership
Communication /Access to the management
Stimulating process
Local expertise
Revenue /Market
Access to manufacturing or assembly sites, and subcontractor's premises
Student Internship

Industry? For which process/product?



… before and during the engineering process

- ***Do something similar have been already designed produced?***
  - When? By whom? For which project?
    - Inquire the involved people for feedback and detailed summary of lesson learnt
- ***Are the technical solutions adopted affordable by standard company?***
  - Often engineers and technicians in our Institute, with similar tools regularly available in the market are able to achieve much better results
- ***Do you have already in mind possible company for the production***
  - Yes: Involve them in the engineering process
  - No: Too bad, looks asap on the market
- ***Are the technical/manufacturing specifications in line with the documentations/specs adopted by the company ?***
  - Compatibility of design and production tools is a key point

…before to start a production process

- ***Do the production will require a dedicated Technological Transfer?***
  - The process should start asap, possibly with a pre-series production as qualification step for a possible call for tender
- ***Single supplier or splitted order?***
  - Both solutions have pro and cons, correct risk analysis should be carried out before adopting one or the other strategy
- ***Production in batches, per components types, mixed, …***
  - Projects needs could not match the "modus operandi" of the company, for large production of several different components, companies use to work in series completing the production of each single type before to move to the next one; This could not fit with the general project plan. Switching continuously production between different type of similar but not identical components could easily lead to production mistake and cost increase. Production planning, with adequate float, should be steered and submitted to the company at the time of the contract
- ***Logistic and communication matter***

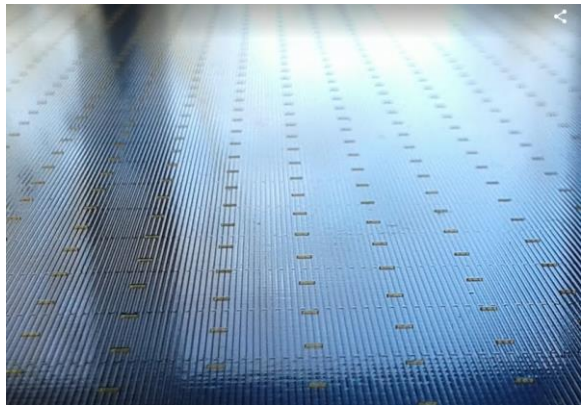
Bureaucracy, something we have to deal with

- ✓ *Tender and Price Inquire are mandatory in procurement process*
- ✓ *@ CERN, baseline criteria for adjudication of contract is the best economic offer*
- ✓ *Involvement of company in an R&D project could be considered not enough to assign a contract directly*
- ✓ *Best Practice: Price inquire should be issue during the R&D, possibly including part of the R&D as requirement of the contract, (R&D is different from pre-production, after successful R&D step could not follow a production step)*

Selection of experiences of Relation with Industry

ATLAS NSW MM anode boards production

- **Largest industrial production of MPGD ever: 1300 m2 detector surface**
  - Resistive Micromegas fully produced in industries (first time)
  - Mass production: 2112 boards of unprecedented size: up to 45 x 220 cm^2
  - Technology developed at CERN and transferred to industries



- **Two companies selected: ELVIA (F), ELTOS (IT)**
- **Choice to split production in 2 sites**
  - Pros:
    - Helped in keeping the schedule. None of the firms could stand the full production in the required time
    - Each firm knew about the other → helped in promoting a good competition
    - Allows to find a quick fallback solution in case of failure of one company (saving the time for the technology transfer to a new company, still slowing down the total production)
    - Experimenting different technical solutions to adapt production to the specific firm → knowledge improvement
    - Allowed to quickly disentangle issues coming from components (common) wrt firm production specific issues
  - Cons:
    - Double efforts to follow up production at the two firm's premises
    - Develop firm-specific adaptation of production (facing different problems)
    - Establish two communication lines
- **Final comment: was the right choice**

I. photolithographic creation of copper pattern
standard process.
complex due to: size of board, required precision & board elongation (humidity).

