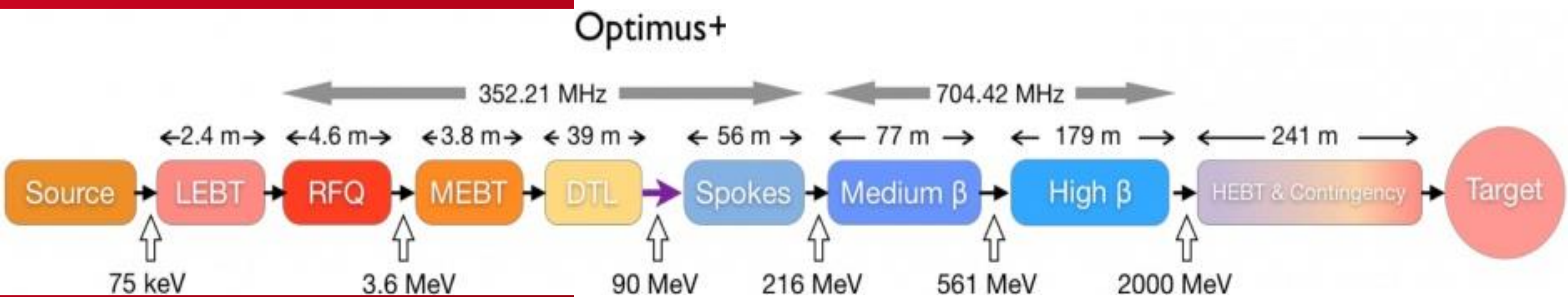
DE LA RECHERCHE À L'INDUSTRIE

IPM TEST BENCH DESIGN AND BEAM TEST STRATEGY



P. Abbon, F. Belloni, F. Benedetti, X. Coppolani, J.-F. Denis, F. Gougnaud, C. Lahonde-Hamdoun, J. Marroncle, V. Nadot, L. Scola

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OVERVIEW

electron/ion detection?

Read-Out

- RO presentation and their needs
- CS needs

test bench design and installations

test program

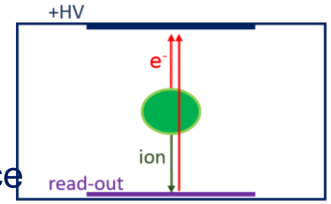
backgrounds and lifetime materials

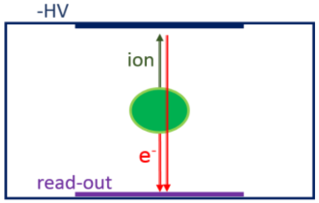
interfaces & risk list

draft planning

summary

ELECTRON OR ION DETECTION?





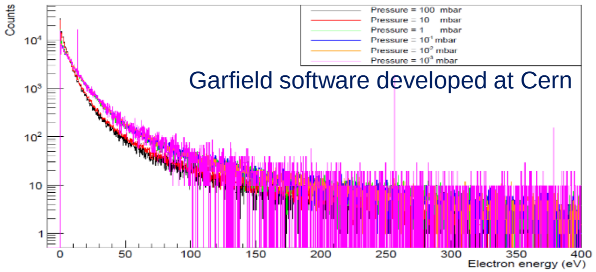
ions are interested at least for 3 reasons

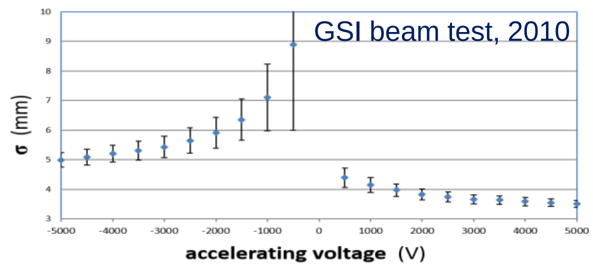
1. electron secondary emissions
   - if signal amplifiers (MCP, Si pixels) → SEE ≈ 0, since induced current ≈ 0
   - no Frish grid

2. Proton bean energy transfered to ions << electrons
   - Momentum conservation
     → K_e = 10 eV imply K_{H2+} = 2.7 meV
   - well known than profile with ions smaller than electrons (JL Vignet @ Ganil, G Cuttone et al., PAC 1997)

3. Space charge effect
   - Following what Francesca has calculated, ion profile are less sensitive to electron ones.

Proton beam energy transferred to electrons



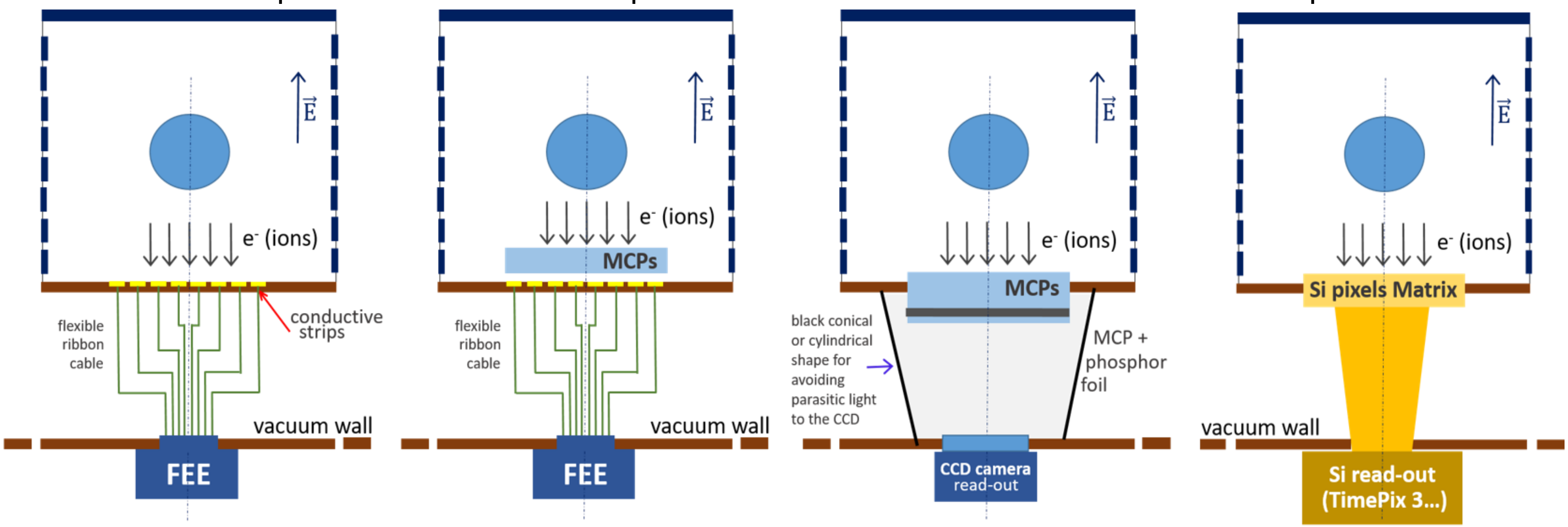


ions drawbacks

- very small depth penetration, even for 60 kV
  → enough to produce signal in TimePix3 for instance?
- induced damage in materials → to be investigated
- to be considered, deposit of MGO on MCP to increase the gain

