BTF2 and PADME status

53rd LNF Scientific Committee

Paolo Valente

On behalf of

The BTF upgrade team

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AIDA 2020 BTF PADME INFN Ministero degli Affari Esteri della Cooperazione Internazionale

BTF new lines final layout

Details changed with respect to original project:

① Modified (and removable) staircase to get **larger access** space from the front of new hall

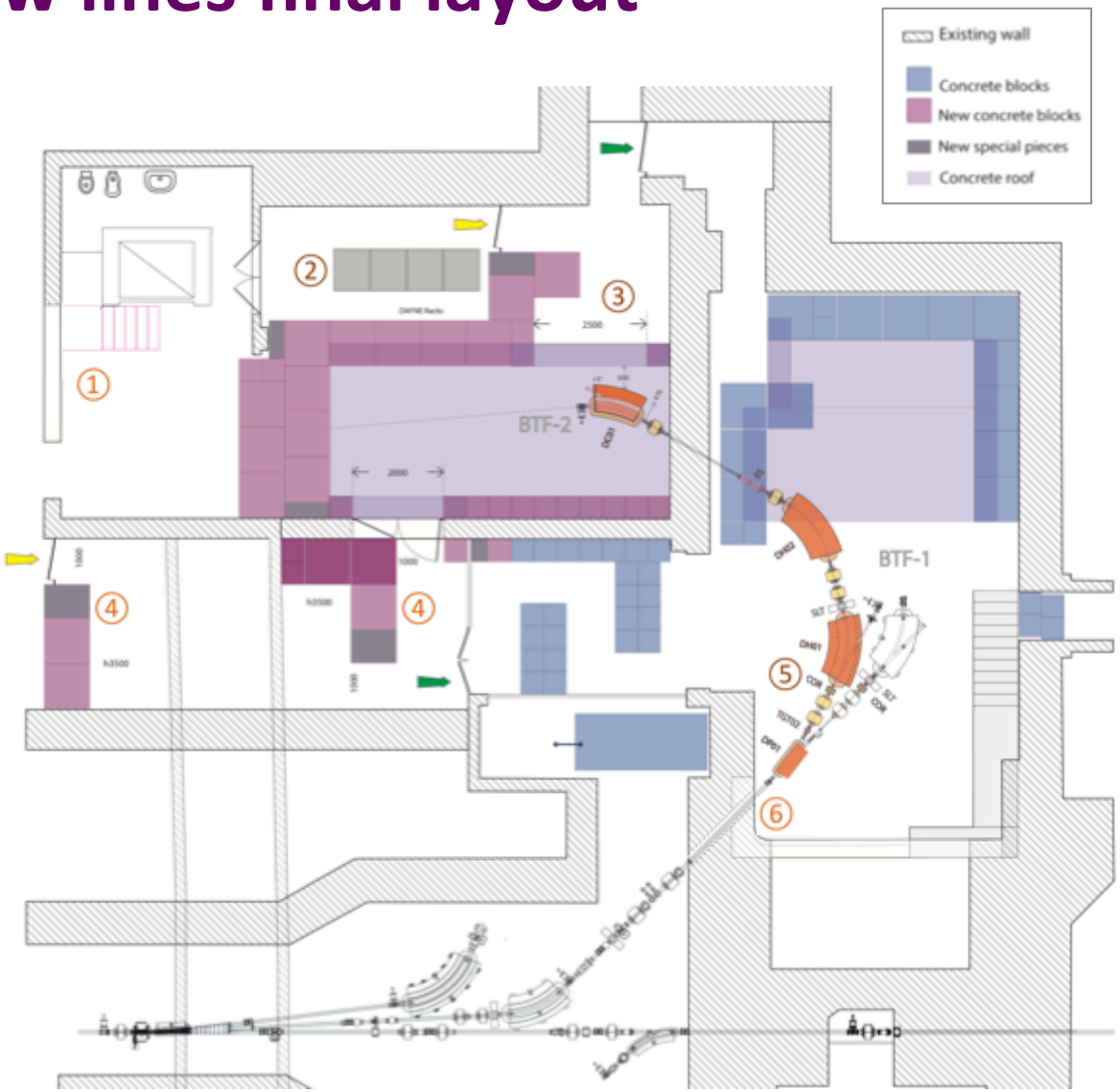
② Preserve DAΦNE racks in order to have **no interference with SIDDHARTA-2 run**

③ Enlarged (top) side access for **better use of the area** and at the same time **improve protection of racks area**

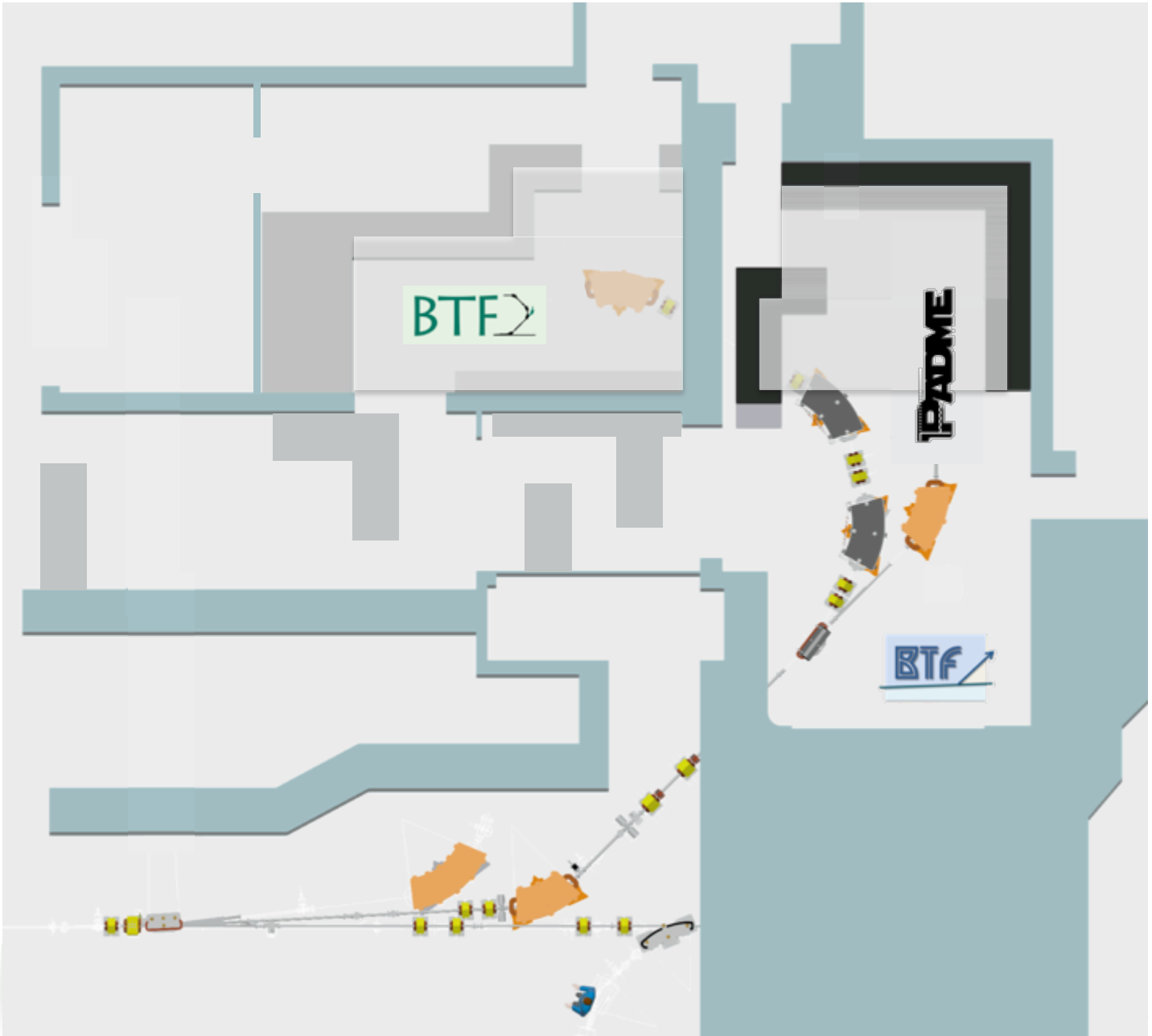
④ Additional labyrinth in place of sliding shielded door on the (bottom) side of new hall for **simpler and faster civil engineering**

⑤ Correctors added for **better beam control**

⑥ Secondary vacuum for new BTF lines, separated from LINAC primary vacuum for **safer operation**: added pump, modify interlock.



Final layout: 3D



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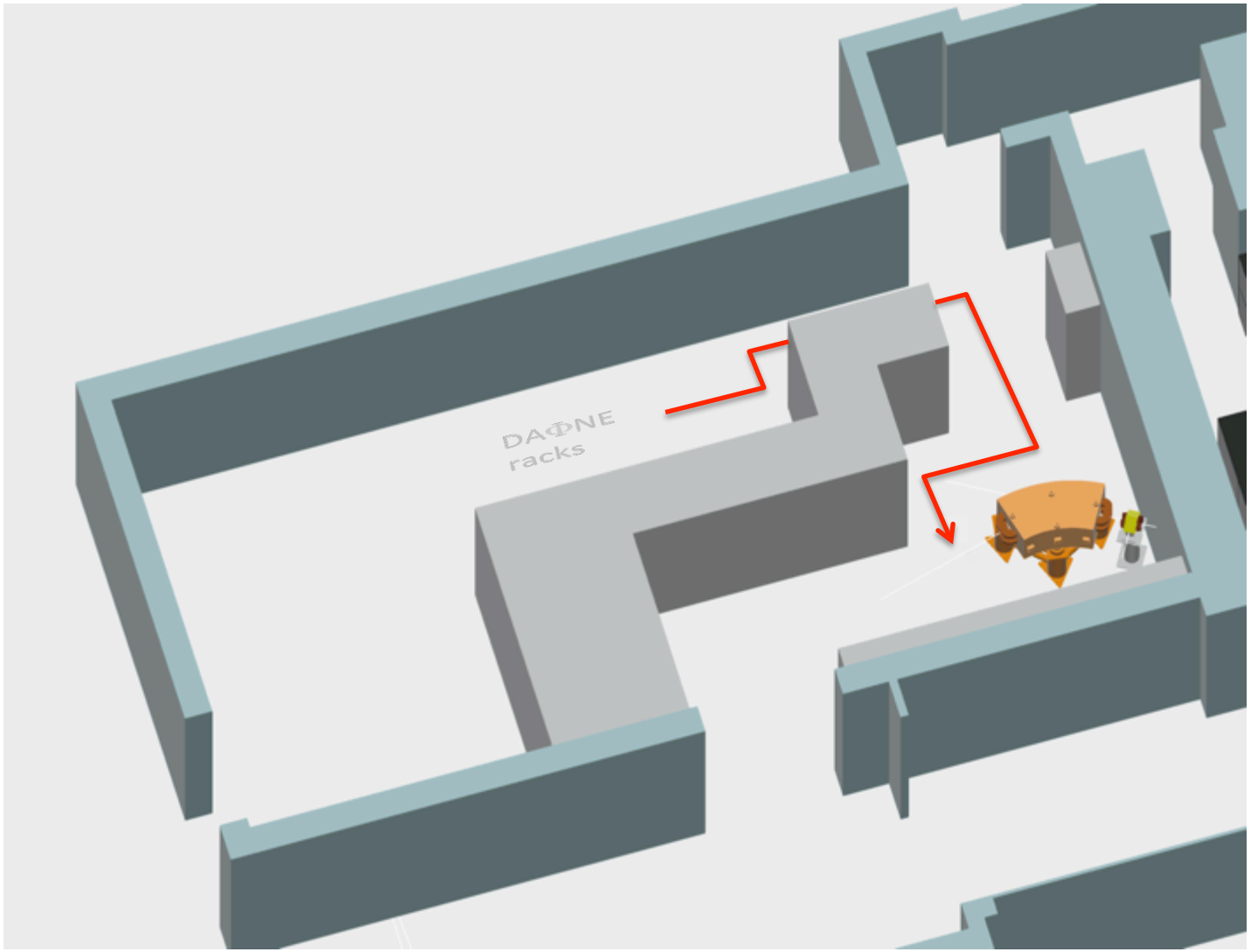
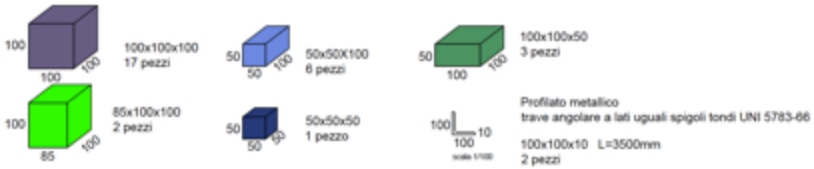
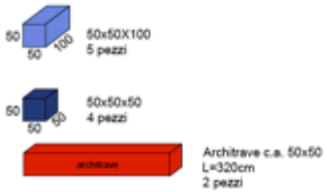
New area

