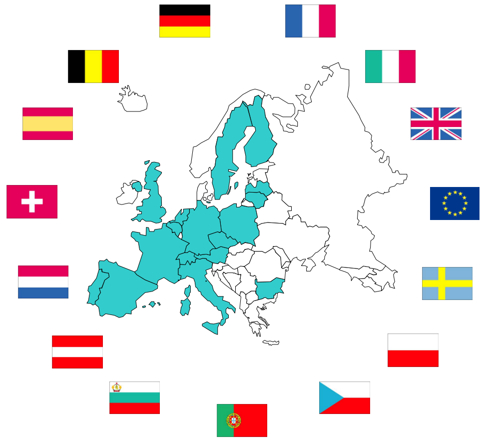

The Reliability Requirement
for the
XT-ADS & EFIT Accelerator

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On behalf of the EUROTRANS WP1.3 working group

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cnrs dépasser les frontières
In2p3

Proton beam specifications

High-power proton CW beams

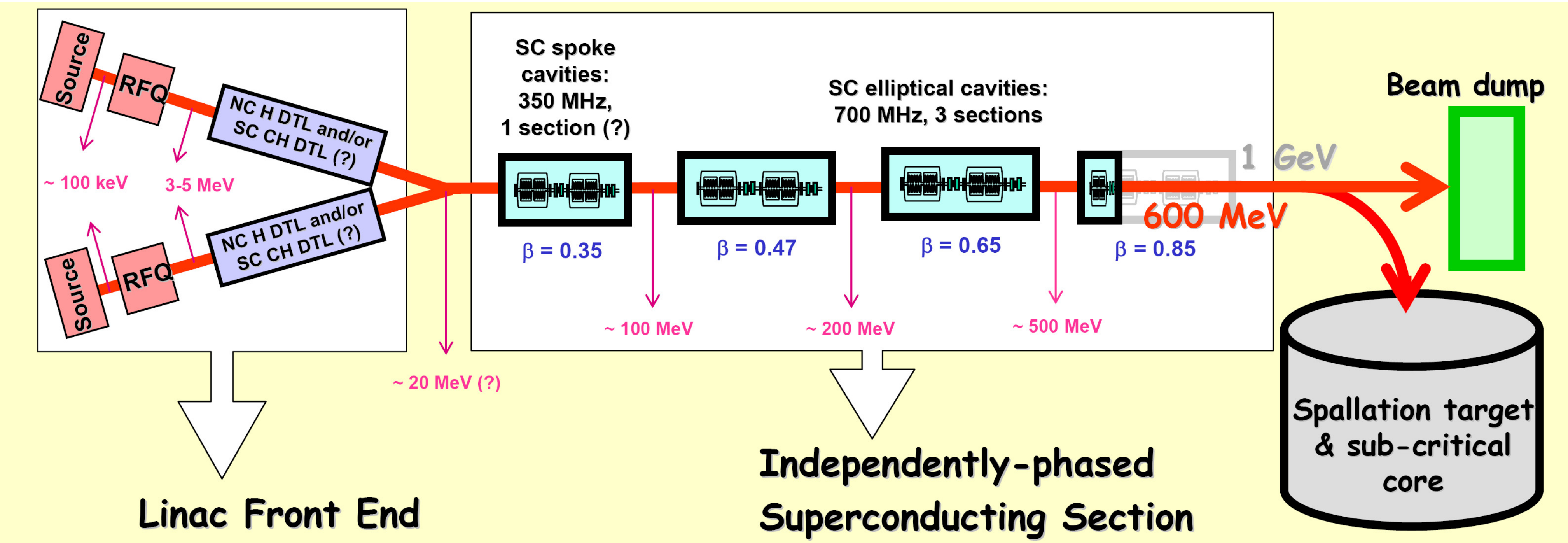
Table 1 – XT-ADS and EFIT proton beam general specifications