Identification of 3 / 4 ROs we foresee to test

1. conductive strips **2.** MCP **+** strips **3.** P-MCP + CCD **4.** Si pixel matrix



1. CONDUCTIVE STRIPS

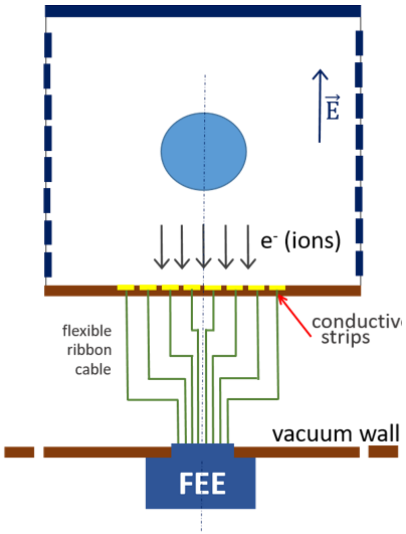
Conductive strips (copper on ceramics)

- strip width min = 0.4 mm
- ratio = 0.3 → minimum strip gap 120 µm

For nominal beam intensity

- DDC264 (TI) → linearity down to 50 fC (**conservative**)
  gain ≈ 10^4 missing

For beam tuning (I=6 mA) → **gain ≈ 10^5**

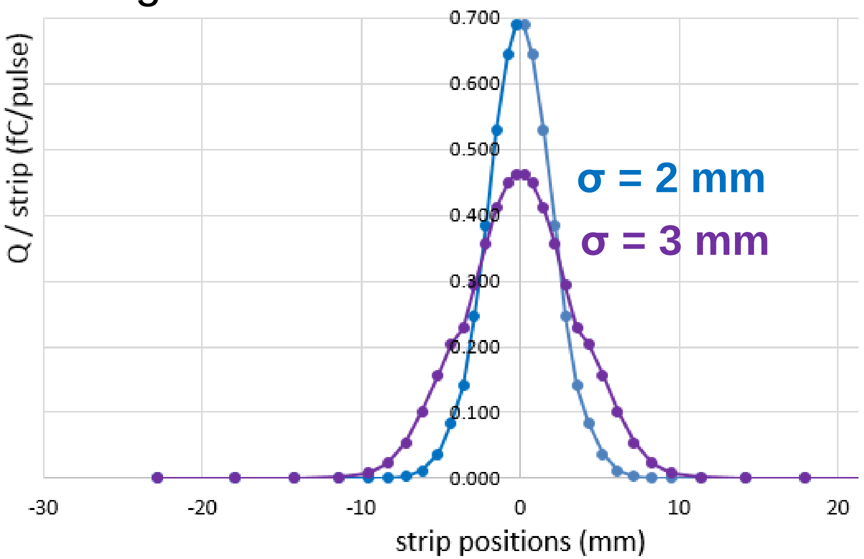


Expected charge on 32 RO strips, for 2 cm RO length at 2 GeV

Strips spread over ±24 mm = ±12 σ_0 (σ_0 = 2)

strip #	11 to 22	10-23	9-24	8-25	7-26
size	0.4	0.5	0.6	0.7	0.8
gap	0.8	0.1	0.12	0.14	0.16

Strip #	6-27	5-28	4-29	3-30	2-31	1-32
size	0.9	1	2	3	4	5
gap	0.18	0.2	0.4	0.6	0.8	1



1. CONDUCTIVE STRIPS (2)

Response test of DDC 264

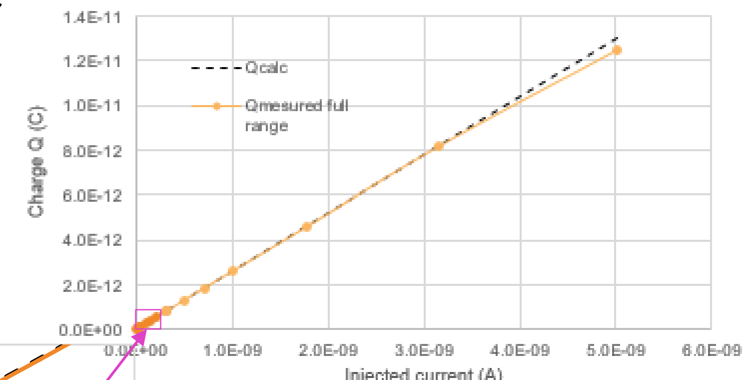
- very low DC current injection
- integration time = 2.6 ms

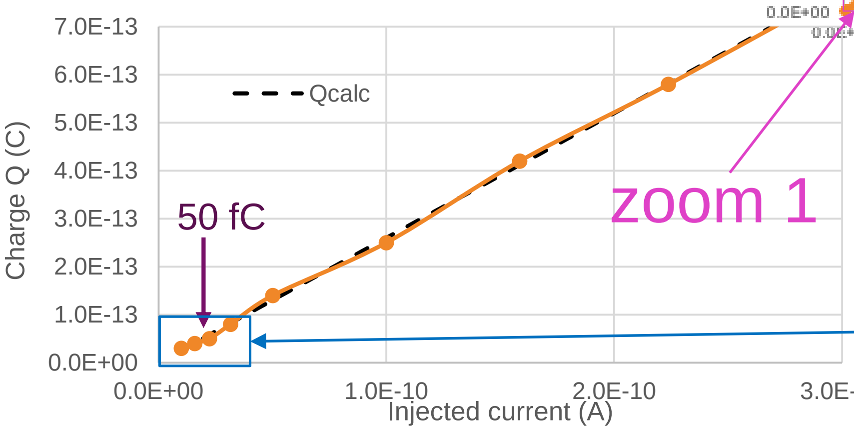
Response

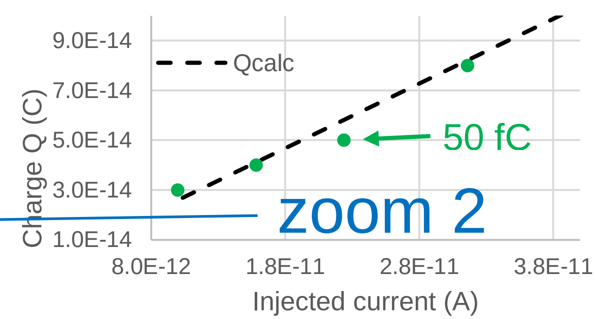
- linearity down to 50 fC (***conservative hypothesis***)