II. cutting of Kapton foil with resistive pattern
non-standard but simple & required accuracy only ±1mm

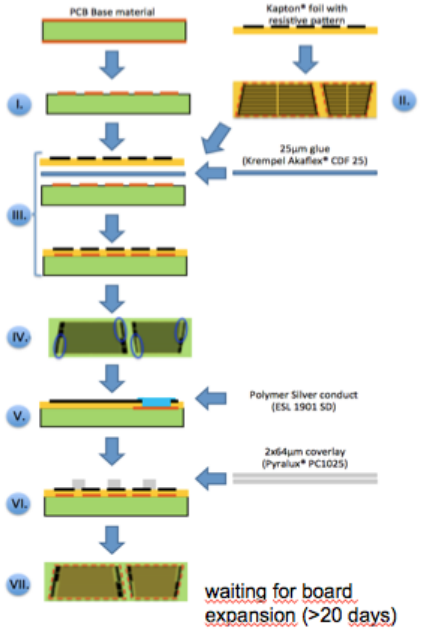
III. stacking and high-pressure & temperature gluing of Kapton foil, glue foil and board
standard process for small boards
complex due to: size of board & required cleanliness.

IV. chemical silver plating of copper pads
standard process

V. screen-printing of silver paste
non-standard but rather simple & required accuracy only ± 1mm

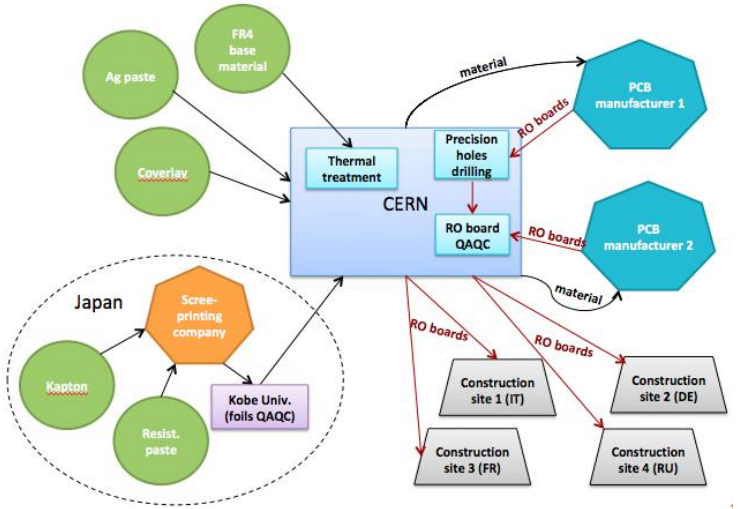
VI. lamination of coverlay & pillar creation
standard process for small boards.
complex due to: size of boards, highly non-standard pattern, required flatness

VII. cutting of boards and drilling of non-precision holes
standard process on CNC machine.
complex due to size of boards, required cutting precision & board elongation (humidity).



ATLAS NSW MM anode boards production

- Main problem: schedule! Mass production had to start before the companies mastered the production process → Final TT during the production, not ideal, affected the initial yield.
- Main technical problems: Some production steps were new/unusual for the companies. Needed time and side-by-side work with ATLAS experts to adapt to their production process (part of TT).
- Complex logistics. ATLAS made the choice of procuring all the material for the production → huge effort allowing to carefully control the supply chain of the companies and reduce delays. Kapton foils with resistive coating produced in a third company.
- Problems with subcontractor of one of the two companies (both used subcontractors) created delays and quality issue. Asked and obtained that the operation done by the subcontractor was moved to the main company → required to develop the new operation on the flight, worked well.
- The technical responsible of our production in one of the company changed three times → visible impact on the production
- The two companies had different styles and policy. Need to adapt to them.