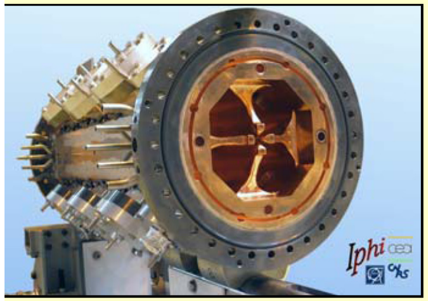
	XT-ADS	EFIT
Maximum beam intensity	2.5 – 4 mA	20 mA
Proton energy	600 MeV	800 MeV
Beam entry	Vertically from above	
Beam trip number	< 20 per year (exceeding 1 second)	< 3 per year (exceeding 1 second)
Beam stability	Energy: ± 1 %, Intensity: ± 2 %, Size: ± 10 %	
Beam footprint on target	Circular ∅ 5 to 10 cm, "donut-shaped"	An area of up to 100 cm² must be "paint-able" with any arbitrary selectable intensity profile
Beam time structure	CW, with 200 μs zero-current holes every 10^{-3} to 1 Hz, + pulsed mode capability (repetition rate around 50 Hz)	

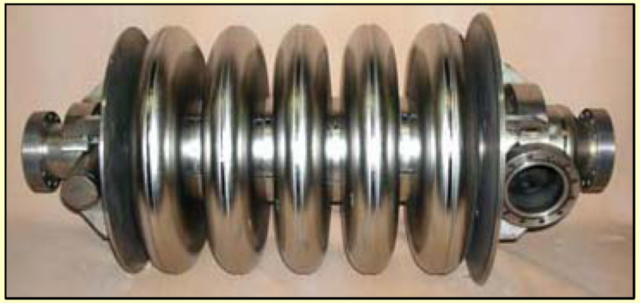
Extrememely high reliability required !!!

SUPERCONDUCTING LINAC

Highly modular and upgradeable; Excellent potential for reliability ; Very good efficiency





Linac front-end

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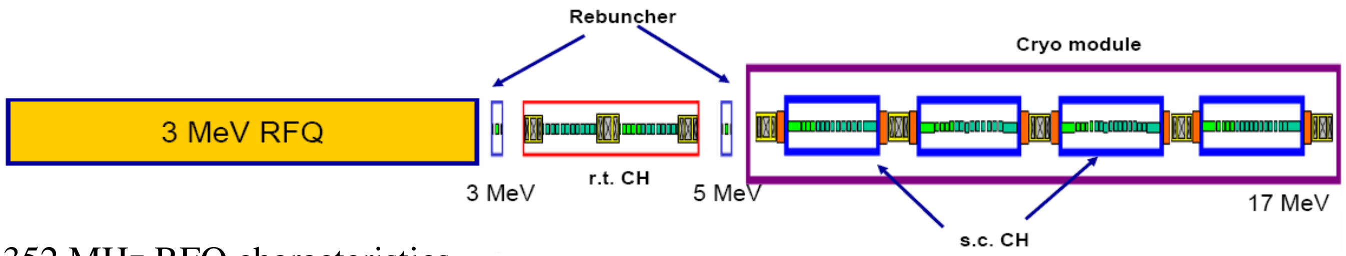

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352 MHz RFQ characteristics

Parameters	Values
Beam Current [mA]	30
Frequency [MHz]	352
Input Energy [keV]	50
Output Energy [MeV]	3.0
Inter-Electrode Voltage [kV]	65
Kilpatrick Factor	1.69
$\varepsilon_{in}^{trans., n., rms}$ [π mm-mrad]	0.20
Output Synchronous Phase [°]	-28.8
Minimum Aperture [cm]	0.23
Maximum Modulation	1.79
$\varepsilon_{out}^{x., n., rms}$ [π mm-mrad]	0.21
$\varepsilon_{out}^{y., n., rms}$ [π mm-mrad]	0.20
$\varepsilon_{out}^{z, rms}$ [MeV-deg]	0.09
Electrode Length [cm]	431.8
Beam Transmission [%]	99.9

