RadSynch13 - BNL

A comparative study between passive and electronic radiation dose detectors

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Objective: answer this question

How is the **influence** of a **pulsed** particle field in the **readings** of the Alba Synchrotron **electronic** dose rate detectors?

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Conclusions

1. ALBA's detectors

- Active radiation detectors:

		FHT192	FHT 762 Wendi-2	EPD
0	**Manufacturer**	Thermo Electron GmbH	Thermo Electron GmbH	Thermo Electron GmbH
1	**Particle**	Photons	Neutrons	Photons
2	**Energy range**	30 keV– 7 MeV	25 meV–5 GeV	15 keV–10 MeV
3	**Measuring range**	100 nSv/h–1 Sv/h	1 nSv/h – 100 mSv/h	Resol. 1 mSv/h: <0.5 Sv/h – 4 Sv/h Resol. 1 Sv/h: 4–50 Sv/h
4	**Energy response**	Calibration factor resp. Cs-137: For low dose rate: 0.01-0.02 (µSv/h)/cps For high dose rate: 1.9 - 2.2 (µSv/h)/cps	Calibration Factor: 1.14 (µSv/h)/cps	Ref. Cs-137 ±30% from 17keV to 6MeV ±50% from 6MeV to 15Mev
5	**Quantity**	Hp(10)	Hp(10)	Hp(10)
8	**Type**	Active Ionization chamber	Active Proportional counter	Active semiconductor dosimeter
9	**Sensitive material**	Inert gas (7 bar)	He-3 (2 bar) + polyethylene moderator	Silicon diode detectors
10	**Dead Time**	Dead Time for high dose rate: 6-7 µs	Dead Time: 1.8 µs	--

1. ALBA's detectors

- Passive radiation detectors

ONLY FOR THE STUDY

		TLD	TLD_Spherical	IPN_gamma	IPN_n
0	**Manufacturer**	Centro de Dosimetría	Centro de Dosimetría	IPN Orsay	IPN Orsay
1	**Particle**	Photons and beta	Photons	Photons	Neutrons
2	**Energy range**		15 keV - 7 MeV	E>20 keV	50 keV à 40 MeV
3	**Measuring range**	10 µGy - 10 Gy	50 µSv - 10 Sv	50 µSv - 1 Sv	0-1 - 250 mSv
4	**Energy response**	Ref. Cs-137 ±10% From 20keV to 662keV	Ref. Cs-137 ±20% From 20keV to 662keV	No data available	No data available
5	**Quantity**	Hp(10)	Hp(10)	Hp(10)	Hp(10)
8	**Type**	Passive dosimeter	Passive dosimeter	Passive dosimeter	Neutrak dosimeter
9	**Sensitive material**	Thermoluminiscent LiF	Thermoluminiscent LiF	Radiophotoluminiscent glass	Solid-state nuclear track detector CR39 (allyldiglycol carbonate) and a polyethylene radiator
10	**Dead Time**	--	--	--	--