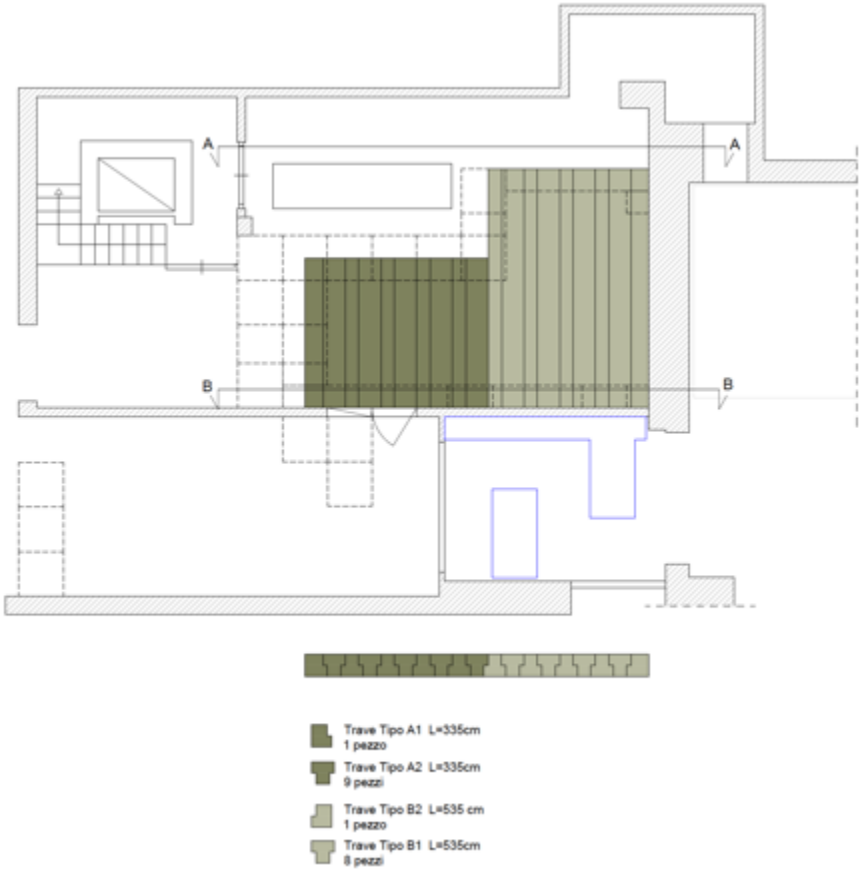


Civil engineering and shieldings/1





Civil engineering and shieldings/2



- New magnet power supplies: three racks in room upstairs of the (old) control room, path for cables identified **without major intervention**
- Path for additional cooling piping and power cables **being fixed**
- Cooling and power plants modifications **under preparation**

- April 2017: survey of buildings (LINAC tunnel, building 54) for checking maps
- Final project **ready**
- These days: **starting bid** for building modifications
- Work start >August/September

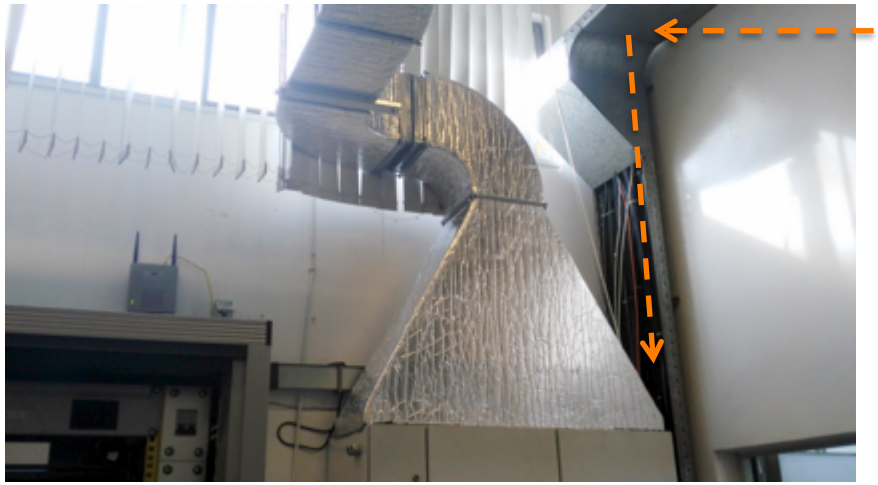
Building modifications

Present situation

Building modifications

Upstairs

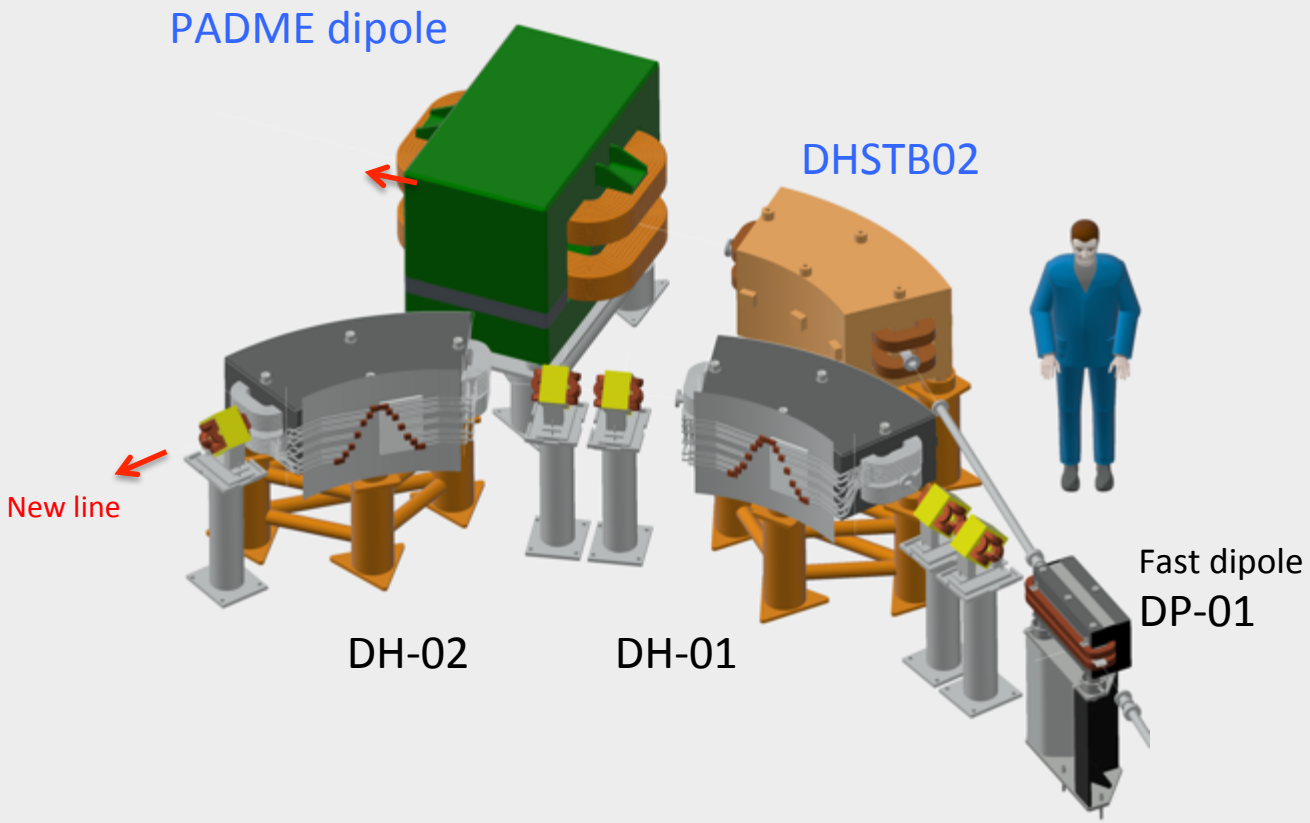
Downstairs



New magnets

13 new magnets:

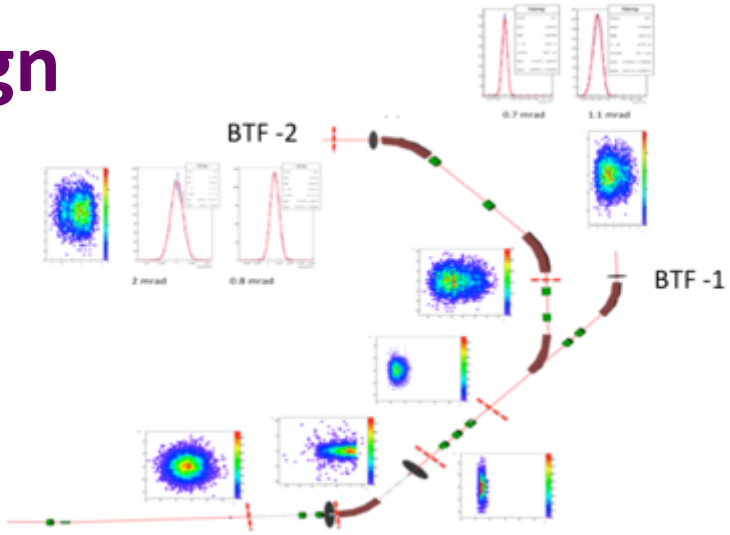
- 3 types of dipole
- Quadrupoles
- Correctors