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352 MHz DTL characteristics

Cavity	Gaps (φ_s [°])	Length [cm]	$W_{s,out}$ [MeV]	Eacc* [MV/m]
Rebuncher I	2 (-90°)	~7	3.0	2.79
RT-CH	11 (0°) 4 (-40°) 8 (0°)	~160	5.2	2.72
Rebuncher II	2 (-90°)	~7	5.2	5.11
SC-CH I	3 (-40°) 10 (0°)	~90	7.5	3.99
SC-CH II	4 (-40°) 10 (0°)	~105	10.4	3.97
SC-CH III	4 (-40°) 12 (0°)	~130	14.3	3.98
SC-CH IV	4 (-40°) 12 (0°)	~145	18.3	3.96

* Eacc: active acceleration gradient.

- Classical 4-vane RFQ with moderated Kp
- DTL booster using CH structures (KONUS beam dyn.)
- 17 MeV gained in less than 15 metres

Superconducting linac

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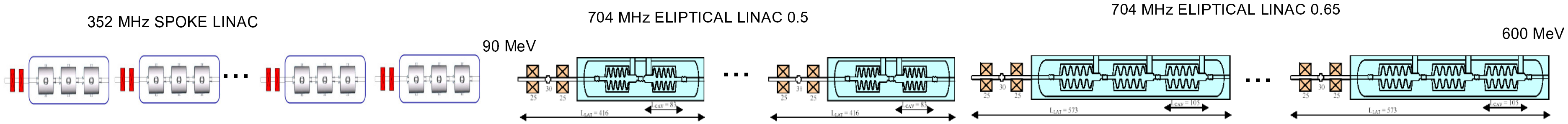

Section number	1	2	3	4
Input Energy [MeV]	17	90	190	450
Output Energy [MeV]	90	190	450	610
Cavity Technology	Spoke 352 MHz	Elliptical 704 MHz		
Structure β	0.35	0.47	0.65	0.85
Number of cavity cells	2	5	5	6
Number of cavities	60	30	42	16
Focusing type	NC quadrupole doublet			
Cavities/Lattice	3	2	3	4
Synch Phase [deg]	-40 to -18	-36 to -15		
Lattice length [m]	2.5	4.1	5.7	8.4
Section Length [m]	50	61	80	34
<gradient> [MeV/m]	1.4	1.6	3.4	4.7

IN-WORK

- Modular, independently-phased accelerating structures
- Moderate gradients (50mT B_{pk}, 25MV/m E_{pk}) & energy gain per cavity
- Overall length: about 225 metres