→ RO capacitance (cable length 50 pF/m → noise)

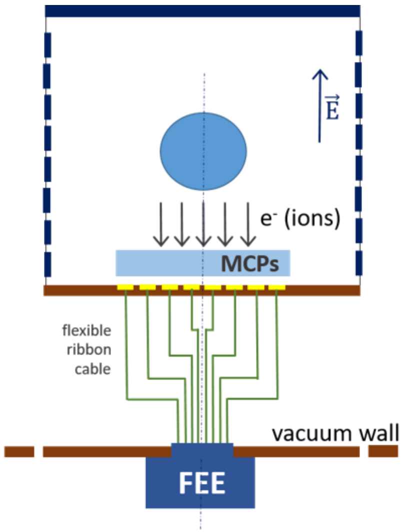
Note: for 2 m, extra noise is 1.6 fC







2. CONDUCTIVE STRIPS + MCP



MCP

- Hamamatsu insures gains of 10^4 for 1 stage, and 10^6 for 2 stages
  - active areas: 55×8 / 45×35 / 81×31 mm^2 (+6 mm)
  - thickness < 0.6mm

Insertion of MCPs in the IPM

- use the previous IPM with a mechanical system to mount and unmount MCPs

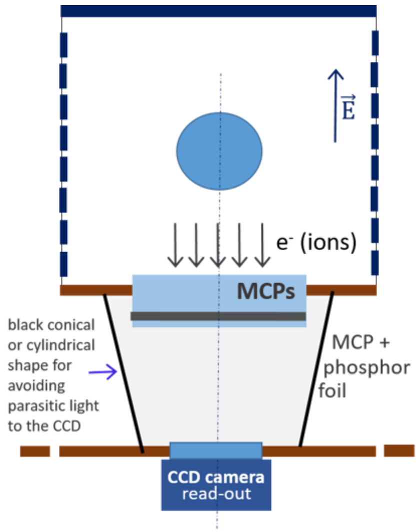
To be done for 1 & 2

- electric field study uniformity, with and without MCPs → COMSOL
- increase the IPM height (>10 cm) to avoid direct sight MCP wrt the beam pipe
- mechanical study, particularly the support of the IPM → lever arm
- CS
  - MCP → HVs + optical monitoring system (o.f. + laser light source)
  - Caramel card (32 channels) + SIROCO-AMC → µTCA (already done @ LPC Caen
- vHV implementation (up to 65 kV)
  - double polarity + / -

3. MCP + PHOSPHORESCENT SCREEN + CCD

MCP + Phosphorescent screen

- for instance Hamamatsu propose 1 stage MCP integrating a phosphorescent screen
- a light screen to avoid parasitic light entering in the CCD



CCD

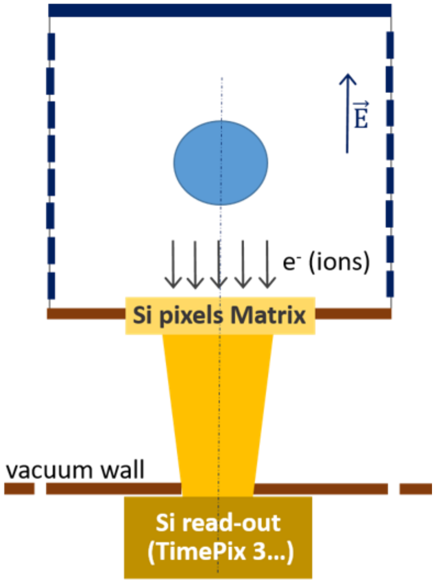
- lens system for adaptation
- Note: for beam test CCD can be installed behind the glass window. If CCD would be chosen, a coherent optical fiber bundle should be used for transporting image in an non radiative location

To be done for 3

- electric field study uniformity, with the MCPs → COMSOL
- mechanical study: for lever arm, same study as before
- CS
  - MCP → same as before
  - CCD data read-out
- vHV implementation (up to 65 kV) → same as before

Silicon matrix based on TimePix3

- beam test
  - FEE → Cern board with 1 TimePix3
  - Read-Out card → FitPix (COTS)
  - cooling system: to be investigated?
- Future with TimePix3 for final IPM → collaboration with J. Storey group @ Cern, contribution to the read-out process progress