- **A constant follow-up at the companies during the whole production (>3 years) from experts was needed**
  - Spot problems as early as possible and implement specific solutions
  - Monitor the production progress, component availability, change in manpower (expertise of technical manpower from the company crucial for the final product) etc
- **Huge follow-up and QC effort (manpower and cost)**

- **Final remarks: both companies considered the ATLAS production as an R&D, not a series production.**
- **Their main goad was to acquire ('for free') new expertise and potentially open up new market. Another advantage was to get credit from known research institutes (CERN & others)**
- **Both reached a yield >80%, larger than expected by both at the start of production. They are potentially interested in other similar commitments, based on the acquired knowledge.**

μ–RWELL Relation with Industry

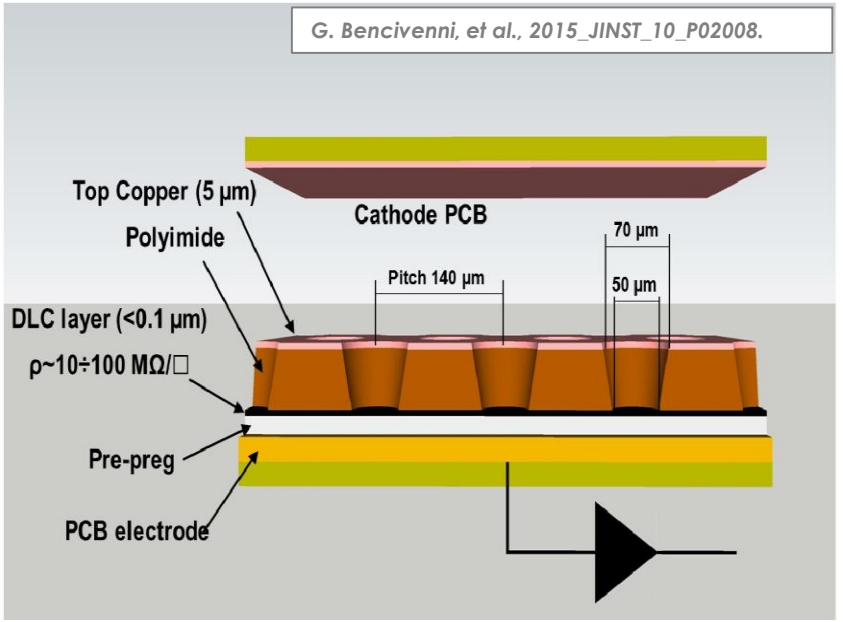
In the framework of AIDA-Innova EU project INFN Frascati is involved in the development of the **industrial manufacturing process of μ-RWELL detectors** in strict collaboration **with CERN and ELTOS SpA.**

The responsibilities in the manufacturing process of the detector are shared as follows:

- Detector layouts design: **INFN-LNF**
- Mechanical drawings: **INFN-LNF**
- PCB with strip/pad readout: **ELTOS SpA**
- Coupling DLC-kapton with PCB: **ELTOS SpA**
- Amplification-stage etching: **CERN EP-DT-MPT Workshop**

Crucial for the development of the technology is the tuning of the DLC sputtering technology on polyimide substrate:

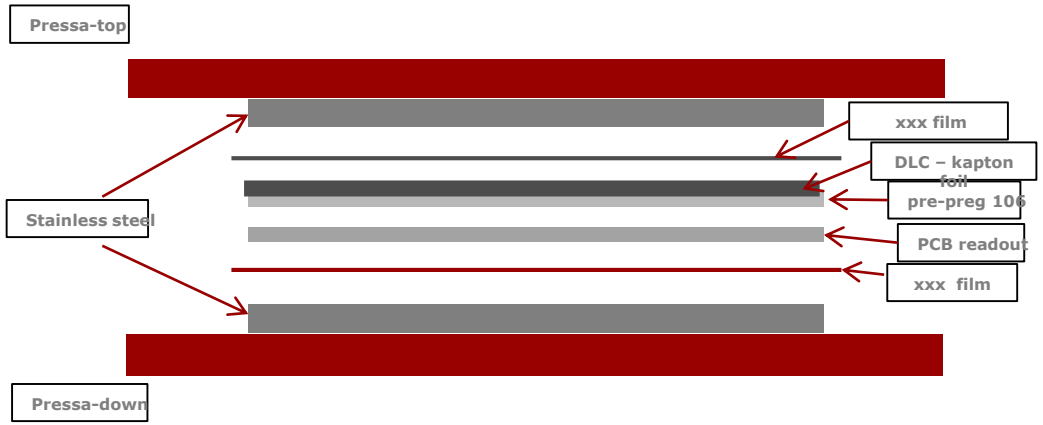
- The **DLC sputtering** technology currently at **Be-Sputter** – Kobe (Japan) and **USTC – Hefei (PRC)**
- A joint **CERN – INFN DLC (C.I.D)** magnetron sputtering facility will be **operative at CERN EP-DT-MPT Workshop from the 2022**



ELTOS performs the coupling of the DLC-foil with the readout PCB.