Final beam line to reactor

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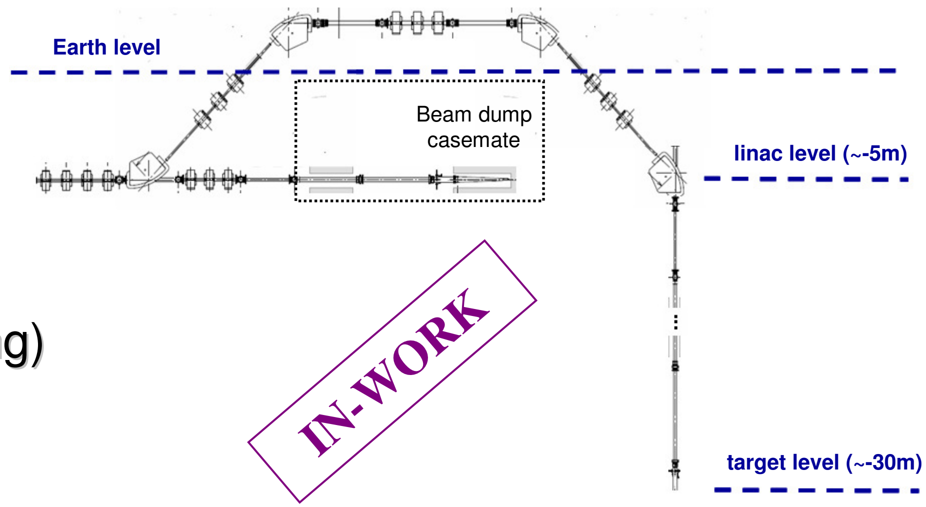
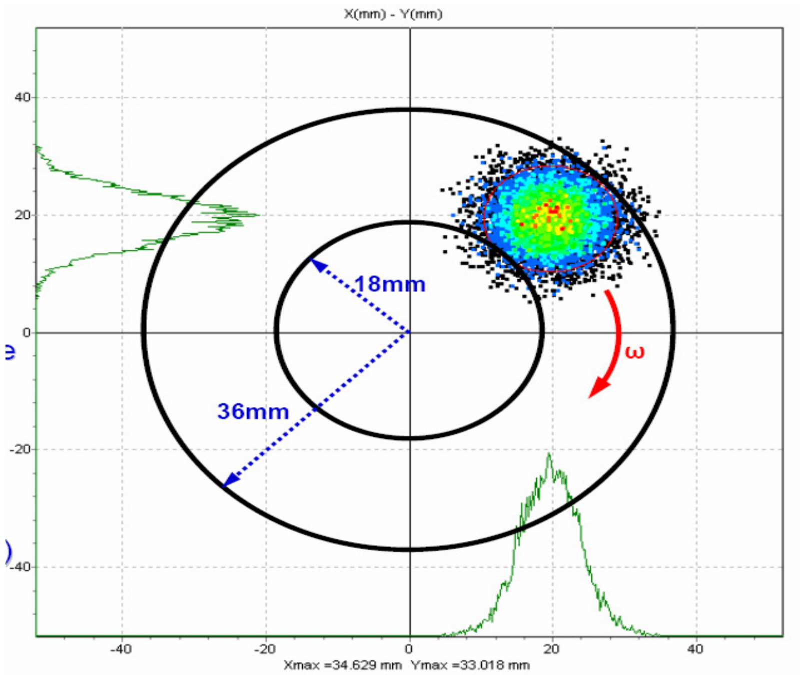
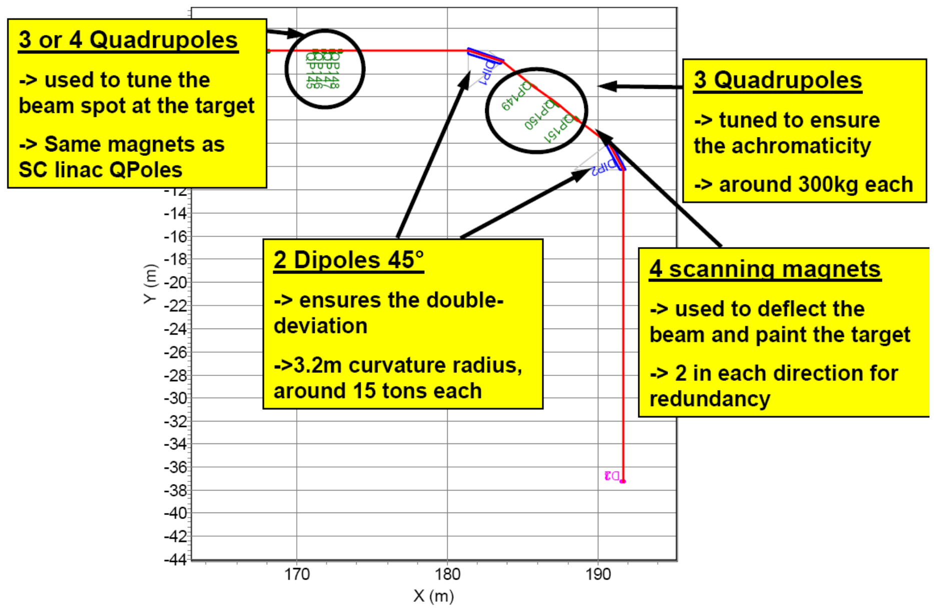
- Final beam line guarantees the position of the beam spot and ensures that only particles of nominal energy are delivered (doubly-achromatic lines)