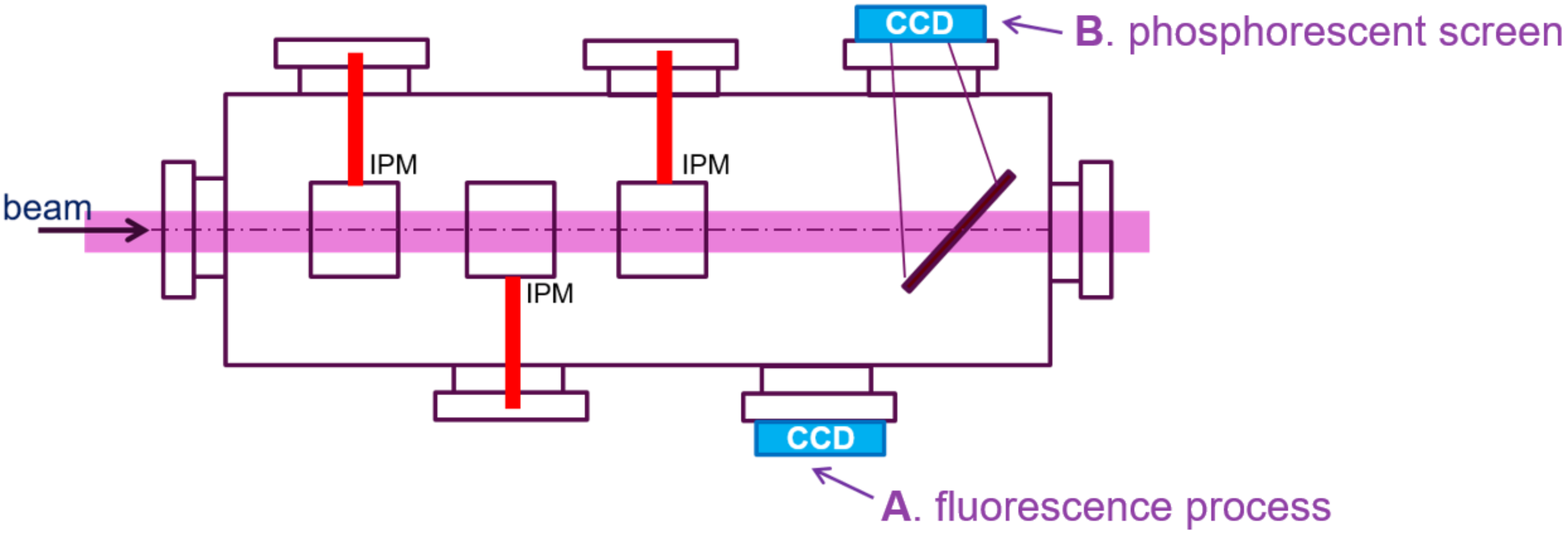
To be done for 4

- electric field study uniformity → COMSOL
- mechanical study → necessity for a cooling system?
- CS
  - FitPix → to be adapted
- vHV implementation (up to 65 kV) → same as before

BEAM TESTS ON IPHI – CEA SACLAY

Beam test into step

- Saclay (IPHI – proton: 3 MeV, up to 100 mA)
  - for development with our on-site specialists + measurements
- other facility, in the energy range of ESS
  - Jülich
  - PSI (Switzerland)
  - other facilities, GSI…



READ-OUT SYSTEMS FOR BEAM TEST BENCH

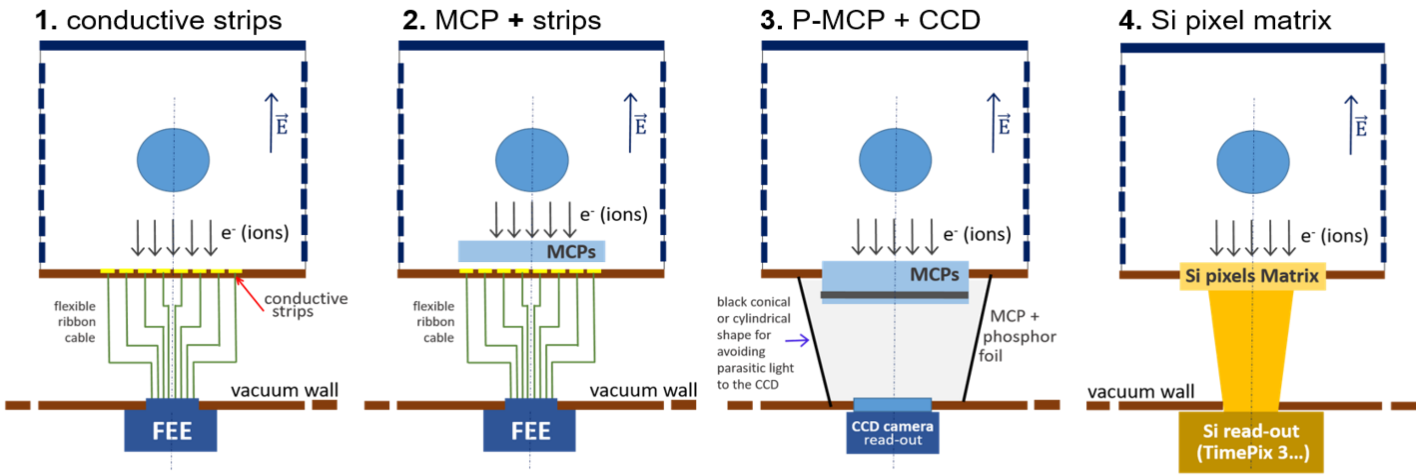
The 3 RO systems for the beam test of the bench based on EPICS

- ROs identified
  - COTS
  - Work on component already done with µTCA
- budget and HR* → AIK 7.3
- what for the final IPMs? still an orphan WP!

*HR → Human Resources

Read-Outs	#	Solution / to be done	COTS
conductive strips	1-2	Caramel + SYROCO_AMC	yes
MCP	2-3	HV monitoring	yes
CCD camera	2-3-A-B	calibration (o.f. + laser source light)	yes
phosphorescent screen	B	insertion monitoring (actuator)	yes
silicon pixel TimePix3	4	FitPix	yes
HV and LW	all	usual	yes
silicon pixel TimePix3	future	parallel coll. with Cern (development)	no

COTS → Commercial Off The Shelf
o.f. → optical fiber



ICS / PROTOTYPE TASKS

Man Power for the Read-outs of the beam tests

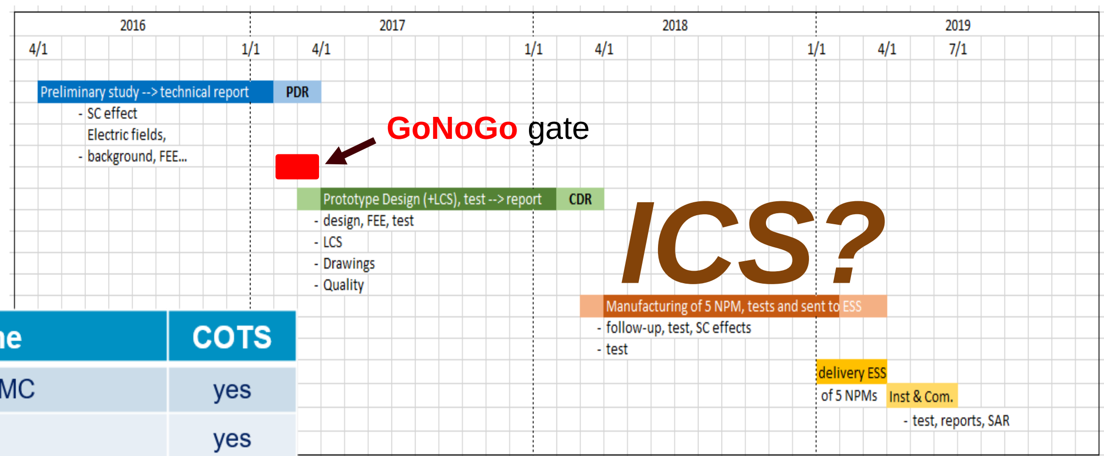
Victor Nadot (internship, involved in Françoise’s team since 9/2015)

