SD-HCAL technological prototype – Chamber and cassette production

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Considerations for a technological prototype

- Build one HCAL module for testing in beams at CERN and / or Fermilab
- Simplifications:
  - All detectors 1m x 1m
  - Only 40 planes (possibility to extend to 50)
- Challenges:
  - Detector + electronics thickness < 6mm
  - Minimize dead zones
  - Homogeneous gain
  - Efficiency >90% + minimize multiplicity
  - Full integrated electronics with power pulsing
  - Realistic support structure for absorbers + RPCs

Chamber performance: key design parameters

- Homogeneity of gain / efficiency
  - Constant gas gap over large areas
  - Efficient gas distribution within chamber
  - No air gaps between readout pads and anode glass
- Optimization of multiplicity
  - Absolute value of coating resistivity
    - Higher values give lower multiplicity
    - Lower values improve rate capability
    - Compromise: 0.5-10 MΩ/□
  - Uniformity of resistivity over surface

Resistive coating

	Licron	Statguard	Colloidal Graphite type I	Colloidal Graphite type II
Surface resistivity ($M\Omega_{/\square}$)	~20	1-10	~0.5	Depends on mix ratio; choose ~0.7
Best application method	Spray	Brush	Silk screen printing	Silk screen printing
Cost, EUR / kg	130	40	670*	240*
Delivery time (weeks)	3	<1	6	6

*Estimate $20m^2$ (10 chambers) / kg using silk screen printing technique

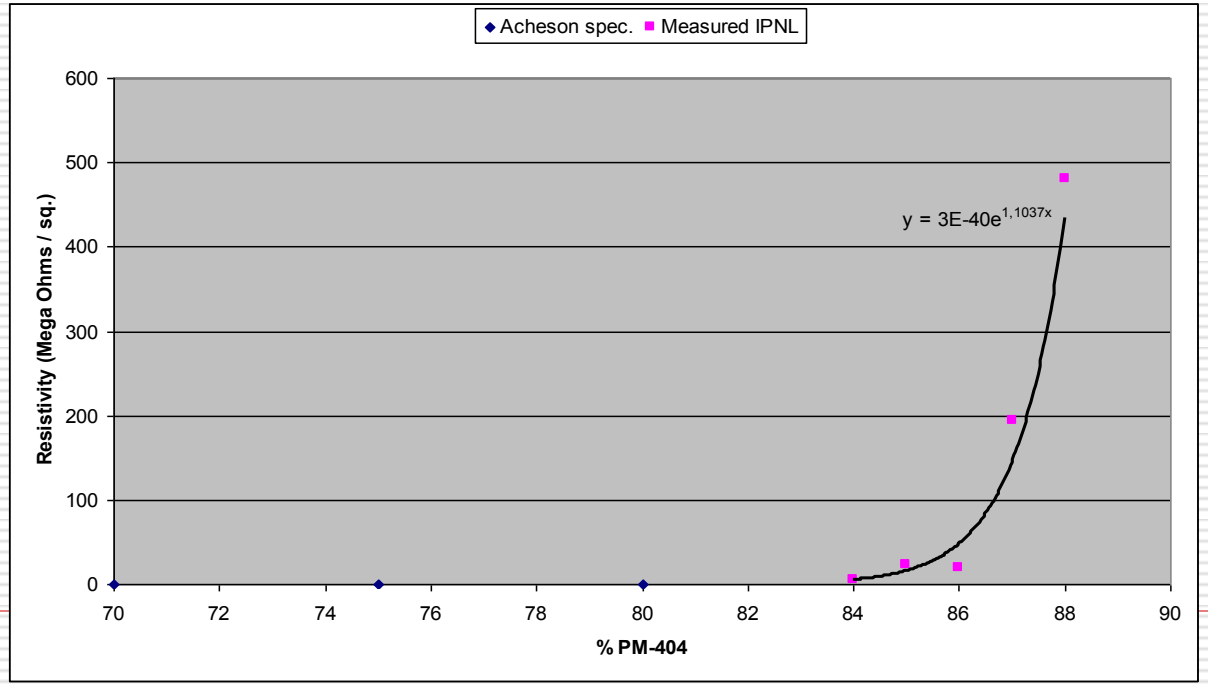
Licron: fragile coating, problems with HV connections over time
Statguard: long time constant for stable resistivity (~2 weeks), poor homogeneity