- Also guarantees the required “donut-shape” distribution at the target (redundant beam scanning)



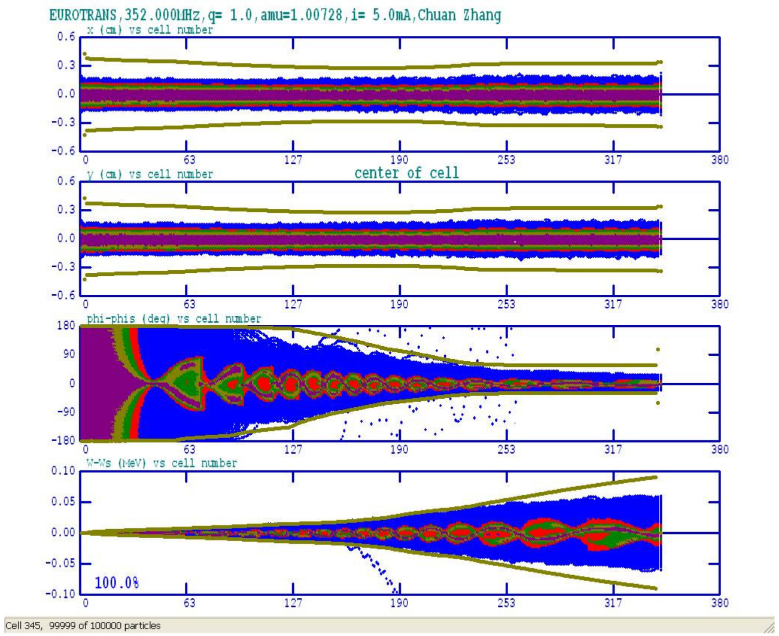


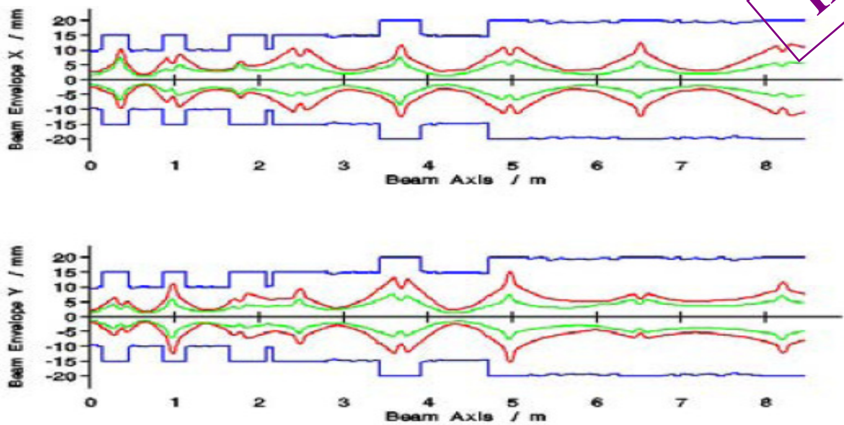


IN-WORK

Less than 10% emittance growth in the whole 17 MeV front-end

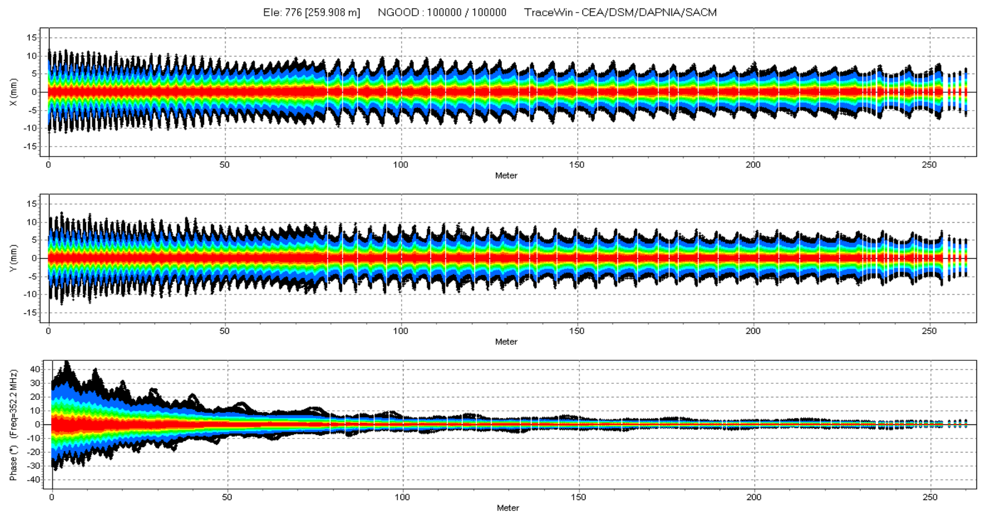