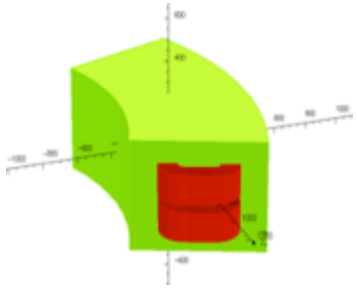


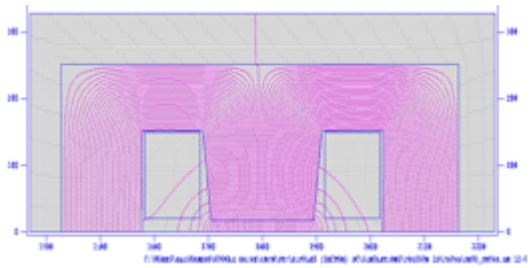
Magnetic design

Main constraints

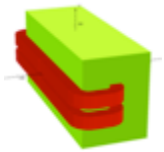
- Fit inside the existing BTF hall for turning by 135° and thus use the former control room as second experimental area
- Split the bending into three dipoles in order to control the dispersion
- Take into account a possible energy upgrade of the LINAC up to 1 GeV: at least **920 MeV** secondary beams
  - As a consequence, iron core dipoles working close to saturation

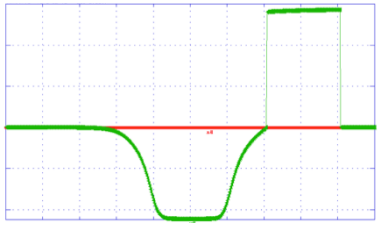






- Allow the use the parallel of the two lines as much as possible:
  - Be compatible with present DAΦNE operation without linking too much to it
  - Pulsed dipole for splitting sequence of LINAC pulses
    - Lamination core dipole, making a relatively small angle (15°)
    - As compact as possible





Pulsed dipole

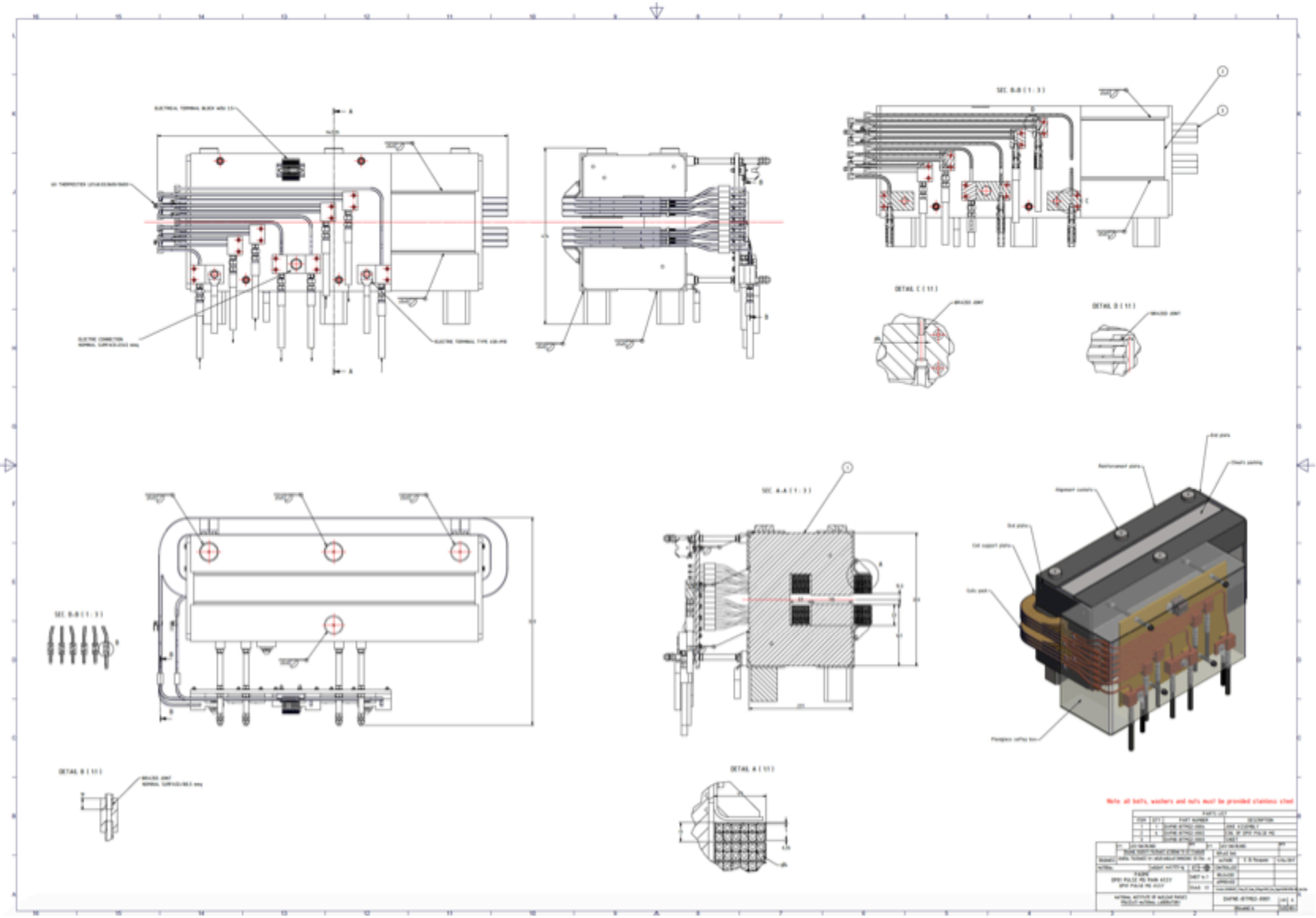
GENERAL DATA	
Beam energy (MeV)	1000
Curvature radius (m)	3
Gap (mm)	25
Pole width (mm)	110
Nominal flux density (T)	1,11
Bending angle (deg)	15
N per pole (turns)	36
Ampere-turns/pole	11052
Yoke Width (mm)	277
Yoke Height (mm)	359
Yoke Length (mm)	760
Overall Length (mm)	329
Overall Height (mm)	359
Overall Length (mm)	913
Good Field Region (mm)	±25
Field quality (ΔB/B)	6,4E-03
Integrated Field quality (ΔIB/IB)	2,3E-03
Total weight (kg)	516
ELECTRICAL INTERFACE	
Conductor dimension	7x7 Φ4
Nominal Current (A)	316
Nominal Resistive Voltage (V)	113
Rtot (Ω)	0,078
Nominal inductance (H)	0,029
Nominal Power (kVA)	35
Maximum Line Cable lenght (m)	20
Proposed cable cross section (mm^2)	95
Proposed Output PS Current (A)	330
Proposed Output PS Voltage (V)	130
Proposed Output PS Power (kVA)	42,9
WATER COOLING	
Number of pancakes per pole	3
Number of pancake circuits	6
Number of series circuits	2
ΔT water (°C)	15
Maximum Water flow (m^3/s)	0.117
Maximum Water velocity (m/s)	1,55
Maximum ΔP (bar)	2,94

IRON			
V (mm3)	PACK FAC	d (kg/dm3)	Weight (kg)
6,75E+07	0,96	7,85	509
COILS			
V (mm3)	FILL FAC	d (kg/dm3)	Weight (kg)
9.46E+06	0,59	8,9	50

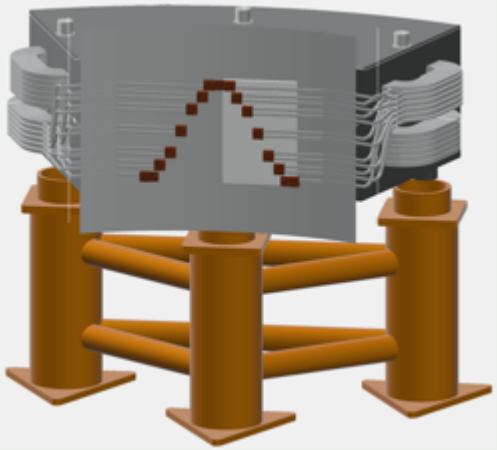
Iron lamination dipole

- Magnetic and electro-thermical design, mechanical drawings **completed**
- Construction **ready to start**
- Power supply specifications **ready**; ramping+stabilization within ≈**100 ms**

Pulsed dipole



New DC dipoles



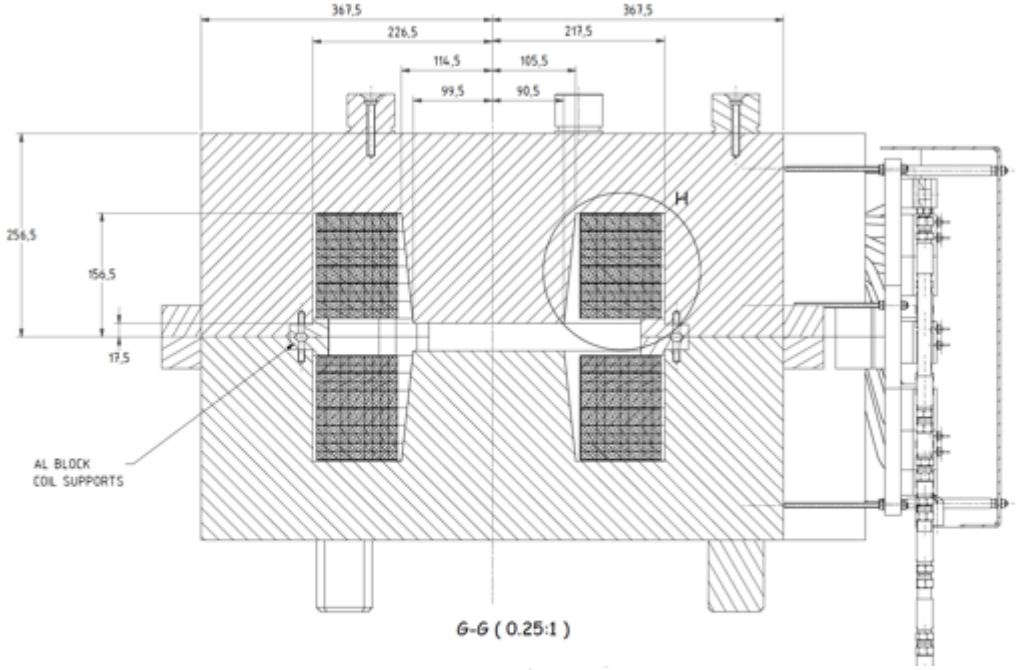
GENERAL DATA	
Beam energy (MeV)	921
Curvature radius (m)	1,8
Gap (mm)	35
Pole width at the gap (mm)	190
Pole width at the yoke (mm)	220
Nominal flux density (T)	1,7056
Bending angle (deg)	45,00
N per pole (turns)	120
Iron Width (mm)	735
Overall Width	780
Overall Height (mm)	503
Overall Lenght (mm)	1672
Good Field Region (mm)	±15
Field quality (ΔB/B)	4,29E-04
Integrated Field quality (ΔIB/IB)	3,78E-04
Total weight (kg)	4006
ELECTRICAL INTERFACE	
Conductor dimension	9.5x9.5 Φ5.5
Nominal Current (A)	262
Nominal Resistive Voltage (V)	72
Rtot (Ω)	0,276
Nominal inductance (H)	0,423
Nominal Voltage on magnet (V) with a 10 s raising time (V)	83
Nominal Power (kVA)	22
Maximum Line Cable lenght (m)	20
Proposed cable cross section (mm^2)	95
Proposed Output PS Current (A)	280
Proposed Output PS Voltage (V)	95
Proposed Output PS Power (kVA)	26,6
WATER COOLING	
Number of pancake per pole	6
Number of Turn per pancake	(10 H 2 V)
ΔT water (°C)	15
Maximum Water flow (m^3/s)	3,44E-04
Maximum Water velocity (m/s)	1,21
Maximum ΔP (bar)	3,82