Jean-François Denis (engineer, Victor’s adviser)

Françoise Gougnaud (ESS WP manager, already involved)

Man Power for manufacturing phase

Victor, Jean-François & Françoise



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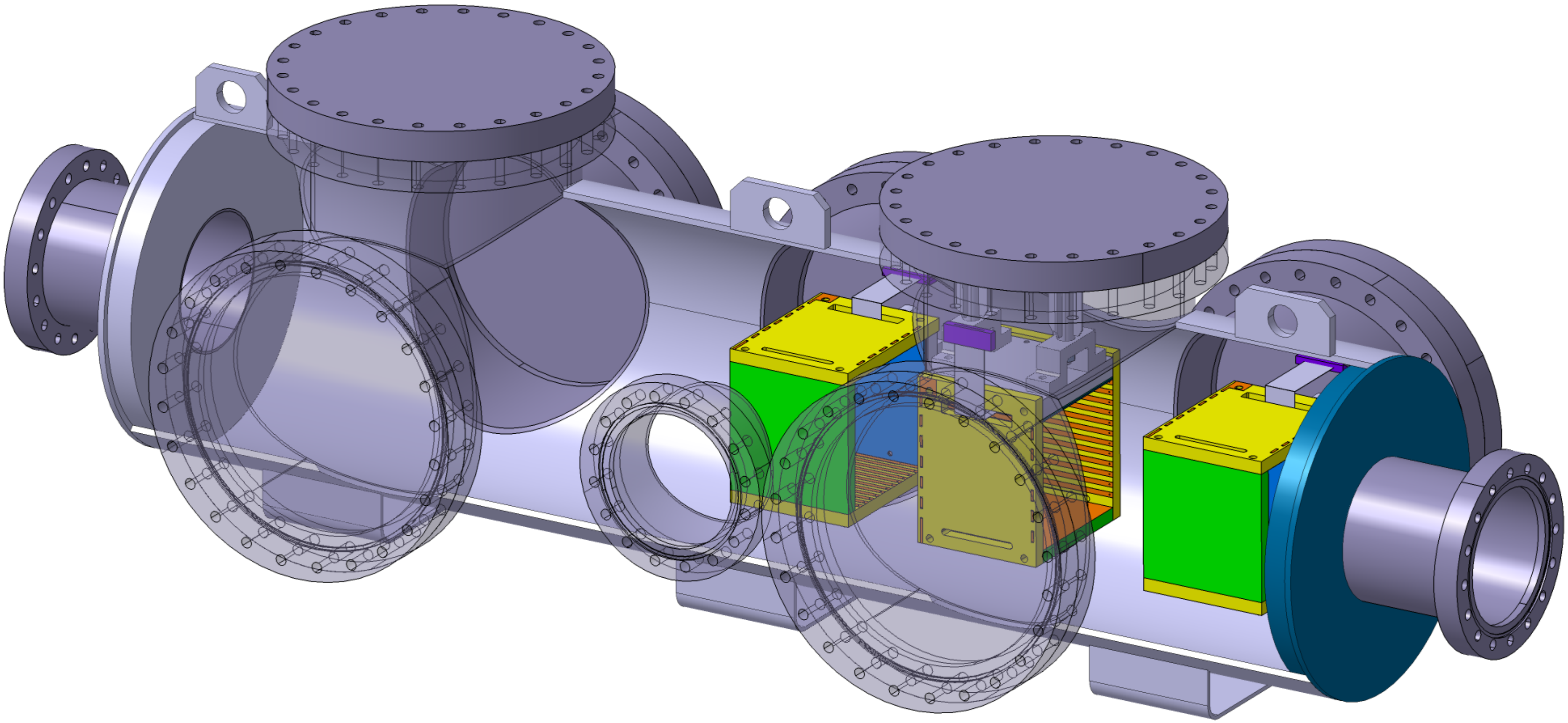
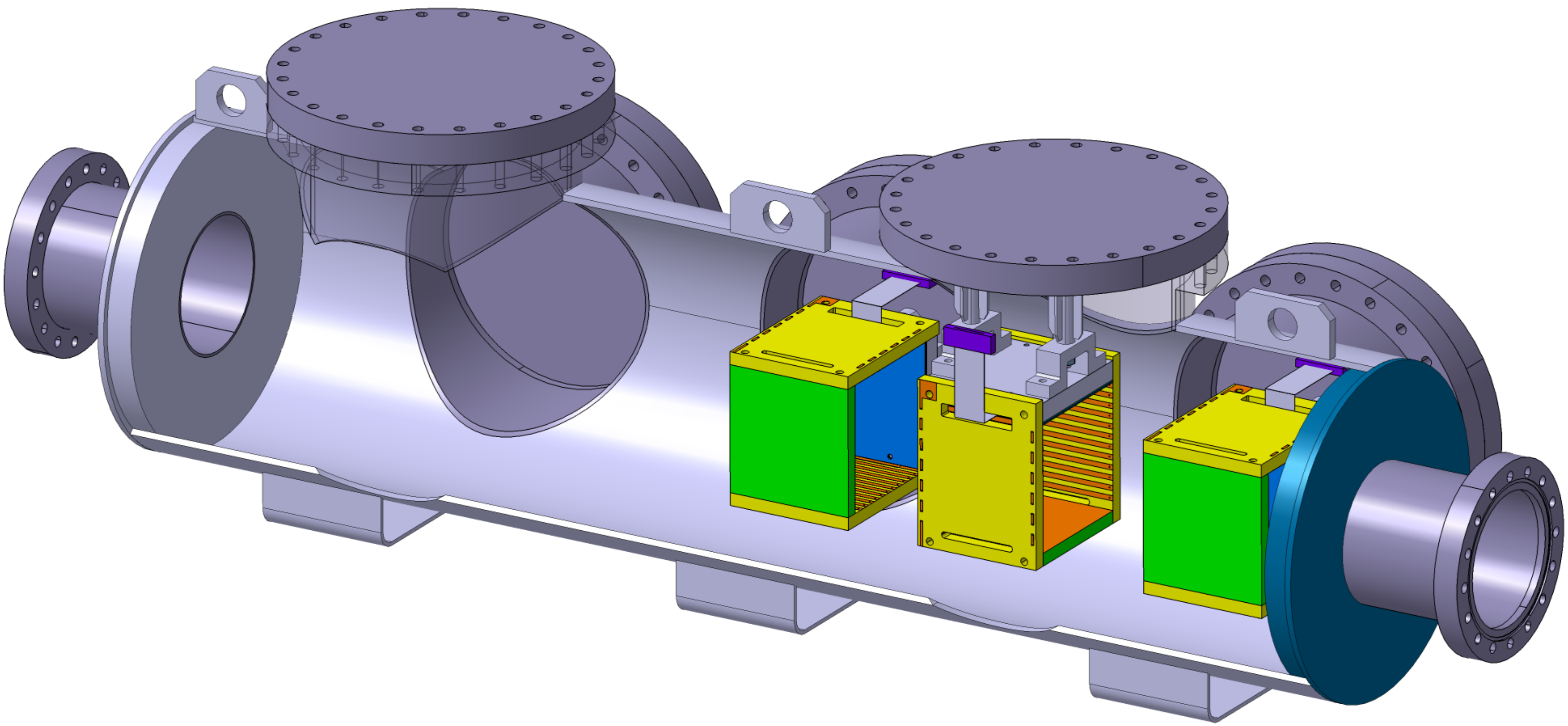
TEST BENCH