Baseline for $1m^3$ is colloidal graphite type II

Resistivity as a function of mix ratio

Company spec. →

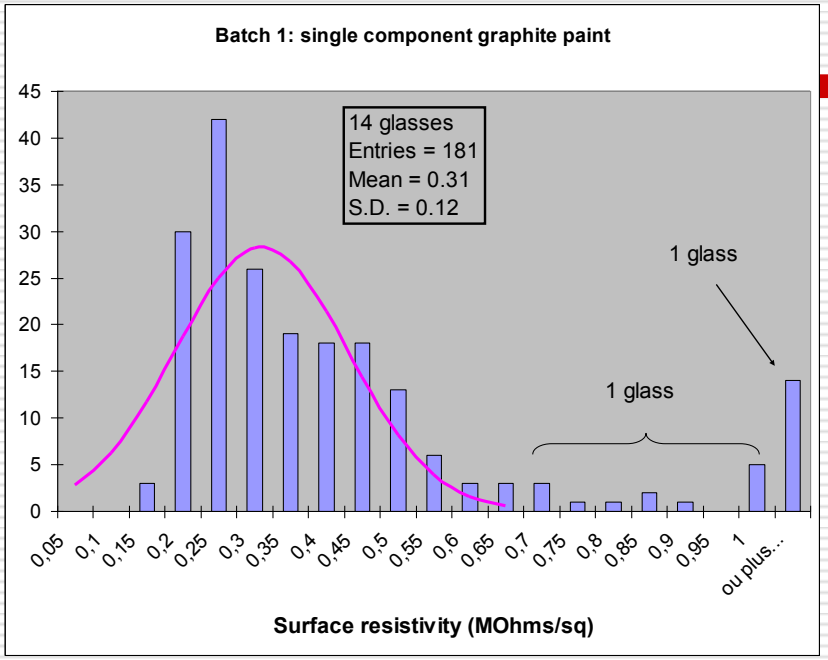
Electrodag 6017 SS (% by weight)	Electrodag PM-404 (% by weight)	Approx. sheet resistance (Ohm/sq. at 25 µm dry coating thickness
100	0	35
90	10	50
80	20	70
70	30	105
60	40	170
50	50	290
40	60	675
30	70	2160
25	75	4500
20	80	35000
10	90	$> 10^9$

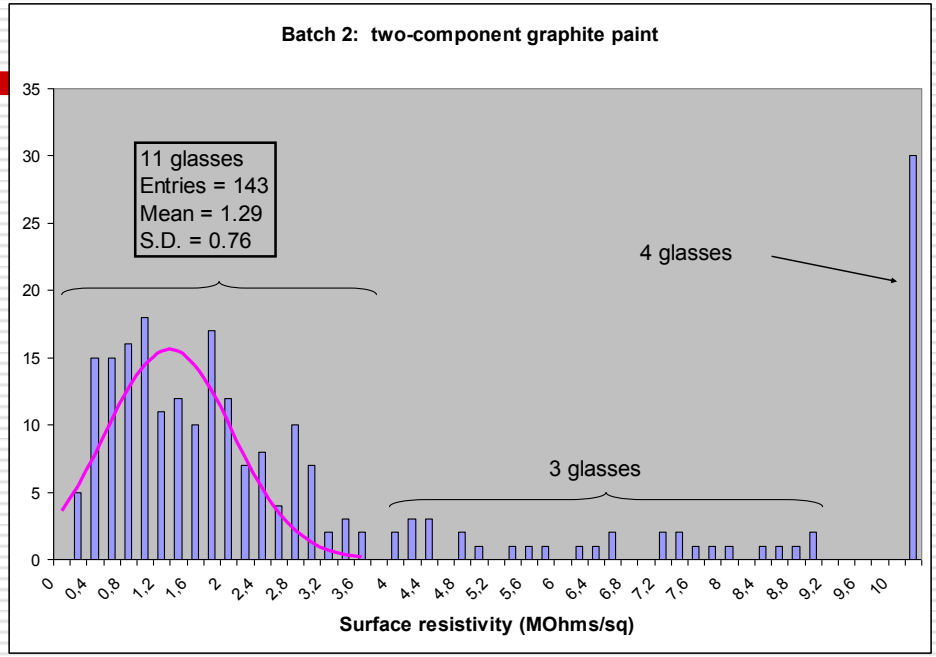


Silk screen printing at local company

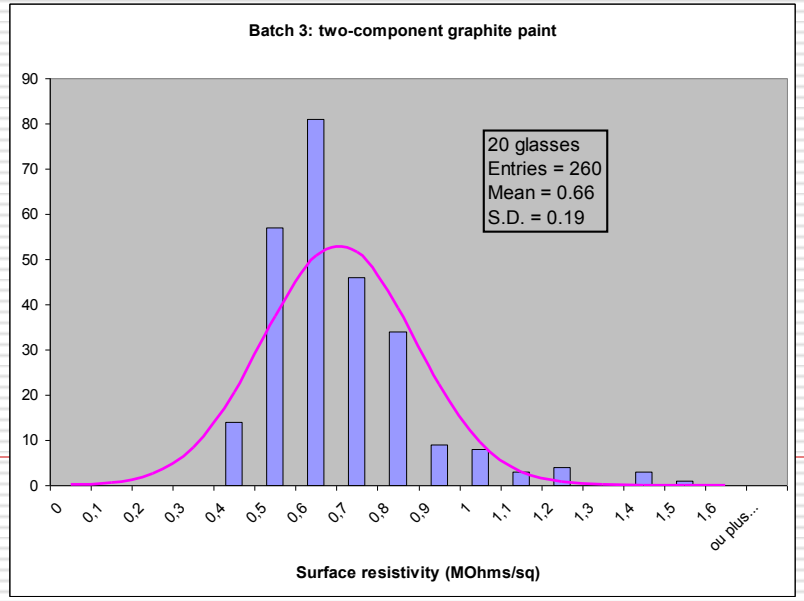
Product requires curing at 170°C – company has suitable drying tunnel