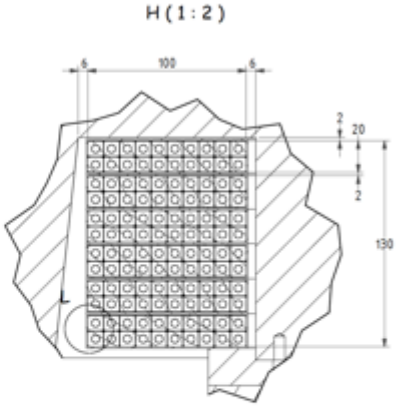
IRON			
V (mm3)	PACK FAC	d (kg/dm3)	Weight (kg)
3,99E+08	1	7,86	3140
COILS			
V (mm3)	FILL FAC	d (kg/dm3)	Weight (kg)
9,5E+07	0,599	8,9	506

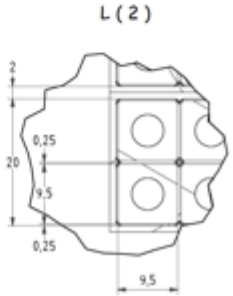
Iron core dipoles

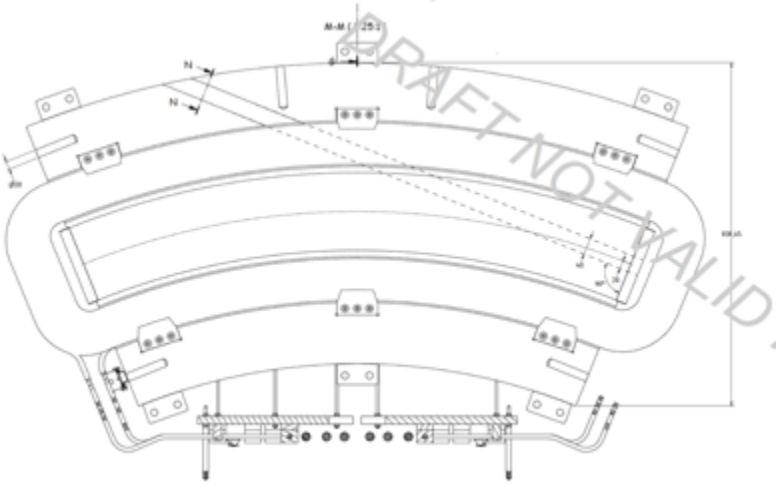
- Magnetic and electro-thermical design, mechanical drawings **almost completed**
- Power supply specifications **being finalized**

New DC dipoles



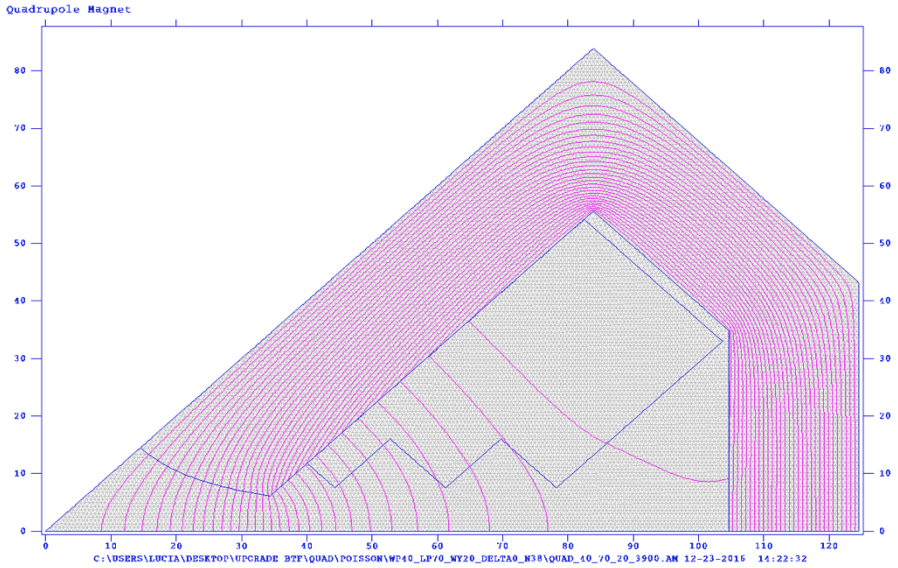






New quadrupoles

QUADRUPOLES	
Gradient (T/m)	20
Bore (mm)	45
Magnetic length (m)	200
Pole width (mm)	45
N per pole (turns)	46
Overall width (mm)	
Overall Height (mm)	
Overall Lenght (mm)	
Field quality (ΔB/B)	
Field quality (ΔIB/IB)	
Iron weight (kg)	
Coil weight (kg)	
Total weight (kg)	
ELECTRICAL INTERFACE	
Conductor dimension	5x5 Φ3
Current (A)	88
Voltage (V)	10
Rtot (Ω)	0,11
L (mH)	22
Total thermal load (kW)	0,85
Proposed PS Current (A)	95
Proposed PS Voltage (V)	14
Proposed PS Power (kVA)	1330
WATER COOLING	
Number of pancake	2 cooling circuit
ΔT water (°C)	15
Water flow (l/s)	0,007
Water velocity (m/s)	0,93
ΔP (bar)	3,2



Iron core dipoles

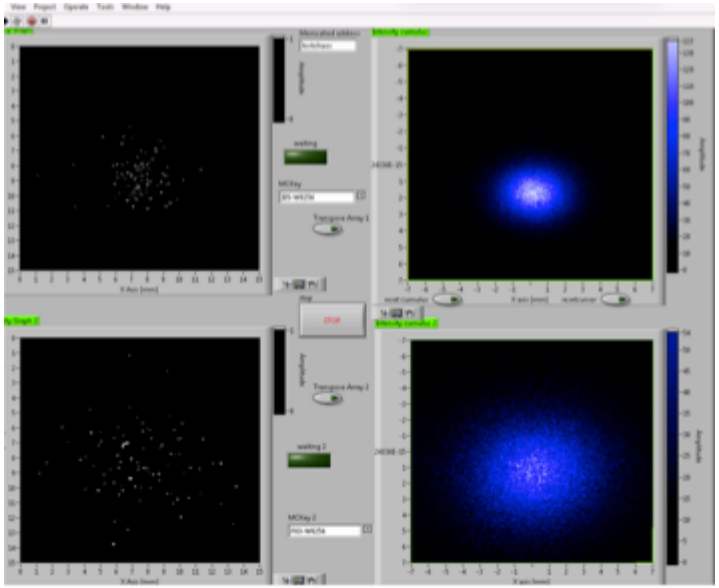
- Magnetic, electro-thermical, design **almost completed**
- **Detailed mechanical drawings to be done**

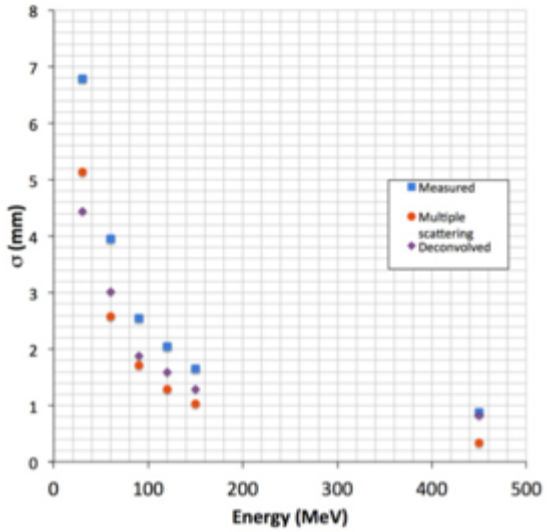
- Power supply specifications **being finalized**

Power, cooling & services

- Detailed estimate of additional electrical and thermal power
- **Technical solutions both for cooling and power identified**
  - New pumping and secondary circuit distribution for the BTF area
  - Revision and upgrade of power distribution for the area
- Detailed projects **being prepared**
- Impact on **civil engineering** also **being evaluated**
  - Trying not to modify LINAC tunnel to BTF area connections

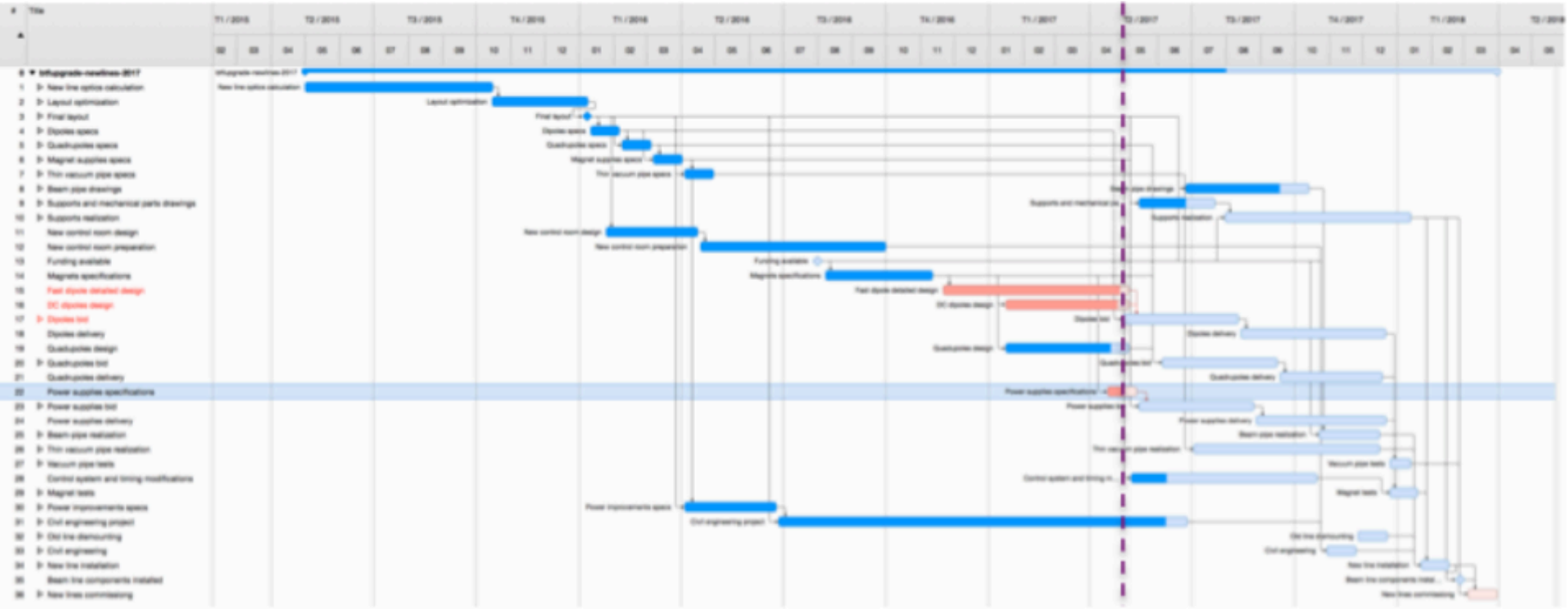
BTF-2 FitPIX tracking





- Hybrid pixel detectors
  - 256×256 pixels, 55 μm pitch, 300 μm thickness sensor
  - 14×14 mm^2 active area
  - Timepix3 chip
- **Essential tool for second BTF line**
- Three FitPIX devices **ready, readout integrated** in MEMcached based BTF control system
  - >> 50 frames/s achieved
- Now **working** on **tracking software**