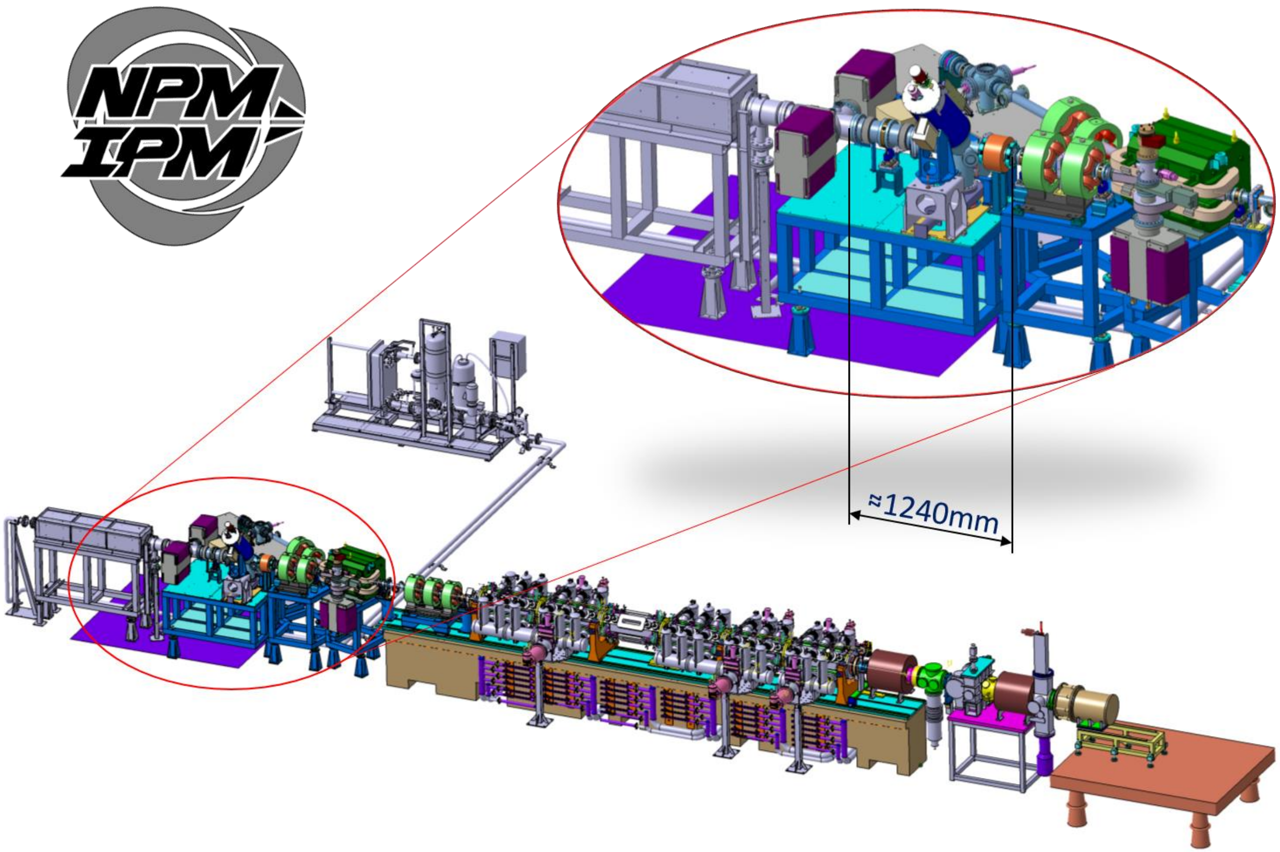
TEST BENCH



TEST BENCH SET UP AT IPHI

IPHI

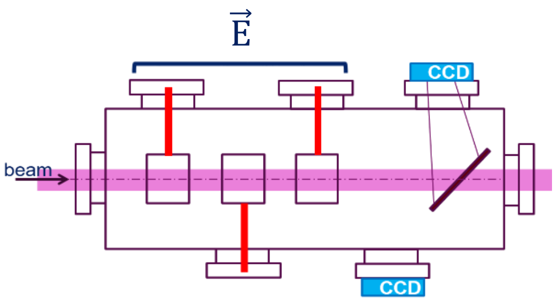
- Discussion with Bruno Pottin (Dec. 13th 2016)
  - welcome us for beam tests after Sept. 2017
  - identification of the bench test location



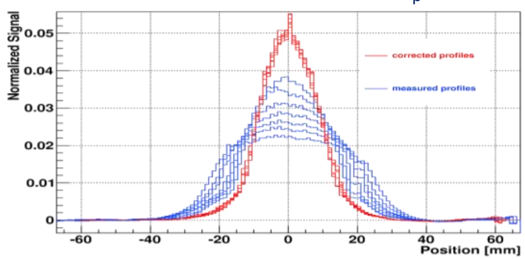
BEAM TEST PROGRAM AT IPHI

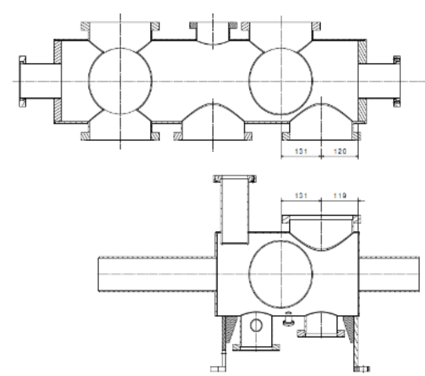
- Installation → after all system tuning
- Read-Outs checking
  - Frish grid effect
  - expected counting rate measured (B-B)
- uniformity of the electric field
  - comparison between $\vec{E}$ / no $\vec{E}$ read-outs (FPM, p-screen)
  - influence of interferences between 2 IPMs
- +/- HV polarity
  - ion detection: does it work? better result?
  - MCP, TimePix3: ion / electron
- Space Charge effect
  - once stabilized beam → beam parameters frozen
  - increasing and decreasing the IPM HV
    → comparison with SC calculation
- sparking effect
  - same entrance geometry VC / bench test
    → HV increasing
- and general improvements…