Surface resistivity: first 54 glasses (27 RPCs)

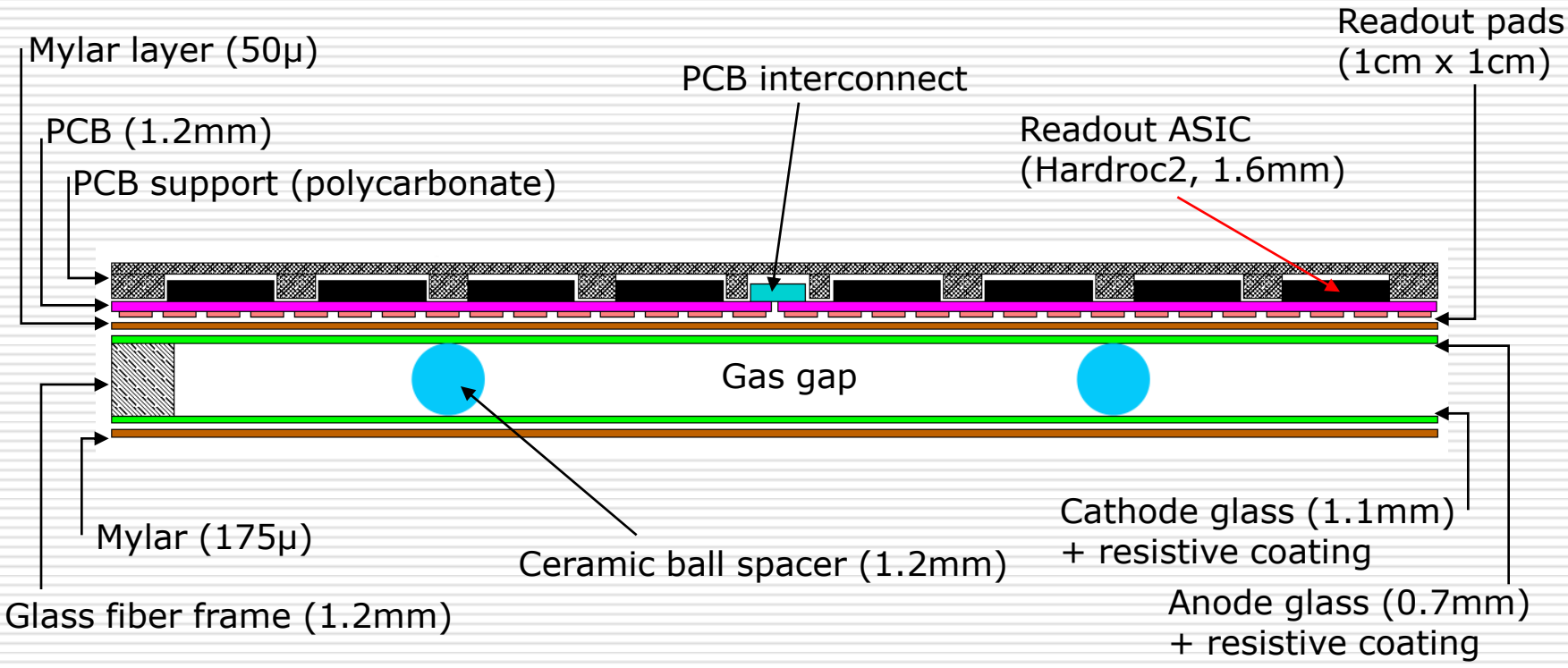




13 test points / glass

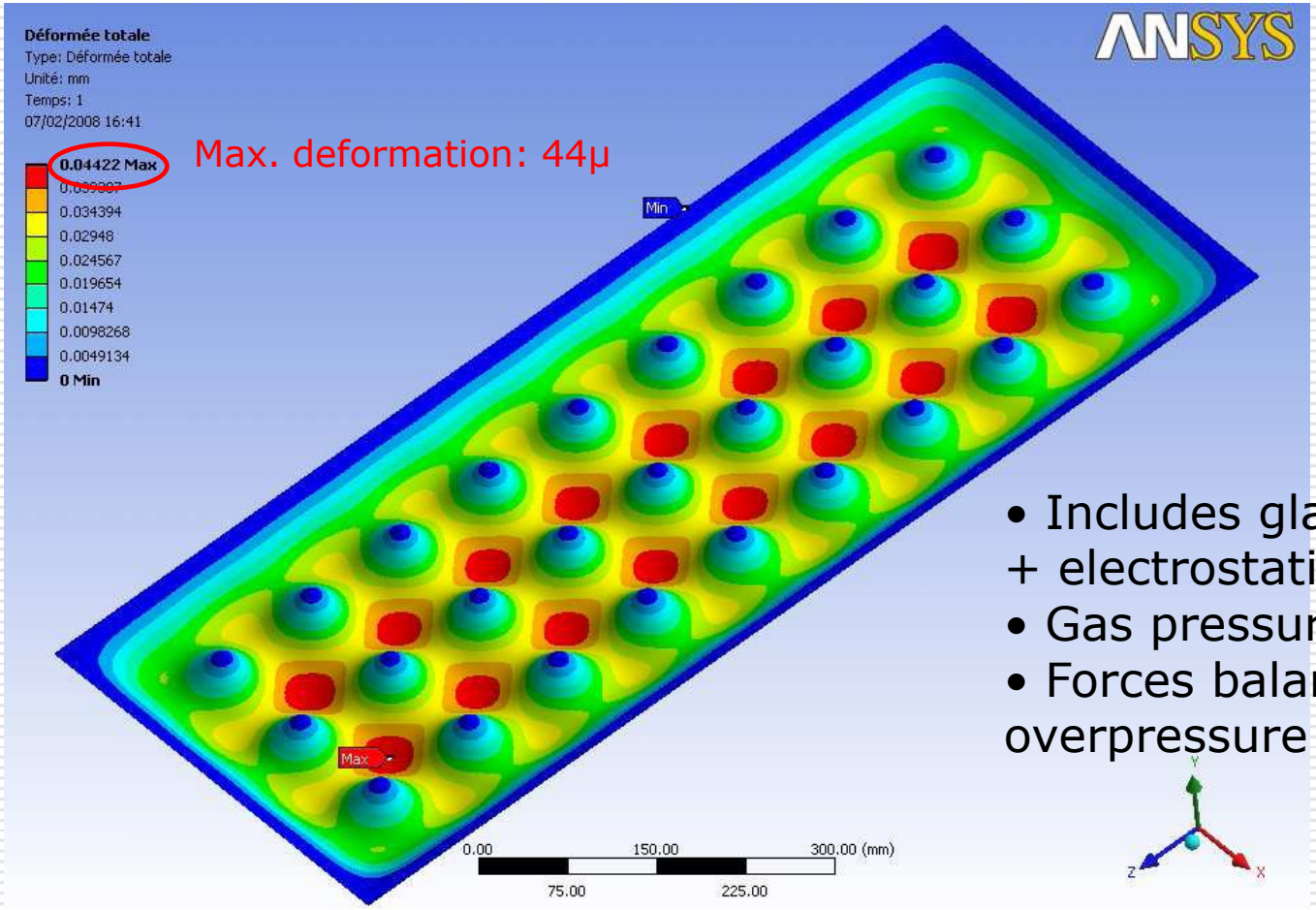


Cross-section of Lyon 1m^2 glass RPCs