The **max size** of the μ-RWELL-PCB that can be produced by ELTOS is about **600×700 mm²**. A stack of **8 PCBs** of such a size can be manufactured at the same time.

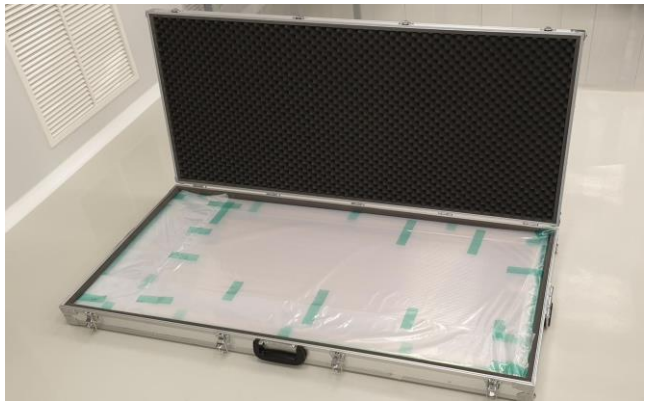
The PI etching done @ CERN.



Lets image now a large production of μ-RWELL, after such partnership and TT; Could the community place the order directly to ELTOS or a Price Inquire (which could allow for money saving but with all the technical risks) would be mandatory?

GEM Production in Industry (CMS Experience)

- Technological Transfer process very long, the company tried to master the single mask etching technique as at CERN but than moved to the double mask technique, this extended quite a lot the R&D and startup time
- GEM foils production expected for GE1/1 project didn't arrived in time
  - The CMS-GEM collaboration didn't push too much the company because backup solution was in place (full production at CERN)
- Facility refurbishment during the R&D process required long interruption of the tests
- Modification of local environmental protection rules imposed additional stop and delay
- *GEM foils size limited by machine/infrastructure and glass masks (~ 1 m long)*
- Company extremely collaborative along all the time of the process
- Several Internship with the SEUL University
- Actually, delivering foils for GE2/1 project, first batch arrived at CERN two week ago, preliminary tests show very good results
- Production rate quite high > 30 large GEM foils/month



MECARO is now on track, able to run large foils production, already looking behind the GE2/1 and ME0 projects

Feedback from the Master of MPGD

(R. De Oliveira)

What's missing to have a company flying like commercial company Hamamatsu for silicon detectors

- Help financially companies sending engineers to collaboration meeting like RD51. First to listen and lately to present their possible contribution.
- Recommend the companies to hire an engineer with knowledge in physics instrumentation (better with technical sales skills also).
- Bring an engineer from a company to an institute for at least a year. With the goal to fully explain him the field and products.
- Ask the company to create STD products (with financial help) to help them to have a continuous production, even limited.
- Help financially the companies to keep the knowledge after mass production projects.
  - Maintain a reduce activity in a field
  - Diversify the product range

Relation with industry for RPC

- Production of low resistivity HPL (Bakelite) in the past has been a case single point of failure, when the single qualified supplier (Pampla) interrupted its activities
- In 2009, in the framework of CMS RPC Upscope project (RE4), with Teknemika and Puricelli firms (Italy) the production of controlled & certified low resistivity HPL (high pressure laminated) panels for RPC electrodes to be used in manufacturing of gas gap volume elements has been resumed
  - Panel dimension = 3.2x1.6m, thickness range = 1-2 mm
  - Panel volumetric (electrical) resistivity = 1-6 x10^{10} [Ω.cm] @ 20°C with high uniformity StDev/AvRho ≤ 0.5
  - Defined a synergic collaboration between industrial and academic partners to secure the availability of relevant skills and know-how
  - Achieved industrial mass production capability (50 panels in 2h), with detailed QC protocol on HPL panel components and final product

RPC detector based on HPL panels is back on the stage, thanks to the availability of Low resistivity HPL panels @ industrial mass production quality level

HPL low resistivity Intellectual Property (IP) and licensing:
CERN KT and INFN TT have defined a protocol for IP concerning the low (controlled) resistivity HPL panel production.
Agreement for licensing of low resistivity HPL panel production to Teknemika and Puricelli under discussion.