→ **Then ready to move to another test facility**



done on 01/2012, IPHI source 6 mA, E_p=90 keV





BEAM TEST IN ANOTHER FACILITY

Need to ask permission and availability (after GoNoGo)

- Jülich
  - Proton beam extracted from COSY
  - E_P = 2 GeV
  - cw 10^{10} proton/s = 1.6 nA
  - Vacuum? Down to10^{-6} mbar?
  - a priori quite large space to install our test bench
  - ESS agreement with this facility
- PSI in Switzerland
  - Cyclotron HYPA → E_P = 590 MeV, I = 2.2 mA
  - Cyclotron COMET (proton therapy) → E_P = 250 MeV

  → Is it even possible to get “parasitic” beam?
- GSI?

RADIATIVE BACKGROUND NEEDS

Available data are not convenient to use them for both following topics

- contribution of uncorrelated beam protons to the profile measurement (inside BP)
  - → need phase space of these protons for estimation (just checking)
  - → yesterday: Mamad meeting (tbd with Yngve)
- radiative dose for material ageing and choice (outside BP)
  - → need calculated doses for 1 W/m for IPM frame, read-outs…
  - → yesterday: Lali meeting (estimation with large error)

Quadruple hypothesis (around 24 cm)

- Made with iron
- Power deposited in quad: 0.01 – 0.1 mW/g → 0.06 mW/g

Read-out

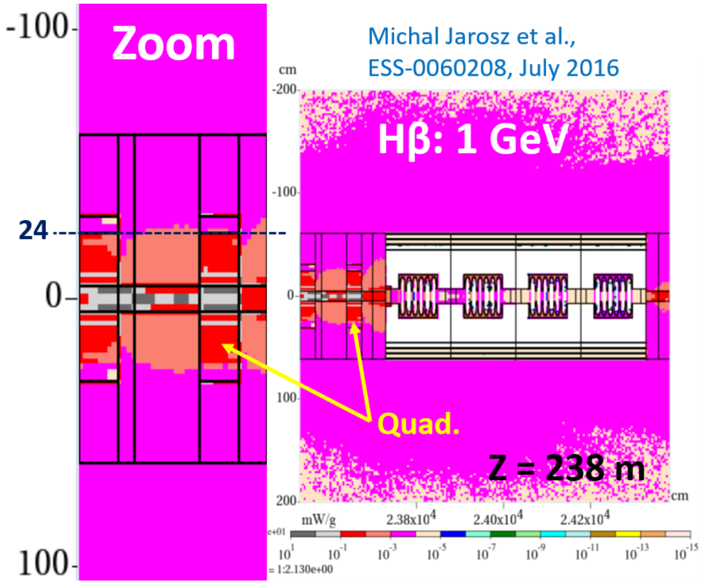
- Material
  - Silicon, PCB, electronic components → $\rho \approx 1$ g/cm^3
  - RO volume $\approx 1 \times 10 \times 20 = 200$ cm^3
- conservative hypothesis: same absorptions as quad!
  - 0.06 mW/g = 0.06 W/kg = 0.06 J/kg/s = 0.06 Gy/s

"Maximal" yearly (6000 h) power deposited in Read-Out

- $0.06 \times 3600 \times 6000 = 1.3$ MGy/year

Caution: such a value can be seen as a "maximal" power yearly deposited in a RO part located closer to 24 cm from the beam axis!

Conclusion: specific calculations are required!

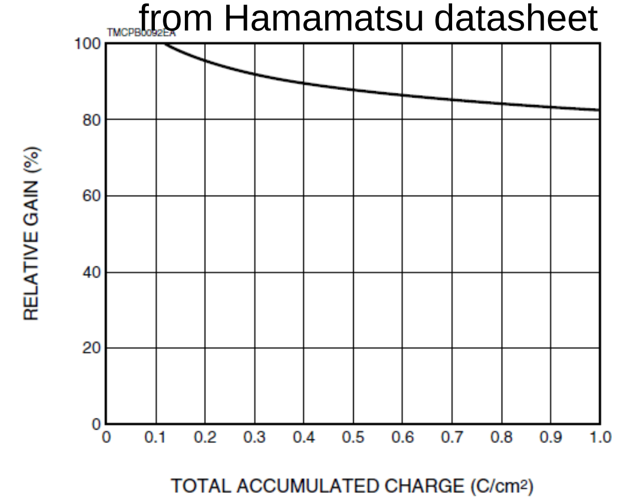


LIFETIME OF MCP AND TIMEPIX3

MCP: considering the worst case

- ESS proton beam: E=90 MeV, I=62.5 mA, P=10^{-9} mbar, 1 year = 6000 h
  → 1.1 10^5 e^-/ion pairs/pulse/RO cm
- number of e^-/ion impinging MCP per year on 2 cm of MCP
  → $2 \times 1.1\ 10^5 \times 14\text{Hz} \times 3600\text{s} \times 6000\text{h} = 6.7\ 10^{13}$
- number of e^- produced by MCP set to 10^4 gain per year
  → $10^4 \times 6.7\ 10^{13} = 6.7\ 10^{17} = 0.11$ C/year
  or $6.7\ 10^{18} = 1.1$ C in 10 years!
  Hamamatsu → 20% gain loss after 10 years

from Hamamatsu datasheet



TimePix3: 10 MGy

- for iron (Quad!): 1.3 MGy/year
  → 10 / 1.3 = 7.7 years

note: TimePix3 ≠ iron and dose unknown inside the BP!