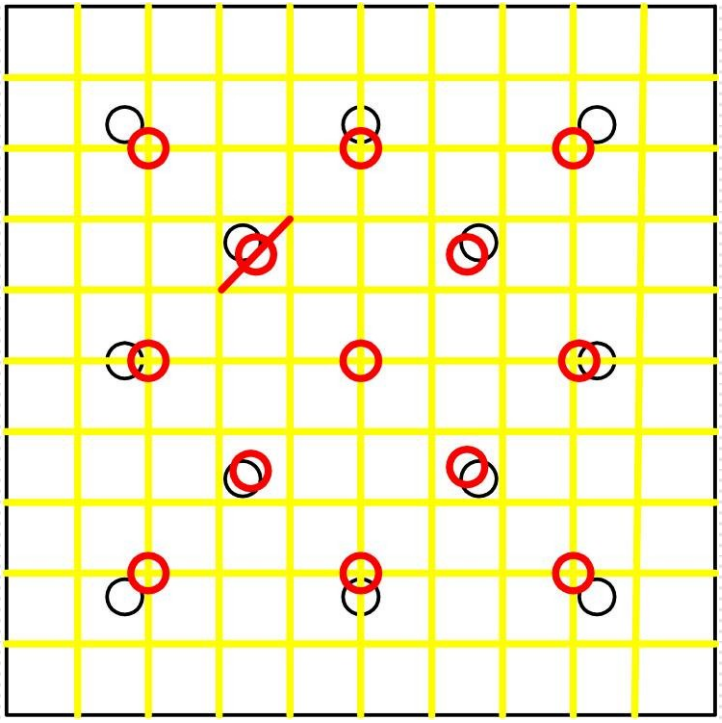
Total thickness: 6.025mm

Ball spacing – FEA study



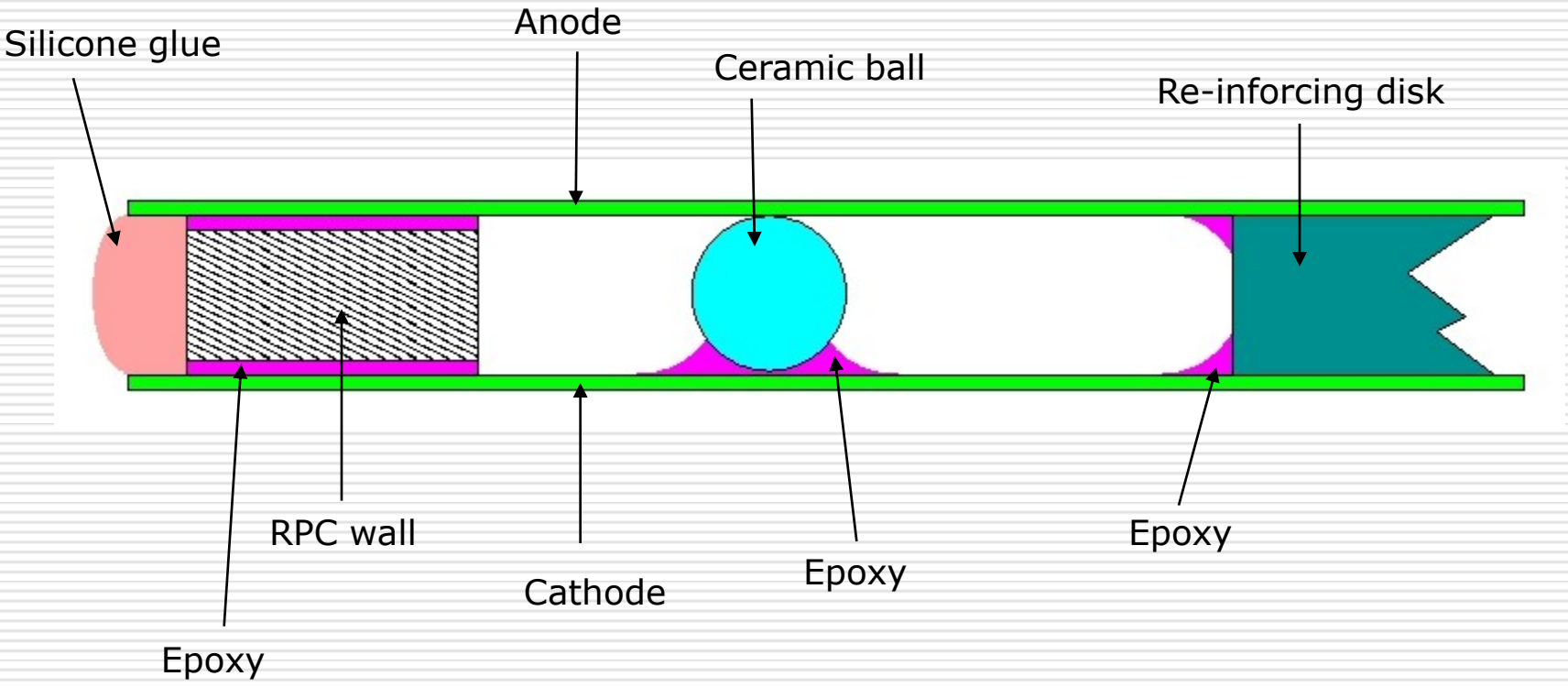
- Includes glass weight + electrostatic force
- Gas pressure *not* included
- Forces balance for 1mbar overpressure

Re-inforcement spacers



- FR4 spacers 6 mm diam. x 1.15 mm glued at red positions
- Yellow grid indicates ceramic ball positions
- 81 balls + 13 re-inforcement spacers