(RFQ simulations with PARMTEQM, DTL simulations with LORASR)





Less than 5% emittance growth in the 17-600 MeV SC linac section

(simulations with TRACEWIN)



Advanced reference design

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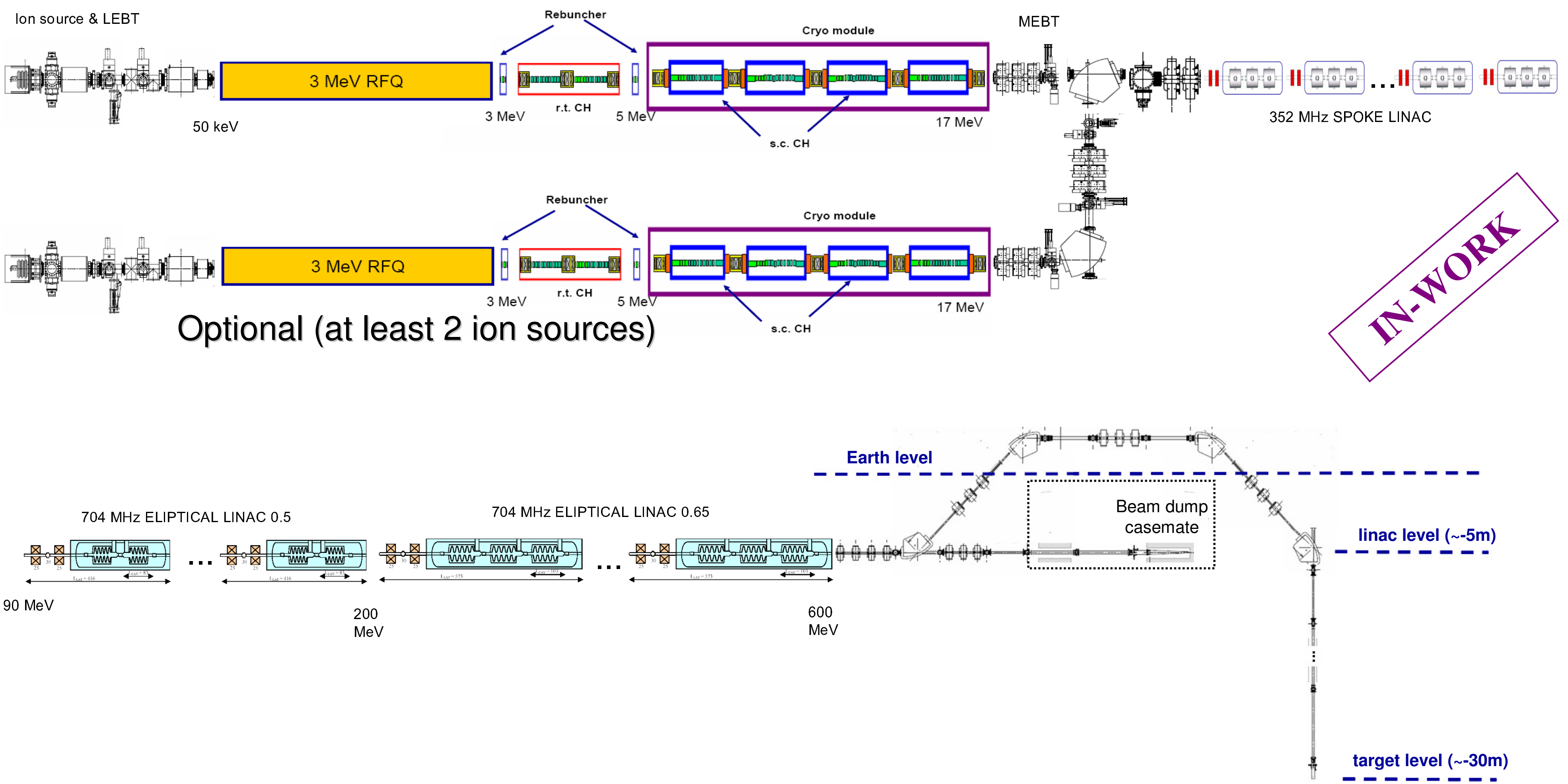
Goal = reach a frozen advanced design by 2010...