BTF-2 updated schedule

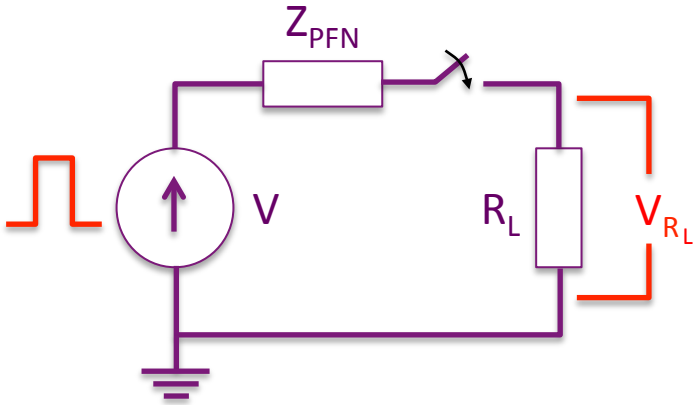


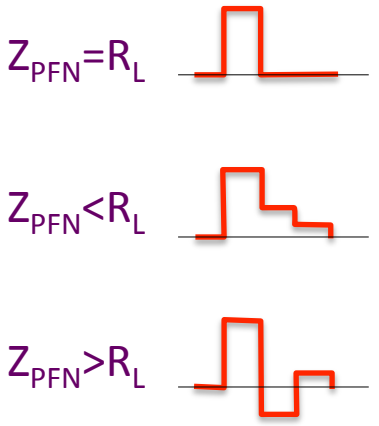
- Construction of new magnets on the **critical path**
  - Try to mitigate by:
    - ✓ Providing a design as detailed as possible (at the level of executive drawings)
    - ✓ Anticipating procurement of raw material (hollow Copper conductors, high-purity iron)

LINAC consolidation/1

Task: replace PFN charging circuit in all four modulators

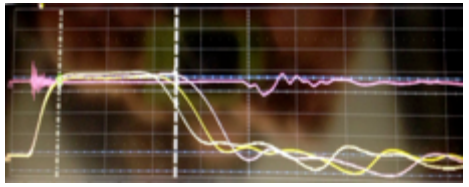
- New step-up pulse transformer, **15×** replacing the original **12×**, **installed in modulator D**, in order to supply a lower voltage to the transformer primary
  - This allows using on-the-shelf high voltage PS
- PFN impedance has to be matched to the klystron load
  - New inductors for re-matching Z_{PFN} installed





$$Z_{PFN} \approx [L_{PFN}/C_{PFN}]^{1/2}$$

- **New configuration operational since January 2017, without issues**



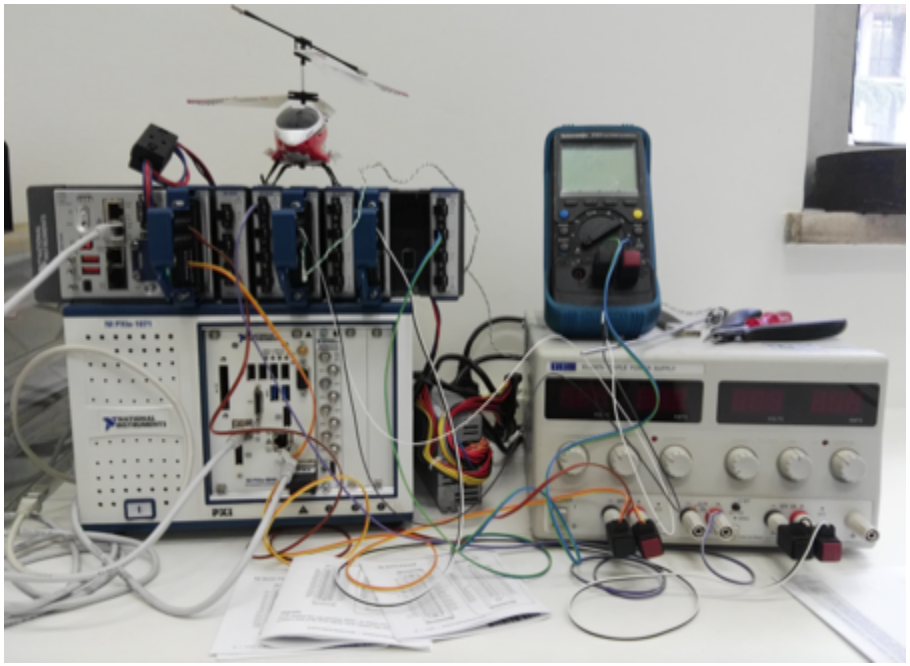
LINAC consolidation/2

Task: 5th modulator for testing and commissioning of new components

Working on:

- **New control** and **interlock** system
  - General design **done**, using modern **modular electronics**
  - First unit **purchased**, currently under test
  - Software development also **started**
- **New tank** being designed
- **New high voltage switch** under study: new thyratron vs. solid state

After validation, all new solutions will be **propagated to the existing four RF power stations**, then, it will be possible to **purchase** new high-power high voltage capacitors, pulse transformers, high voltage power supplies, etc.



AIDA 2020 BTF

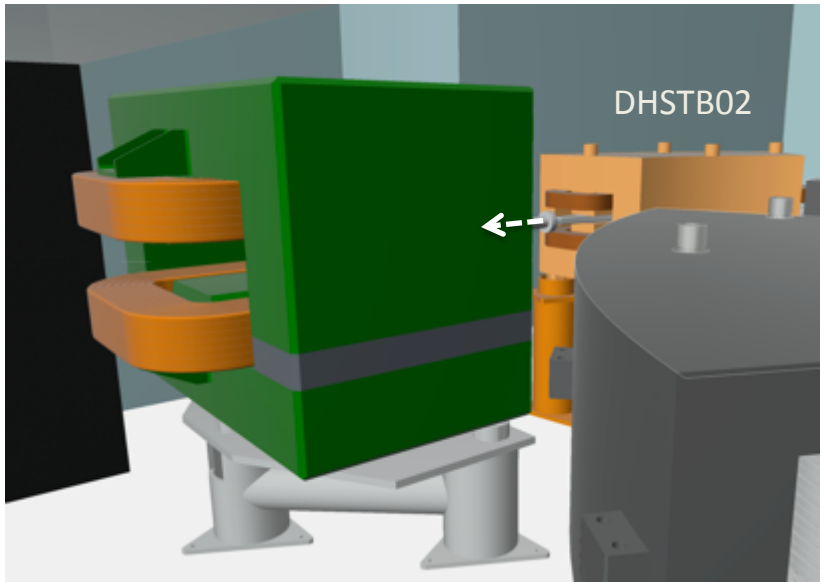
LINAC consolidation/3

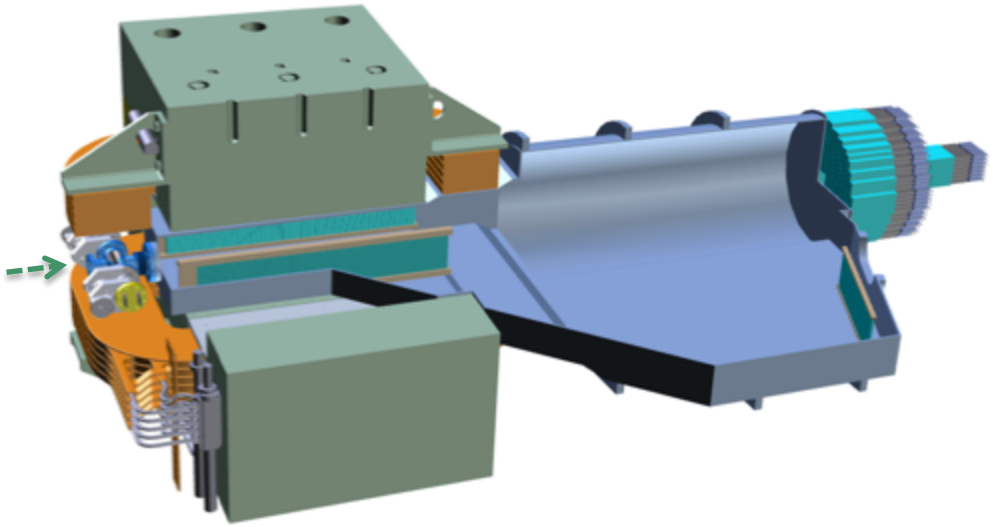
Schedule:

- New components available **not before the end of 2017** (bids starting in the next weeks)
- End of 2017 shutdown probably devoted to ordinary **maintenance**
- Many activities can be done **without stopping the LINAC** operations, but some stops will be needed for:
  - Installing the first new units of PFN charging supplies (on modulator "D")
    - Approximately **1 week**
  - Installing and testing the new modulator in the service gallery
    - Approximately **2 weeks**
  - Commissioning of the new control system
  - Install all new pulse transformers and power supplies and new control system in modulators "A", "B" and "C"
    - Approximately **1 month**