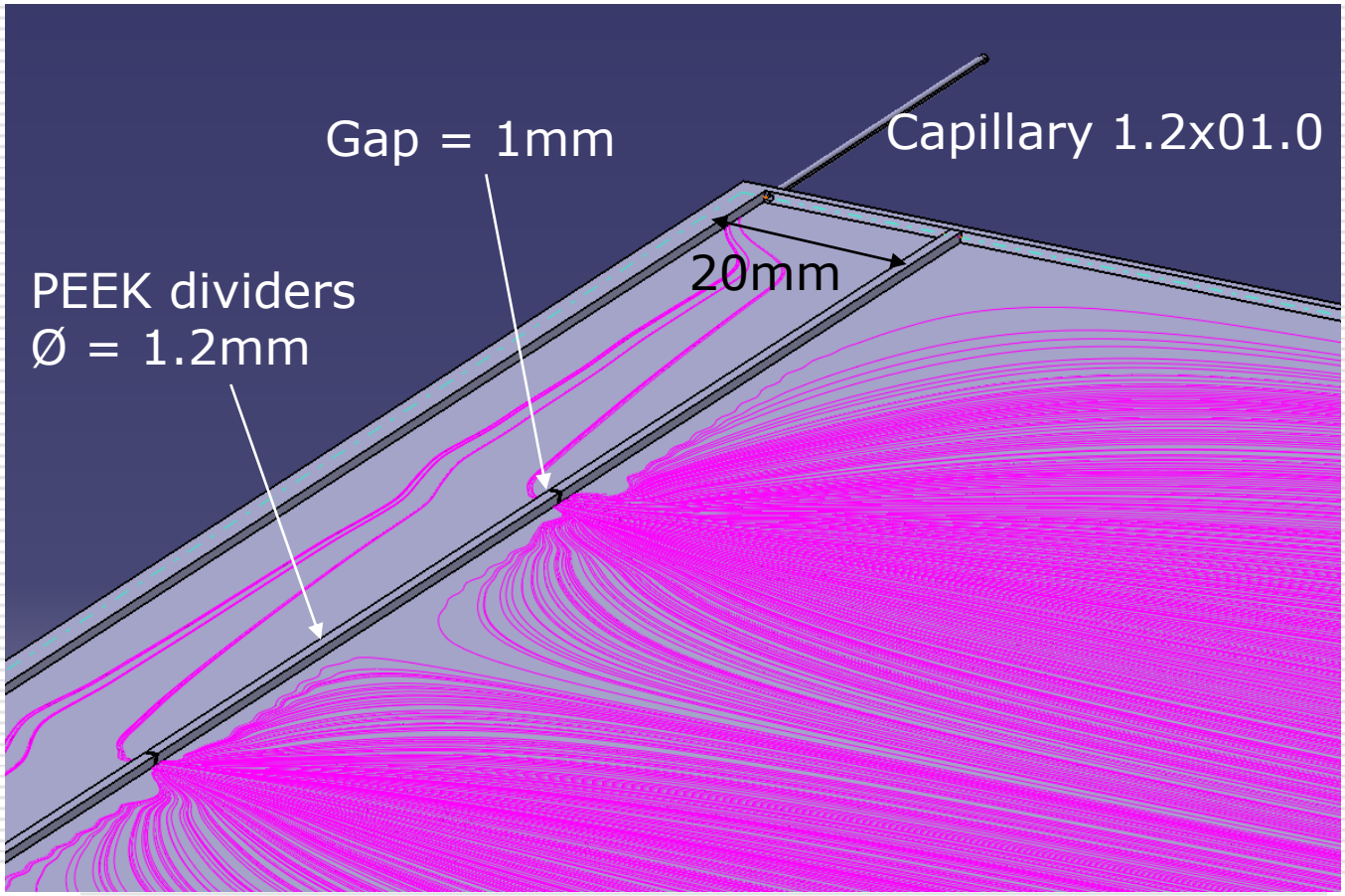
Chamber gluing details



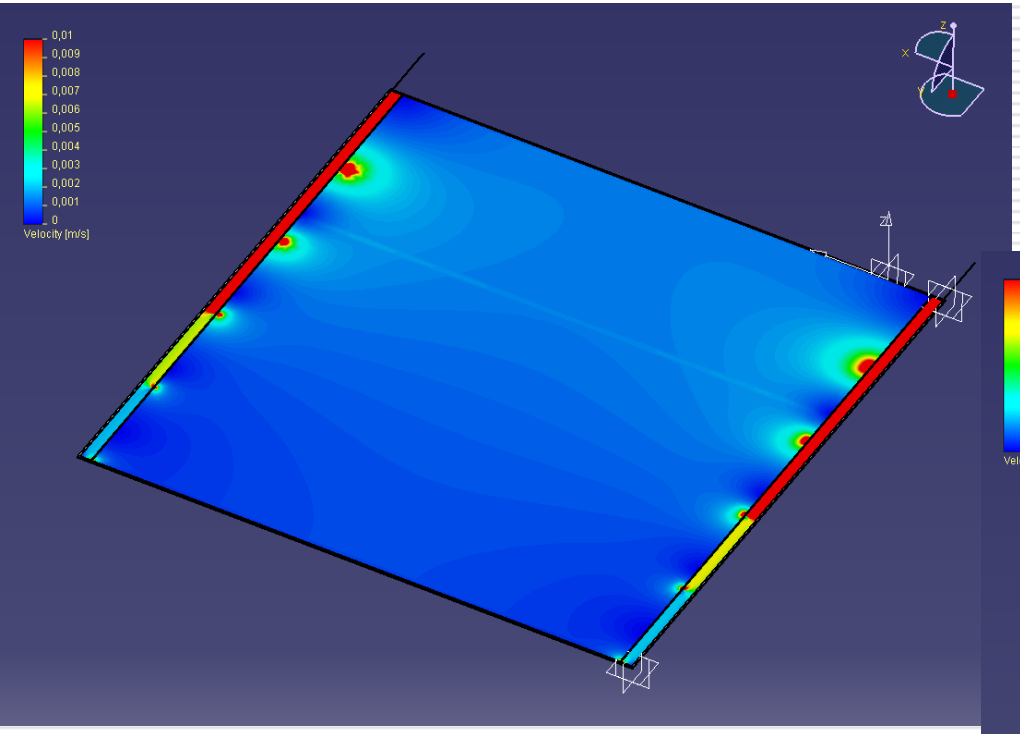
Weights used to ensure flatness during glue drying