Production of gas volumes

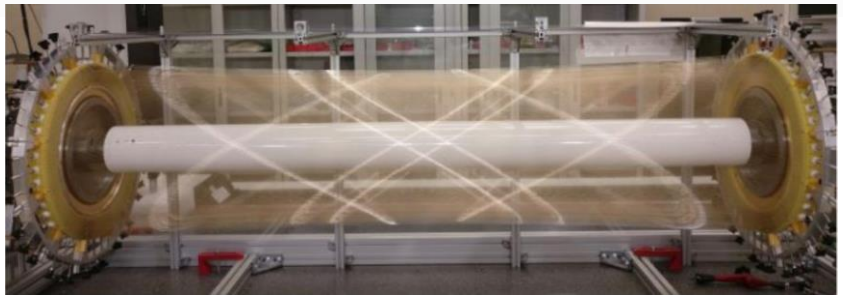
ATLAS collaboration with industry

GAS volume assembled by GT company, very long collaboration, full access to the premises for inspections, tests and local QA/QC of the material/products; but also possible single point of failure. Eventual knowledge transfer to a second company is considered too long and expensive.

CMS Production in house Kodel University (Korea)

All the gas gaps for the CMS RPC endcaps (576 + spares = 600) have been produced in Kodel University site.
They are able to QC the received bakelite, prepare the bakelite panels with graphiting and PET coating before the gap manufacturing with spacer gluing.
Produced gaps are qualified in term of pop up spacers, gas leaks and dark current value/stability.
Kodel site is now taking care of the gap production (200) for the CMS iRPC project with reduced electrode/gap thickness.

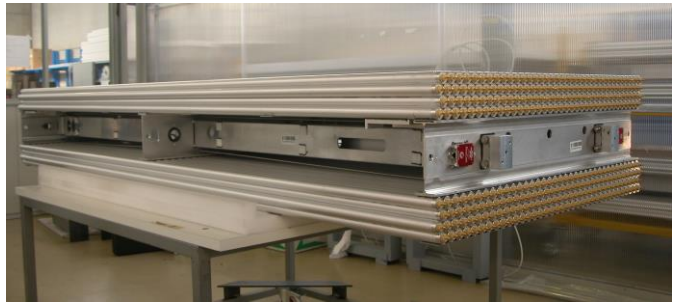
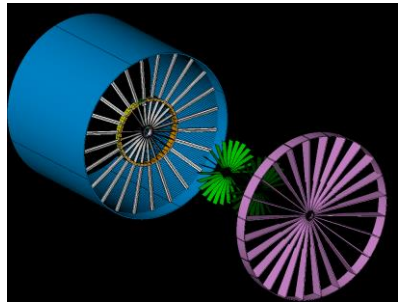
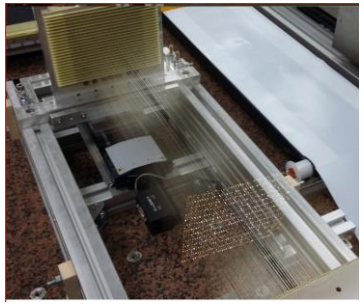
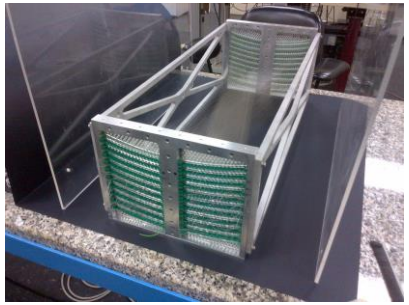
Relation with Industry in production of Drift Chambers



Production of Drift Chamber quite different case

- **Single piece per experiment (may with 1:1 size prototype)**
- **Relative smaller collaboration (Institutes)**
- **Expertise now concentrate in reduced number of Departments**