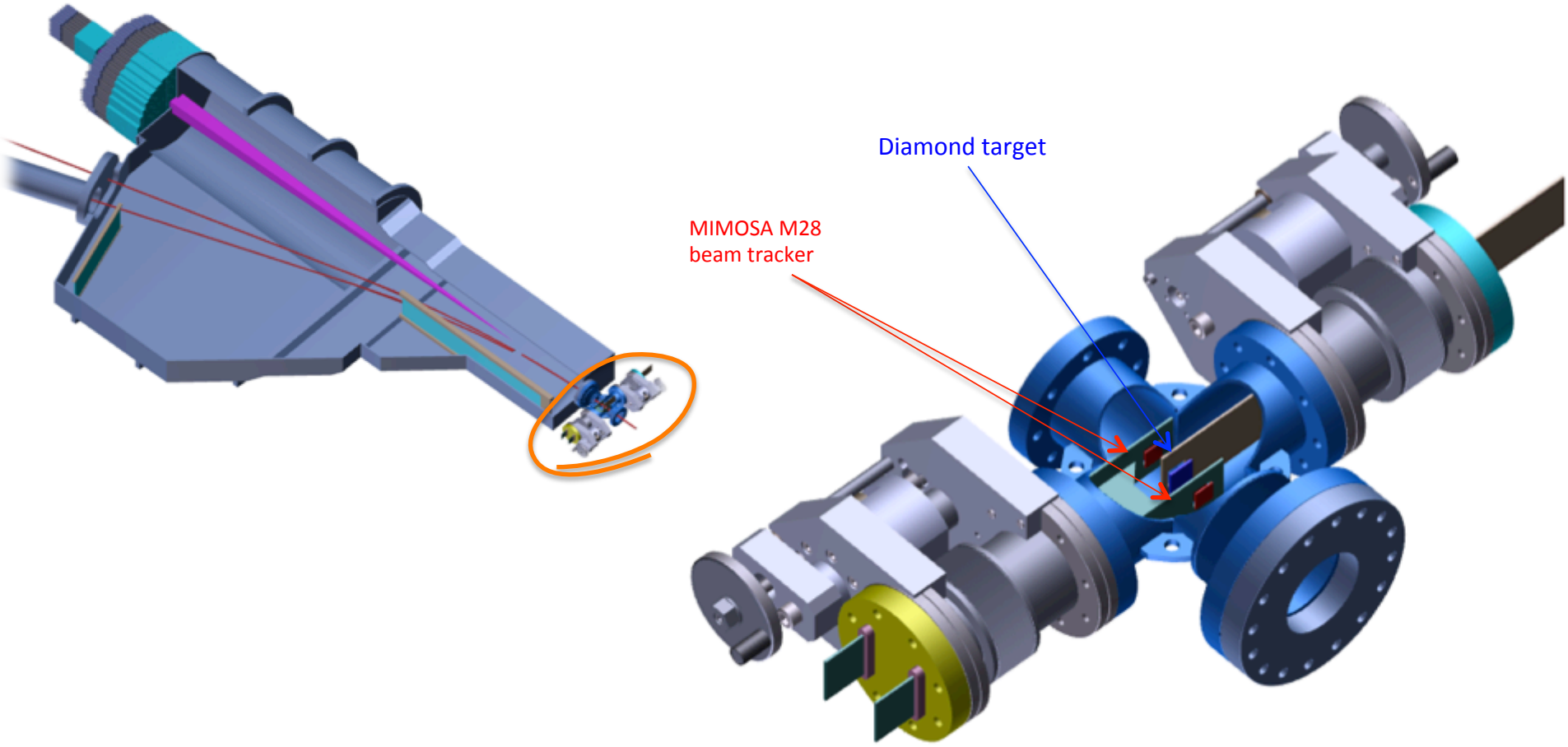
PADME

- PADME setup design **starts** where the **BTF-1 line ends**
- Assume re-using exactly the present vacuum pipe inside DHSTB02, pre-vacuum port, flange, etc.





Beam region and vacuum chamber

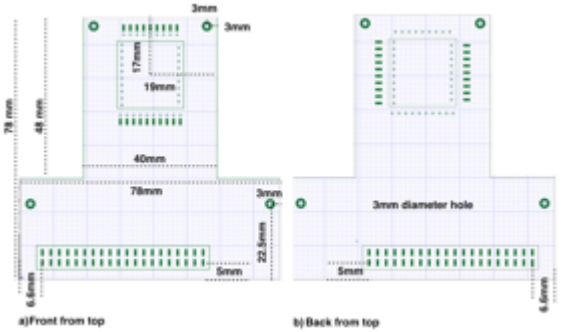


- Design **complete** both for vacuum chamber and target region
  - Few details to be fixed

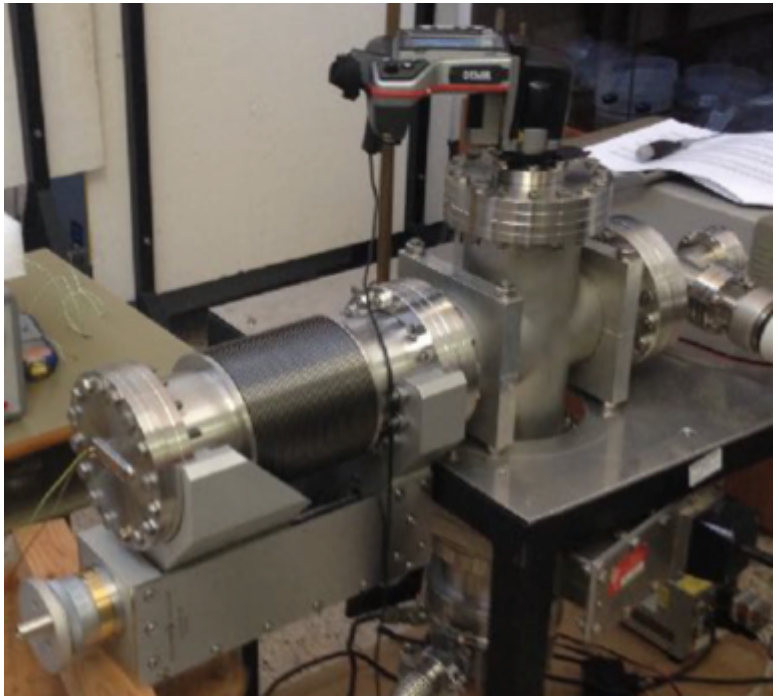
Diamond target

Test board

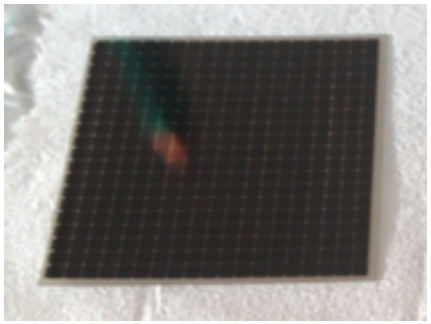
Final board

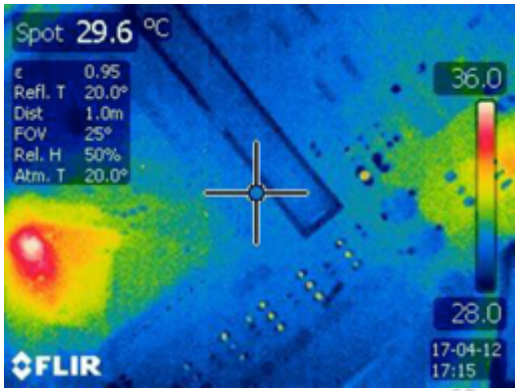


Vacuum setup & test



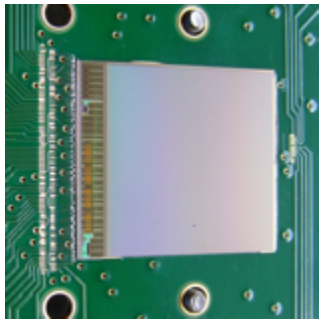
- Both graphite and metallic strips targets **ready**
- Both 50 and 100 µm samples **available**
- Readout electronics **ready**
- Final readout **being designed**
- Mechanics **ready** (motor to be purchased)
- Vacuum tests **OK**

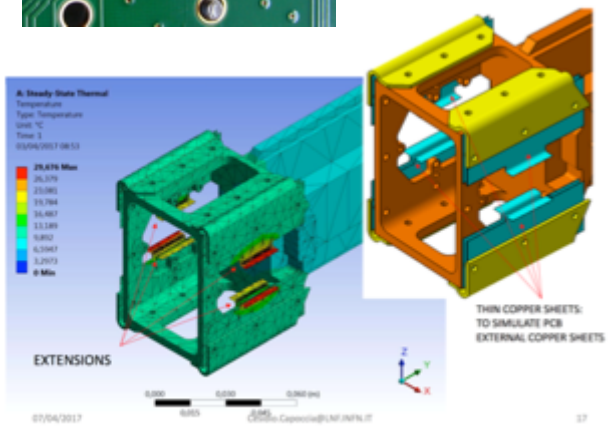


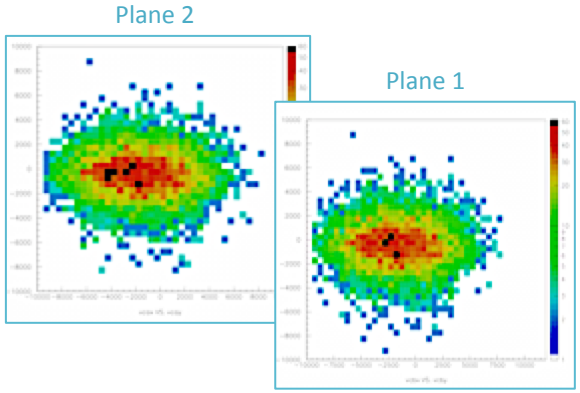


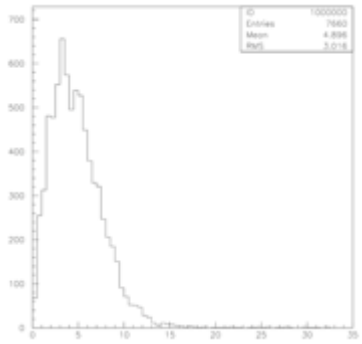
MIMOSA tracking

- Based on MIMOSA M28 (monolithic active pixel, 0.35 μm technology), by IPHC Strasbourg, but **in vacuum** (never implemented, so far)
  - 20.8 μm pitch, 20.2×22.7 mm^2 area
  - 50 μm thickness
- Mechanics and cooling
  - Linear stage mirrored from the diamond side
  - Support and cooling structure details **designed**
  - New board and cooling support **being produced** for final testing
- Sensors: OK
- DAQ, software
  - In advanced development: **April 2017 test-beam successful**





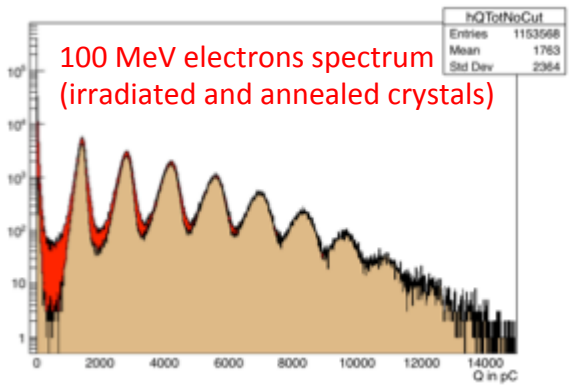


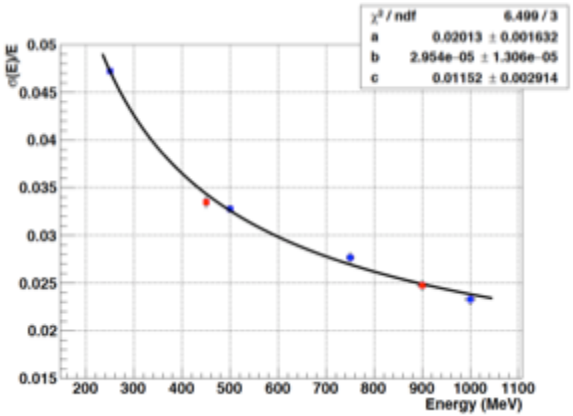


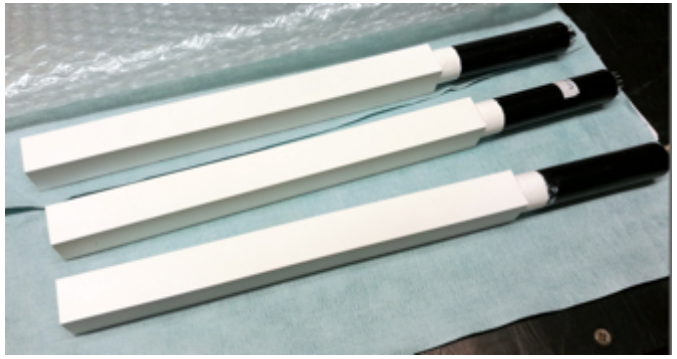
Beam, vacuum & target region: critical issues and plans