... with assessed start-to-end beam dynamics

TraceWin (CEA)

✓ Envelope code with 1st order space charge

✓ Interacting with GenLinWin for the SC linac longitudinal optimization

Benchmarked with: Transport (CERN), Beta (CEA), Path (CERN)…

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Partran (CEA)

✓ Multiparticle code, with 3D space charge routines.

✓ Coupling with TOUTATIS (CEA) for RFQ multiparticle simulations

Benchmarked with: Lions (GANIL), Impact (LANL), Dynamion (GSI), Parmila (LANL), Alodyn (INFN), Path (CERN)…

Code package crucial capabilities

✓ « Close to real » beam tuning procedures using simulated diagnostics

✓ Use of 3D field maps for most of the elements (focusing magnets, RF cavities), high-order aberrations taken into account for the others (dipoles)

✓ Possibility to perform statistical error studies

The reliability requirement

- **Beam trips longer than 1 sec are forbidden** to avoid thermal stresses & fatigue on the ADS target, fuel & assembly & to provide good availability.
  SPECIFICATION : less than 5 per 3-month operation cycle (MYRRHA / XT-ADS)

- **Reliability guidelines have been followed during the ADS accelerator design**

  1. Strong component design ("**overdesign**")
     - All components are derated with respect to technological limitations
     - For every linac main component, a prototype is being designed, built and tested
  2. Inclusion of **redundancies** in critical areas
     - Possible doubled front-end (hot stand-by injector), solid-state RF power amplifiers where possible…
  3. Enhance the capability of **fault-tolerant** operation
     - "Fault-tolerance" = ability to pursue operation despite some major faults in the system
     - Expected in the independently-phased superconducting linac (for both RF faults and QP doublets faults)

Local compensation method

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CONTEXT: We have a strongly non-relativistic beam, and any energy loss will imply a phase slip along the linac, increasing with the distance, that will push the beam out of the stability region -> BEAM LOSS

GOAL: Recover most of the SCRF cavities fault conditions without stopping/loosing the beam more than 1sec

STRATEGY:

- “Local compensation method” in the case of a RF unit or cavity failure : adjacent cavities are retuned to provide the missing energy gain to the beam

- Requires independently-powered RF cavities, good velocity acceptance, moderate energy gain per cavity & tolerant beam dynamics design

- FAST retuning to be performed using pre-tabulated set-points databases stored into the digital LLRF FPGAs