- *Relation with Industries in the composite material field: "Stesalite", "Carbon Fiber", "Carbon Fiber/Cyanate Ester"……*
  - Fundamental to stimulate their interest by proposing technological challenges to which, in general, production companies are not very sensitive, because they are not very very profitable
  - In some cases, relatively small detectors could turn in economic loss for such kind of company
  - Project used to get credit from known research institutes and as flag projects for publicity on regular market
- *Relation with design and mechanical engineering company*
  - CETMA in Mesagne: Extremely collaborative, suggesting specific innovative solutions based on their experience (**F. Grancagnolo feedback: this time it was we who benefited from who benefited from the existing technological innovations, rather than proposing them**). Perhaps due to its non-speculative nature, CETMA by statute the consortium invests all consortium invests all its profits in research and innovation.
  - EnginSoft: Software consultancy, research in the field of scientific and engineering simulation. Involved in the innovative mechanics concept for drift chamber of the 4th-Concept the 4th-Concept at ILC (never approved) and IDEA detector proposed at FCC-ee and CEPC. The collaboration took place through internships of our mechanical engineering engineering undergraduates at their headquarters, possibility to use software which the purchase of the licenses were not affordable
- *Relation with automation company*
  - NI: Realization of the automated wire positioning system of the drift chamber for MEG upgrade of MEG. Robot, totally controlled and synchronized by NI electronics, makes use electronics, makes use of a 5-axis system for the simultaneous wire of a multi-strand layer (32 threads) with controlled tension (50 mg) and positioning (20 microns.) Laser microns.) Laser soldering machine integrated in the controller

Conclusions

- Relations with industry plays a crucial role in the construction of large particle physics experiments. The huge number of detector components would make use of the most advanced technologies that are expected to reach full industrial maturity after the end of the project.
- Extremely challenging requirements of future HEP experiments call for close collaboration between academia and industry. This collaboration should start as early as possible and address prototyping at the R&D stage, through to qualification testing and later tendering and purchasing.
- Good knowledge of the possible industrial applications are required to increase the chances of successful collaborations with industry.
- To motivate industrial partners to invest in sophisticated production lines for building detectors, scientific collaboration must convince (ideally prove) industry that such detectors have a real market potential beyond particle physics
- Very long turn-around within subsequent production could revert into know-how loss, both in the Physics Collaboration both in the Industry
  - Constant communication and continuous production, even if at very low intensity, should be guarantee to assure correct knowledge transfer/maintenance

We should not forget our role as "Academia" and HEP community in Relation with Industry, we are not customer or at least "not standard customer", but we should be a disseminator of knowledge

Backup

Technology transfer done by CERN MPT

Name	field	Company /institute	size	TT effective ?
Techtra	GEM	C/I	small	yes
Mecaronics	GEM	C/I	large	yes
Micropack	GEM	C	Large	on going
Eltos	MM	C	Large	yes
Elvia	MM	C	Large	yes
CIAE Beijing	GEM	I	Small	no
CEA	MM	I	Small	yes
VECC Kolkata	GEM	I	Small	no
Tech-etch	GEM	C	Large	Yes

The situation of the 4 big players of the list

- Eltos activity was really linked to ATLAS NSW , they have accumulated great know-how , can they keep it?
- Elvia is in a similar situation as Eltos.
- Tech-etch already made a step back when they understood the market model.
- Mecaro is really linked to CMS project .Will they continue to serve the full community after CMS ?

→ Companies are mainly looking for large stable contracts

Conclusions #2 Provocative

- Relations with industry plays a crucial role in the construction of large particle physics experiments…. ….. must convince (ideally prove) industry that such detectors have a real market potential beyond particle physics

some time the goal with industry seem to be the outsourcing of complete detector production
…But

- ***Are (or can be) HEP detectors (Gas detector in our case) a real Industrial Product?***
- ***Academia attitude is to push over the limits / Industrial attitude is to produce standardized & very well qualified products; may non-convergent views ?***
- ***Could an "exaggerated industrialization" revert in reduction of our community attitude to detectors innovation?***