- Aim at having the **target region** (main vacuum cross and diamond) connected to a BTF secondary vacuum by the PADME test beam of **July 2017**
- Integrate in the new vacuum configuration (separate LINAC primary vacuum from new BTF & PADME secondary vacuum) by **October 2017**
  - Install MIMOSA system & testing
  - Commissioning with beam as soon as available
- Main vacuum vessel coming with the PADME magnet, to be produced by the **end of 2017**

Calorimeter status and plans/1



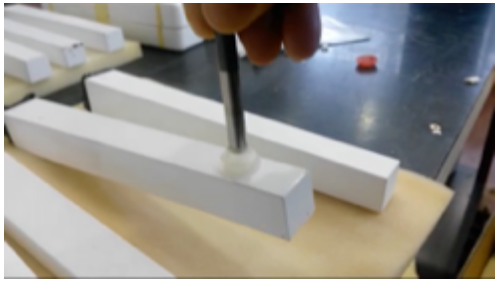


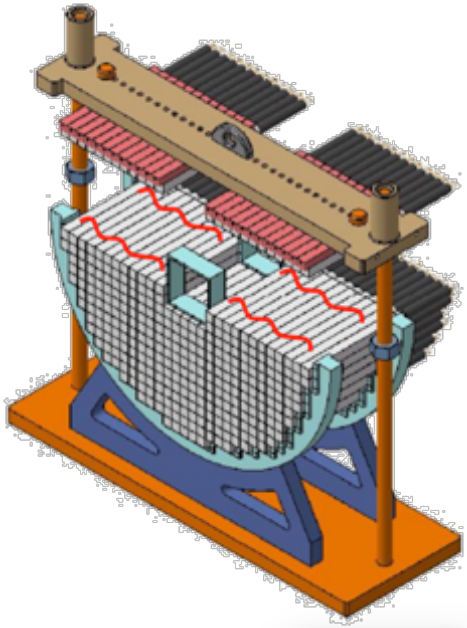


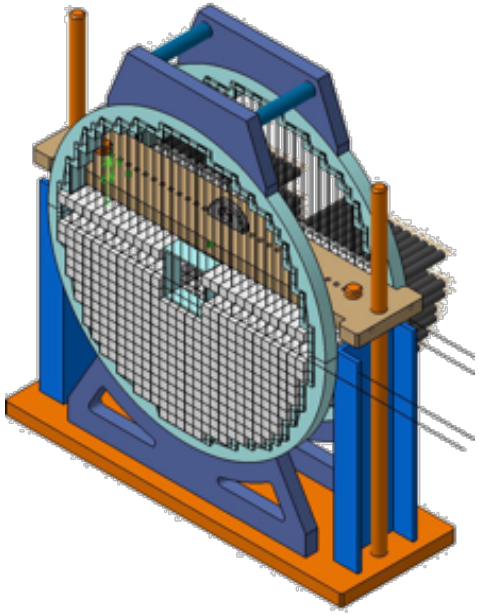
- Several **test-beams** for validating PMT and divider choices, paint, glue, assembly procedure…
  - Results in line with expectations from L3 experience: ≈2% at 1 GeV, excellent linearity up to ≈1 GeV
  - Moreover, 13 pC/MeV, 5±1 pC pedestal: threshold well below 1 MeV
- Conclusions:
  - HZC XP1911 PMT's OK; divider type "B" OK
  - 80 μm paint sufficient for light tightness, also OK from the mechanical point of view
  - Polished surfaces of cut crystals OK
  - **No radiation damage on PMT's**
  - Radiation damage on BGO at the dose level expected from literature **fully recovered** by high temperature annealing
- **All tenders completed**: crystal machining, gluing & paiting (Gestione SILO), PMT's+dividers (HZC Photonics), HV system (CAEN), waveform digitizers (CAEN)

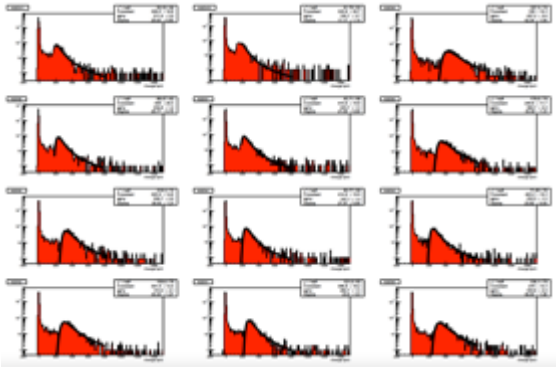
Calorimeter status and plans/2

- Quality assurance/control & calibration systems being prepared:
  - LED pulsing for **PMT QA/QC** and gain measurement
  - Cosmic rays/radio-active source test-stand for finished crystal+PMT **assemblies calibration**
- Assembly procedure **established** and being validated

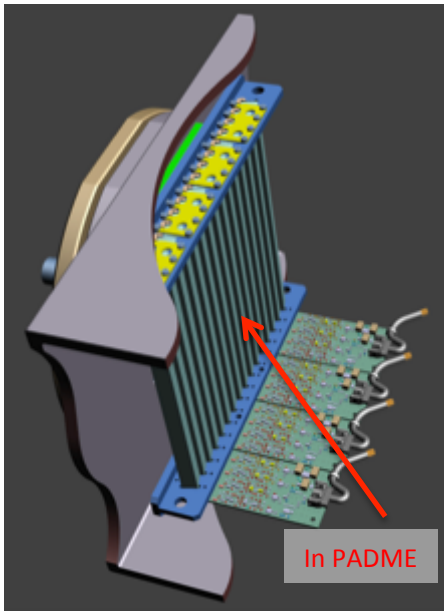


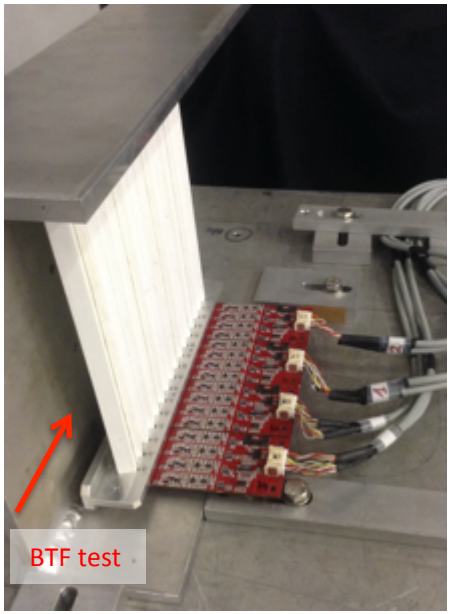


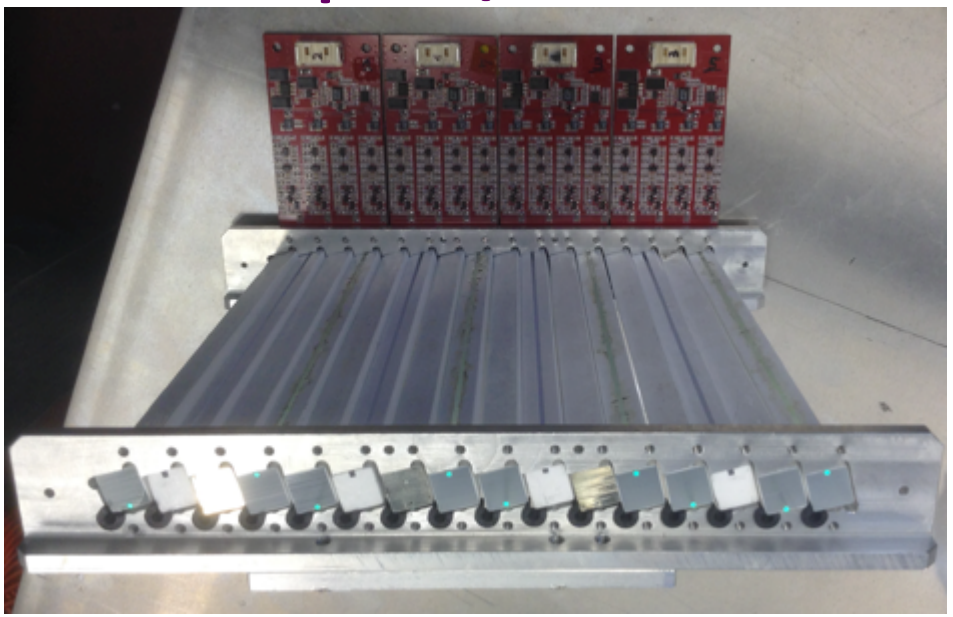




Scintillator veto status and plans/1







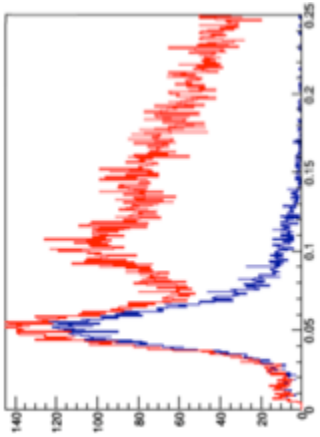
10×10x180 mm^3 scintillator bars

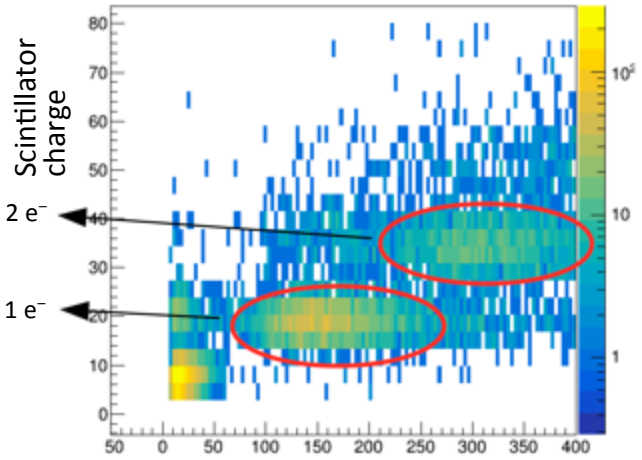
- All scintillator bars **delivered**
- Design of the mechanics **final**
  - Prototype of the mechanical assembly **ready**
- First electronics boards **delivered** and **validated**
  - **Test-beam in April**: **different readout options on 4x4 bars** (**with and without fiber**, polishing, Aluminization, positioning wrt SiPM…)
  - Efficiency and time resolution being studied
- Read-out by same digitizing system as calorimeter (**ready**)