INTERFACES

For details, please consult ESS-0092073 →
"Interface and Risk Management for the Cold Linac NPMs"

Interfaces in production and installation

- materials → comply with ESS vacuum handbook (ESS-0012894…)
- vHV (up to 65 kV) → European/Swedish electrical safety regulations
- cable and rack management
  → list of cables, cables pulled during installation phase…
- cooling (TimePix3) → can be provided by the cooling system pipes group
- mechanical integration → updating and exchange on 3D mockup (Katia)
- EMC → may have concerns with LWU quads (fringe field)
- schedule → for instance LWU installation may be delayed by 2 months
- CS → from LCS to ICS

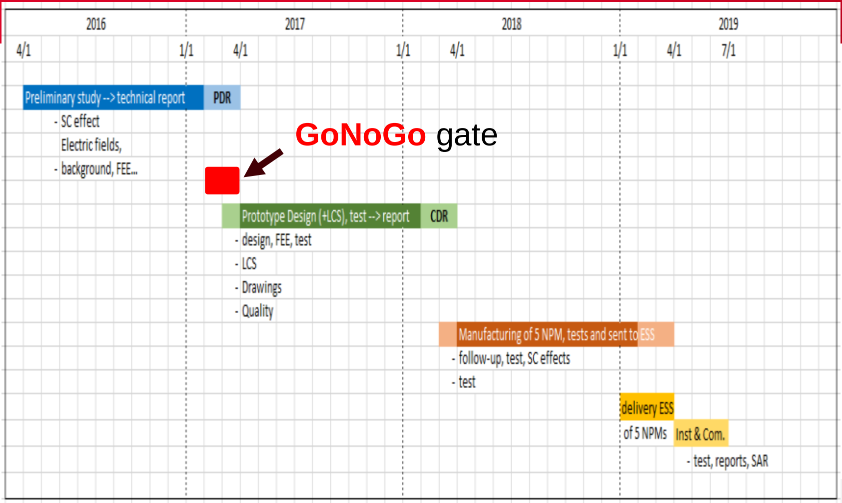
Interfaces in operation

- TimePix3 → up to 10 MGy for the chip, to 200 kGy for the FEE
- MCP → estimation
- CCD →

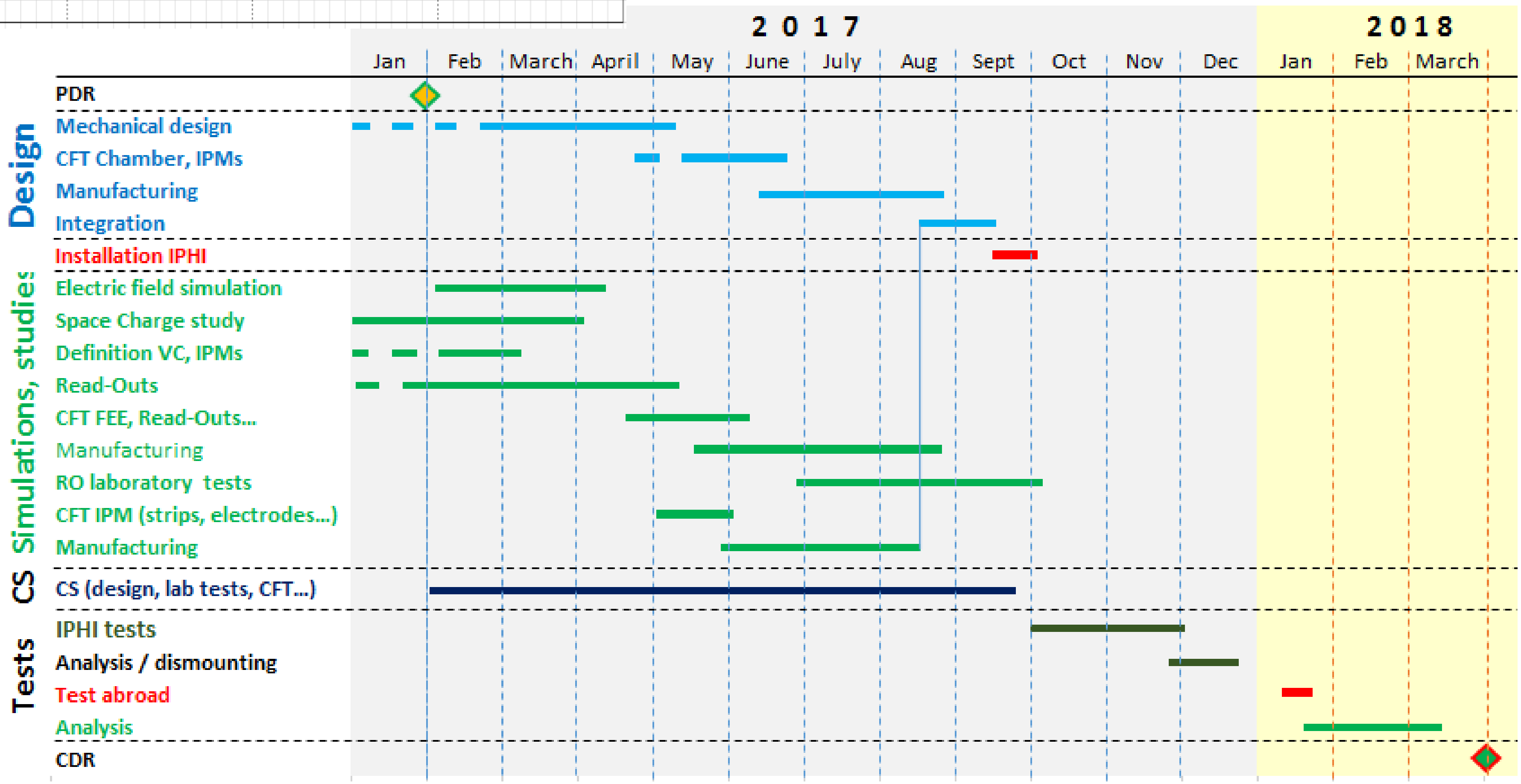
For details, please consult ESS-0092073 →

"Interface and Risk Management for the Cold Linac NPMs"

- performance degradation due to
  - → too low vacuum pressure
  - → to space charge effect
- radiation degradation → shortening the maintenance period



Prototype design and test Planning



SUMMARY

ion detection → better for profile measurement

FEE and CS

- FEE: work to be done
- CS: ROs identified, HR too for the bench prototype, but CS for final IPM still orphan WP!
- test bench prototype: task list at IPHI before to proceed in another facility
- a rough planning is draft for test beam at IPHI Saclay and elsewhere

Miscellaneous

- radiative background inside and outside the “beam pipe”
  → lifetime of materials

Interface and Risk list

IPM PLANNING