Gas distribution

May be an issue for large area, very thin chambers

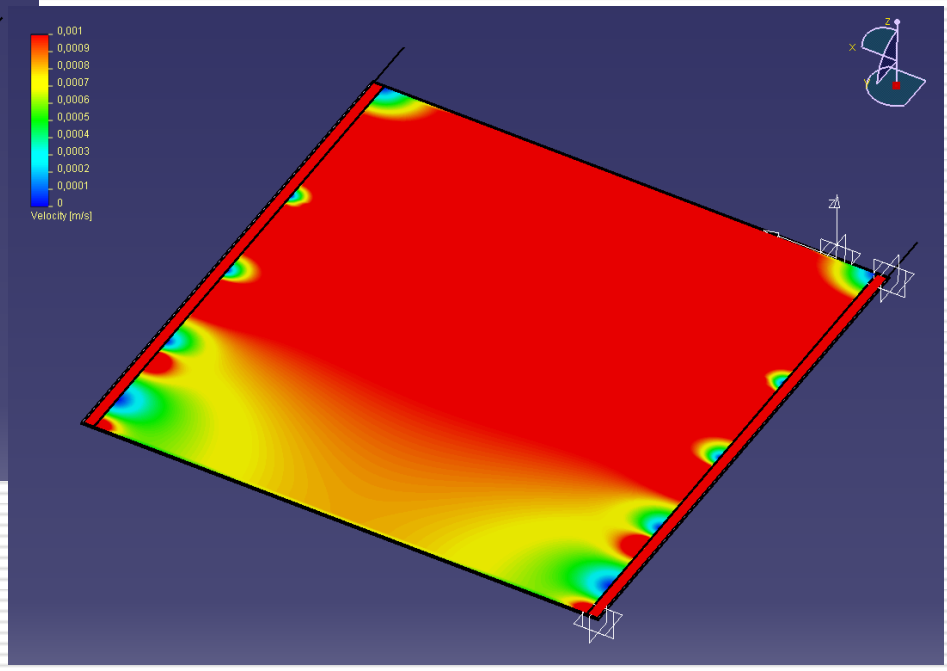


Gas - speed distribution



Boundary conditions:

- Inlet flow = 3.6 l/hr
- Outlet press = 1 atm.



Scale: 0-10 mm/s

Does not include diffusion effects

Scale: 0-1 mm/s

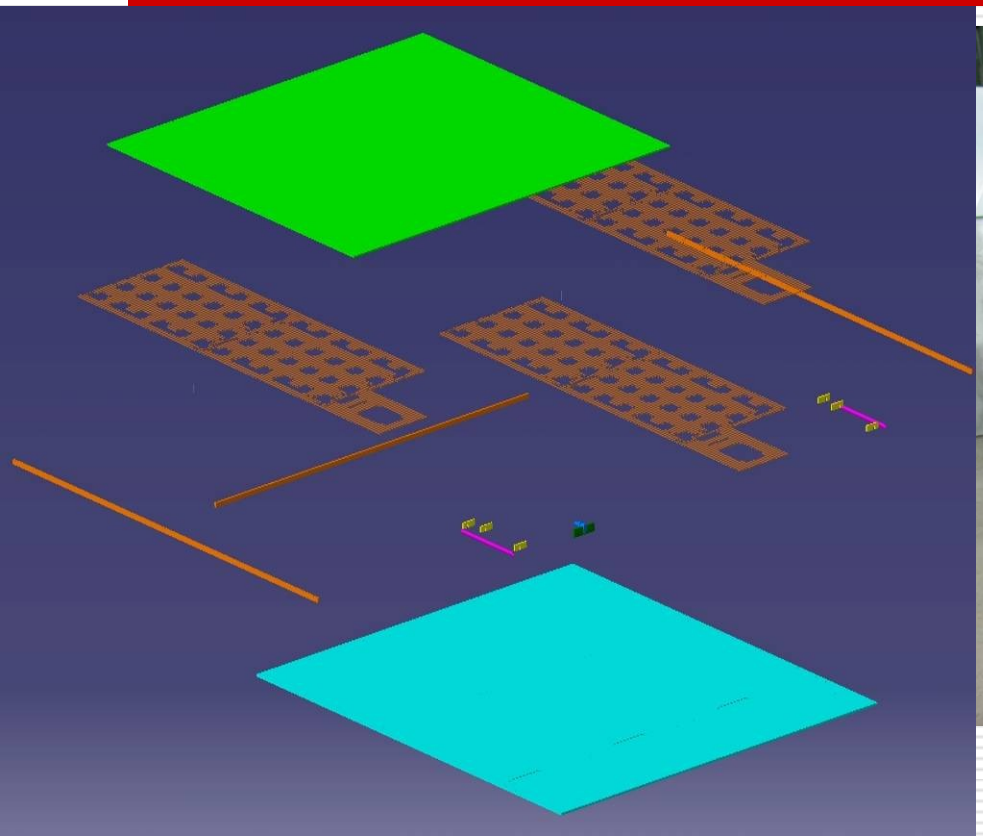
Quality checks: RPCs

- Tin-coated side of glass identified prior to silk-screen printing (paint always on this side)
- Systematic measurements of surface resistivity of coated glasses:
  - 13 measurement points per glass
  - Commercial concentric ring probe to EN 61340-5-1 and ESD-S11.11
- Chamber walls fabricated in-house – thickness checked after production
- Thickness of assembled chambers checked for first units (3.0 mm); this is not measured systematically

Cassettes: components

- Stainless steel plates: laser cut by local company
  - Basic dimensions and cut-outs for DIFs
  - Many threaded holes for assembly, ASU fixation, DIF fixation, HV connectors, LV connectors, gas pipe supports,…
- Walls: standard bars from local company (see later for problems)
- DIF supports: local company
- HV + LV connector supports: in-house
- Gas pipe supports: in-house
- Attachments for crane manipulations: in-house