Scintillator veto status and plans/2

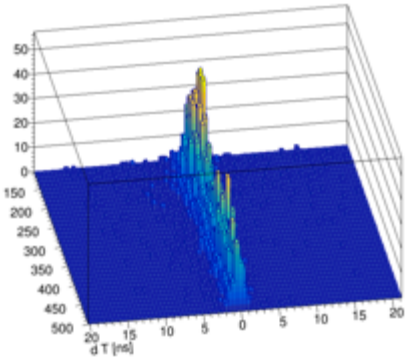
All events

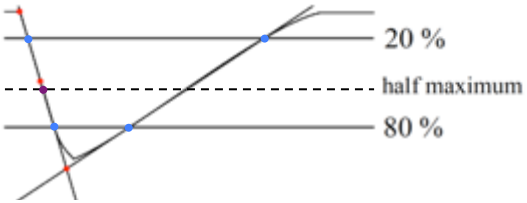
1 e⁻ in calorimeter



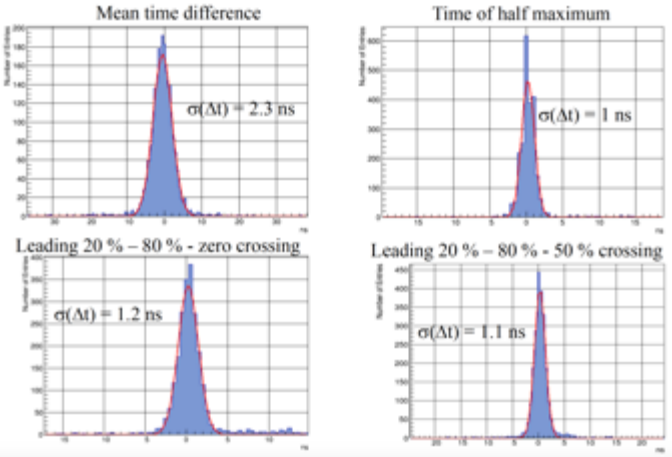


Δt vs charge





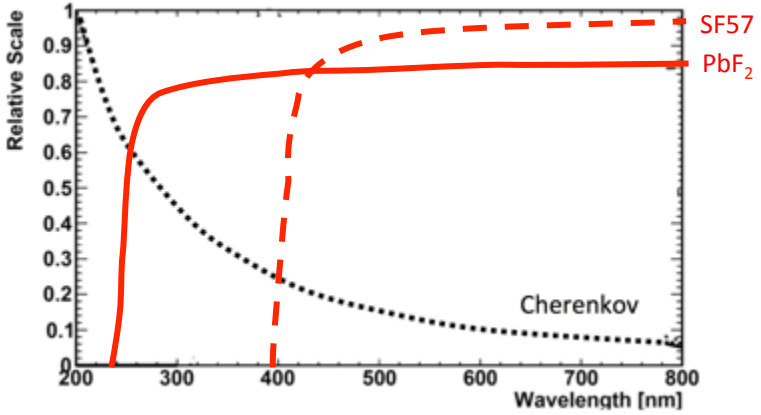
$$T_{\text{Mean}} = \frac{\sum_{peak} A_i * t_i}{\sum_{peak} A_i}$$



- Different resolution values obtained using different definitions of timing
- Already at the level of **700 ps** resolution without any calibration and very preliminary analysis
- Front-end electronics working extremely well

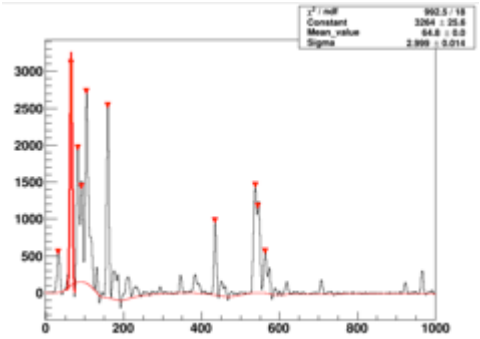
- No slewing

Small angle detector

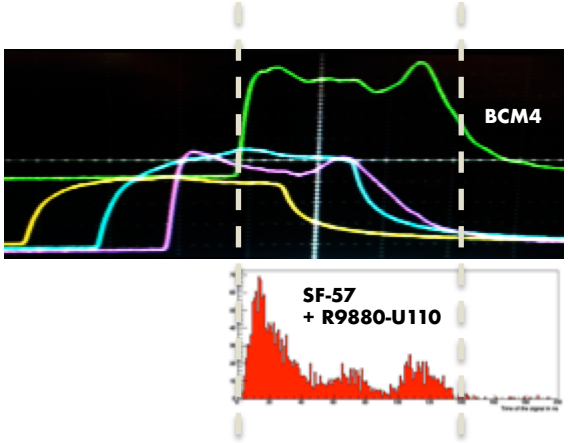


- Evaluating **SF57** (OPAL, NA62, available in large amount) **vs. PbF_2** (better transmission spectrum, i.e. LY)
- **MTA Atomki** colleagues started to work on this detector:
  - Participated to April **test-beam**
  - Re-measured PbF_2 and SF57 samples **transparency vs. wavelength**
  - Running optical photons **simulation**
  - Testing different **wrappings and surface treatments** for optimizing light collection

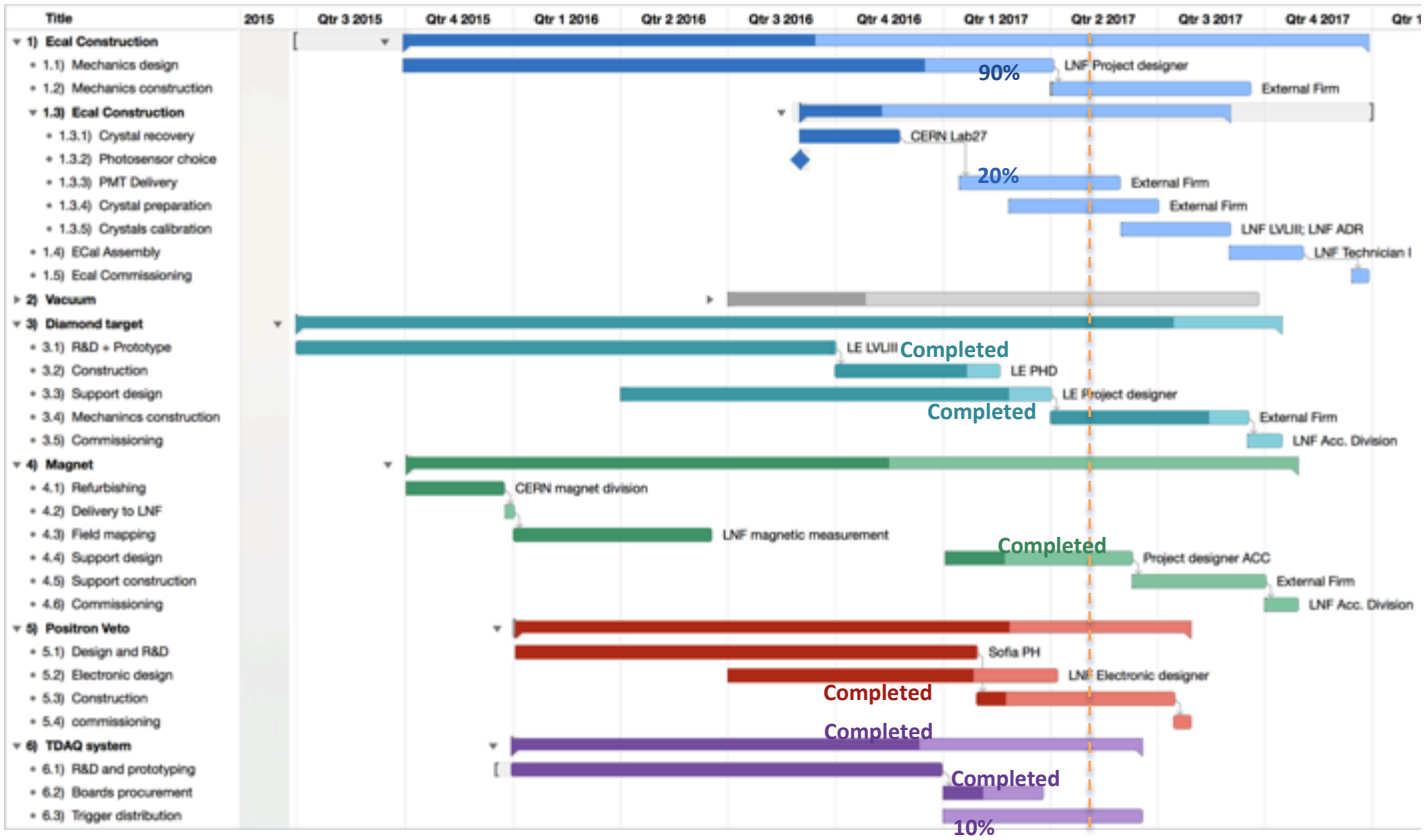
- **Final design**:
  - 25 crystals, 30×30 mm^2
  - Allows using larger **fast PMT's** (with respect to 15 mm), e.g. Hamamatsu R13748, 1" diameter
  - Reduce the number of **readout** channels (from 49 to 25, **1 digitizer board less**)



- **Time distribution**
  - **700 ps** signal width, **2.5 ns** double pulse resolution
  - Ideal tool for beam monitoring
  - Used for long pulse tests (150 ns)



PADME updated schedule



- Crystal preparation slightly beyond schedule, but:
  - Most difficult part – validation of the procedure – done, also checked with beam
- Delivery of PMT's on the critical path:
  - Project of PMT divider **revised**: rejected fraction should be lower
  - Can be mitigated parallelizing **calibration** and **assembly**
- Assembly probably estimated to be (much) **shorter**, ≈1 month

In addition…

- Dedicated manpower for calorimeter construction and installation (Georgiev at LNF for 6 months from **Sofia U.**)
- New help for trigger distribution from **Roma 3**

Summary/1

New components for LINAC consolidation and BTF-2 available starting from the last months of 2017 (bids started or starting in the next weeks)

- **LINAC consolidation**
  - Ordinary maintenance during end of 2017 DAΦNE shutdown
  - First part of new components installation **pushed at the end of the KLOE-2 run**
    - **Trade-off** between reliability of LINAC during PADME run and time subtracted to physics
- **Installation of new BTF line**
  - Can actually start as soon as the BTF stops, with several **weeks advance** with respect to the DAΦNE shutdown (**≈October 2017**)
  - **Civil engineering should come first**
    - Emptying the present control room
    - Re-routing cabling and preparation for new line installation
    - Modifications to the building
    - New shieldings installation
    - Modifications to cooling plant
  - Some intervention on the plants, services and **inside the LINAC tunnel** must be done **during the DAΦNE shutdown**, but a large part of the work can be prepared without stopping operations
  - Separation of BTF vacuum from LINAC one will allow performing further activities independently (e.g. new pipes installation, PADME vessel connection, etc.)
  - **End of March as final dead-line for new line commissioning**

Summary/2

- **Installation of PADME**
  - PADME dipole should enter the BTF hall **before** the installation of the BTF new lines
  - Operation of PADME dipole requires power cables and cooling pipes
    - Existing cables and pipes probably OK per the PADME magnet but not enough also for the new BTF magnets
  - **Most** of the operations for PADME installation can be performed **independently** from the BTF new lines **installation**
- **Interference**
  - **Commissioning** of the new BTF lines will require **closing the experimental areas**, thus stopping all PADME installation activities (a few days also needed for installation of shielding blocks in the access area)
  - **Early completion of PADME installation** implies more time available for testing, **both** for the new lines commissioning and for **the LINAC optimization** (for the **PADME positron beam**)
  - In principle installation of PADME and components of new lines are **compatible**, apart from obvious incompatibilities: usage of crane, access to PADME area with large components after second line installation, etc.