Protective cassette for RPC + electronics

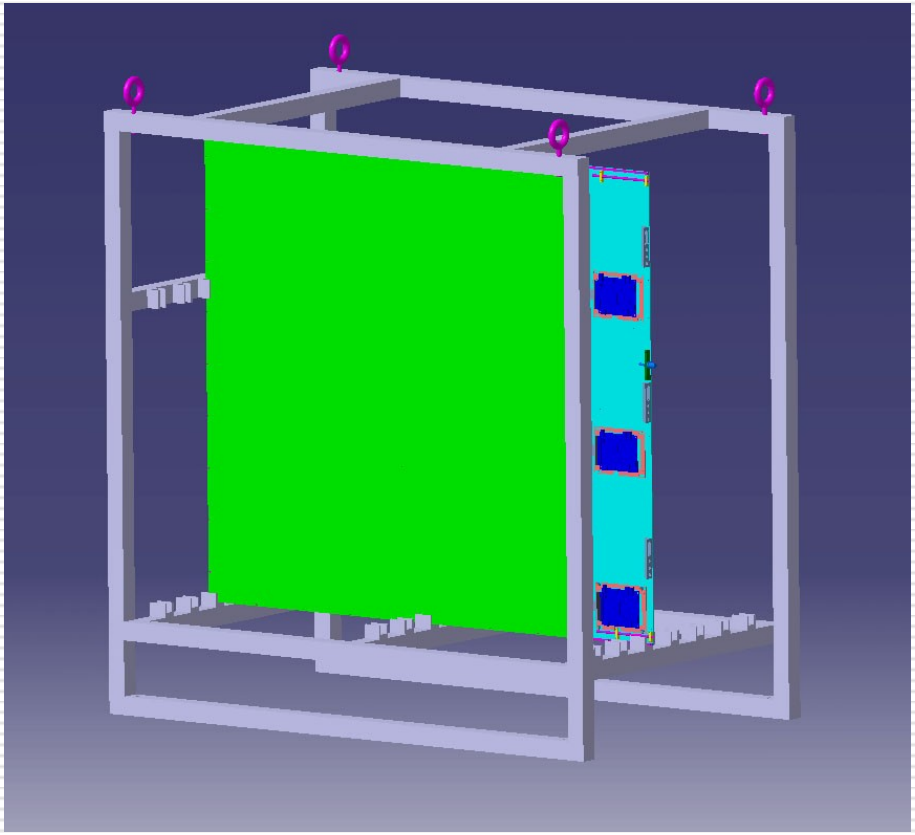


- 2x SS plates 2.5mm thick
- Contribute to absorber layers (15mm + 5mm)
- PCB supports in polycarbonate cut with water jet
- PCBs fixed to support using M1.6 screws

Cassettes: assembly

- Walls screwed to lower plate
- Lower 175μ Mylar cut and formed, placed in cassette
- Chamber slides into cassette
- Add silicone glue lines between chamber and cassette walls
- Add upper 50μ Mylar
- Scotch PCB spacer layers to upper plate
- Fix assembled PCBs to upper plate with M1.6 screws
- Close cassette with upper plate + electronics
- Fix DIFs to their supports and screw onto cassette
- Add supports for all connectors
- Solder HV connector to contacts on the glasses
- Fix gas tubes to cassette

Transport / storage racks



- For storage of finished cassettes
- ~50 kg / cassette: 7 cassettes per rack
- Welded tubular steel
- Relatively cheap: 7 racks ordered

Quality checks: full detector

- Thorough visual inspection and cleaning of all cassette components
- Visual check of bending of cassette cover (see later)
- Systematic verification of overall cassette thickness (11.0 ± 0.1 mm)
- HV test at 8kV
- Gas circulation test with dry air
- Transfer to dome for full readout testing

Problems and solutions (1)

- Chambers expand when gas introduced, breaking glue joints
  - Gluing procedure improved for upper (anode) glass
  - Reinforcement spacer distribution improved
  - Bubbler liquid levels reduced (Δp over bubbler found to be the largest pressure drop in the system)
  - $\Delta p = \rho g h = 0.9$ mbar $\equiv 90$ N/m^2 for 5mm oil height
- Electronics not in full contact with anode glass when cassette vertical, leading to reduced detector efficiency
  - Cassette covers are passed through a rolling machine to make them curve slightly inwards – ensures light pressure on electronics

Problems and solutions (2)

- Difficulty in manufacture of cassette spacers
  - Original design required 6.15 x 5.00 x 1440 mm stainless steel bars
  - Machining of bars introduced unacceptable curvature
  - Solution: reduce chamber thickness by 0.1 mm and use standard 6 x 6 mm bars
  - Dimensional tolerances off the shelf are very good (±50 μ)
  - But adds ‘unecessary’ 2mm to overall width of cassette

Conclusions + Outlook

- Construction of 1m^2 GRPCs with good detector performance well understood
  - Uniform resistive coatings
  - Constant gas gap + optimized gas distribution
- Construction of 50 chambers well underway:
  - Lab infrastructure and procedures in place
  - Glass, paint, spacers, etc. all in hand
  - 23 chambers already built
  - More than 50% of glasses already have resistive coating (final silk screen run within next 2 weeks)
- Cassettes designed and tested
  - 1 x final cassette + chamber + electronics assembled
  - 3 x final cassette + chamber assembled
  - 2 x final cassette + chamber being assembled,…