2. ALBA's accelerators

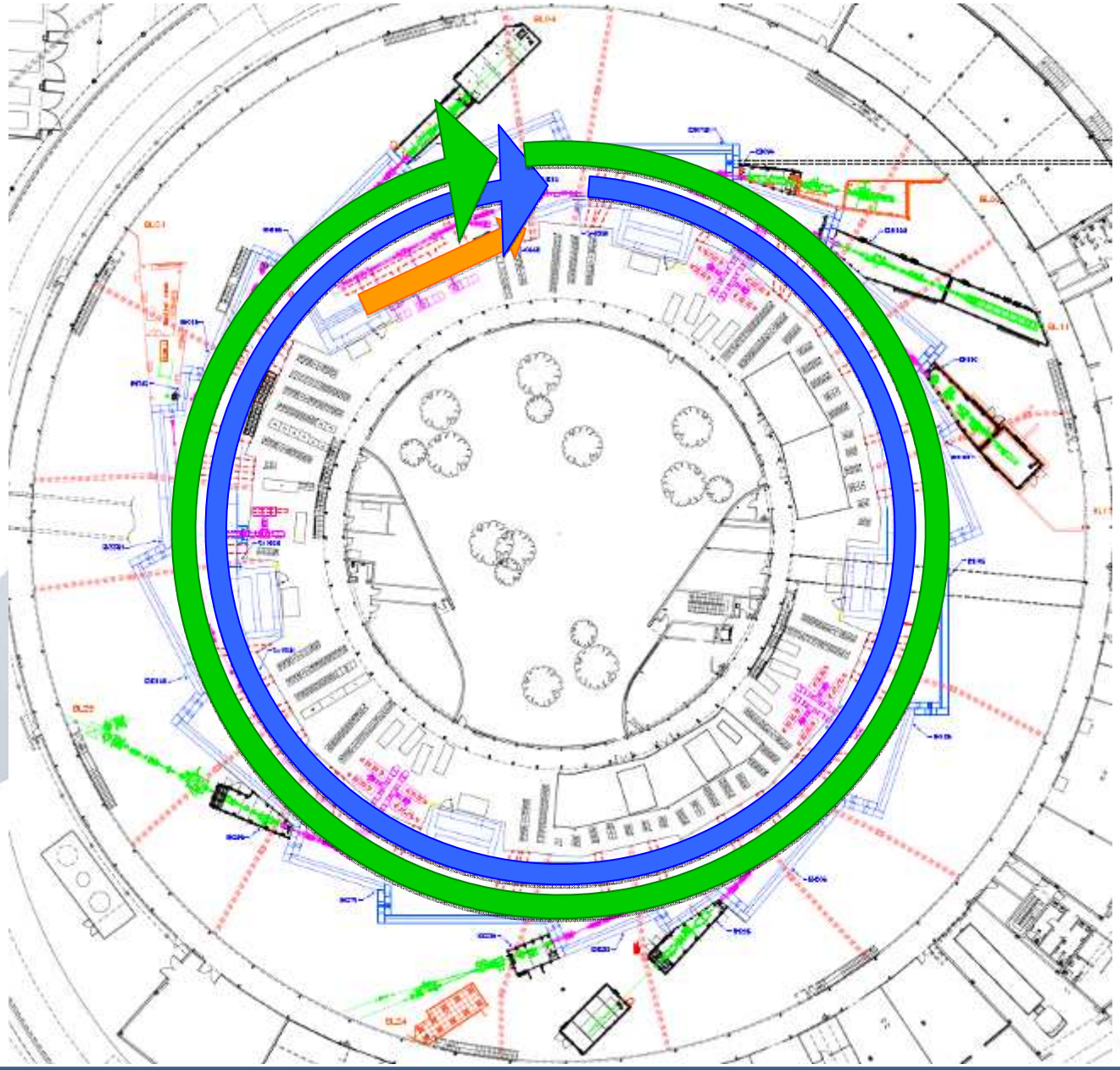
BUNKER

- Linac (110 MeV)

TUNNEL

- Booster (3 GeV)
- Storage (3 GeV)

- Complex and non isotropic fields are created inside the shielding when the e-beam is scattered



2. ALBA's accelerators

Multibunch Mode ALBA Linac Parameters:

Parameter	Specs	Measured
Pulse length	0.3 to 1μs	0.112 μs (*)
Charge	≥3nC (in 1 μs)	4 nC
Energy	≥100MeV	110 MeV
Pulse to pulse energy variation	≤0.25 % (rms)	0.06 % (rms)
Relative energy spread	≤0.5 % (rms)	0.23 % (rms)
Norm. Emittance (1σ)	≤30 π mm mrad (both planes)	< 25 π mm mrad (both planes)
Pulse to pulse time jitter	≤100ps (rms)	25 ps (rms)
Repetition rate	3 to 5 Hz	1-3 Hz (**)

(*) Optimum length according to Beam Dynamics Simulation is 112 ns
(**) **Tested at 1 and 3 Hz**

3. Study conditions

Run timetable

Rutine use of accelerators –
We had no dedicated beamtime for the study

Charge and current measurement devices:
LINAC Charge BCM-01/charge
BOOSTER Current DCCT/average current
STORAGE RING Current DCCT/average current

		LINAC		BOOSTER		STORAGE RING		
Run	Duration (h)	Operation (h)	Maximum charge (nC/pulse)	Operation (h)	Maximum current (mA)	Operation (h)	Maximum current (mA)	Integrated charge (C)
1	8,00	1,40	1,18	0,90	0,78	0,08	20,33	3
2	7,75	0,25	1,13	0,23	0,72	5,85	120,7	2332
3	8,08	0,65	1,14	0,20	0,53	**6,92**	**120,5**	**2887**
4	7,00	3,27	1,24	--	--	--	--	--
5	17,00	1,10	1,24	--	--	--	--	--
6	79,00	**4,57**	**1,24**	--	--	--	--	--

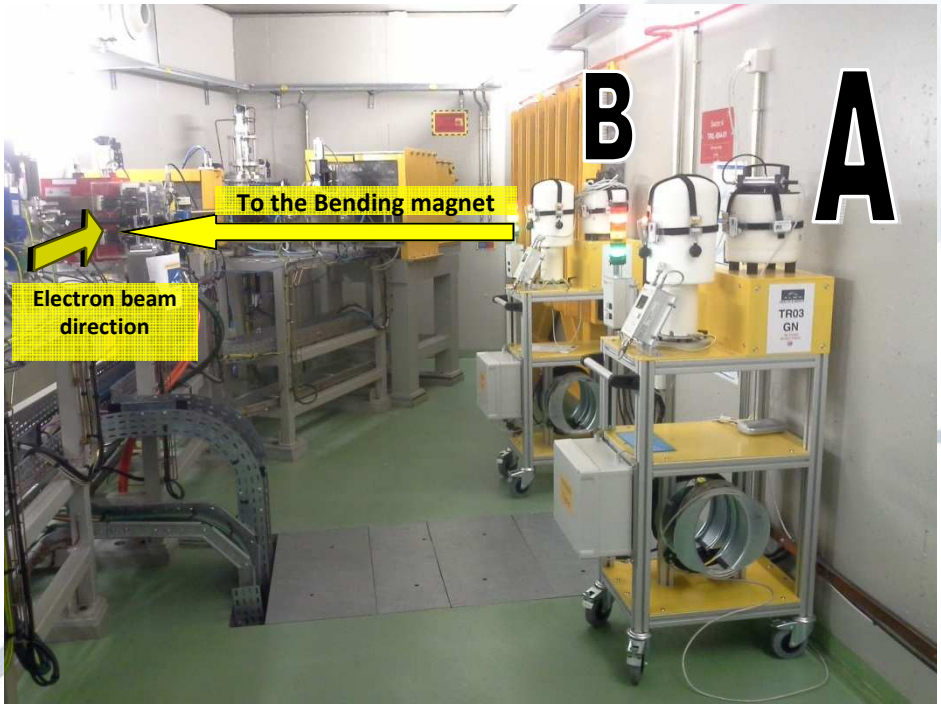
- LINAC's run with longest operation time: 6
- TUNNEL's run with longest operation time: 3

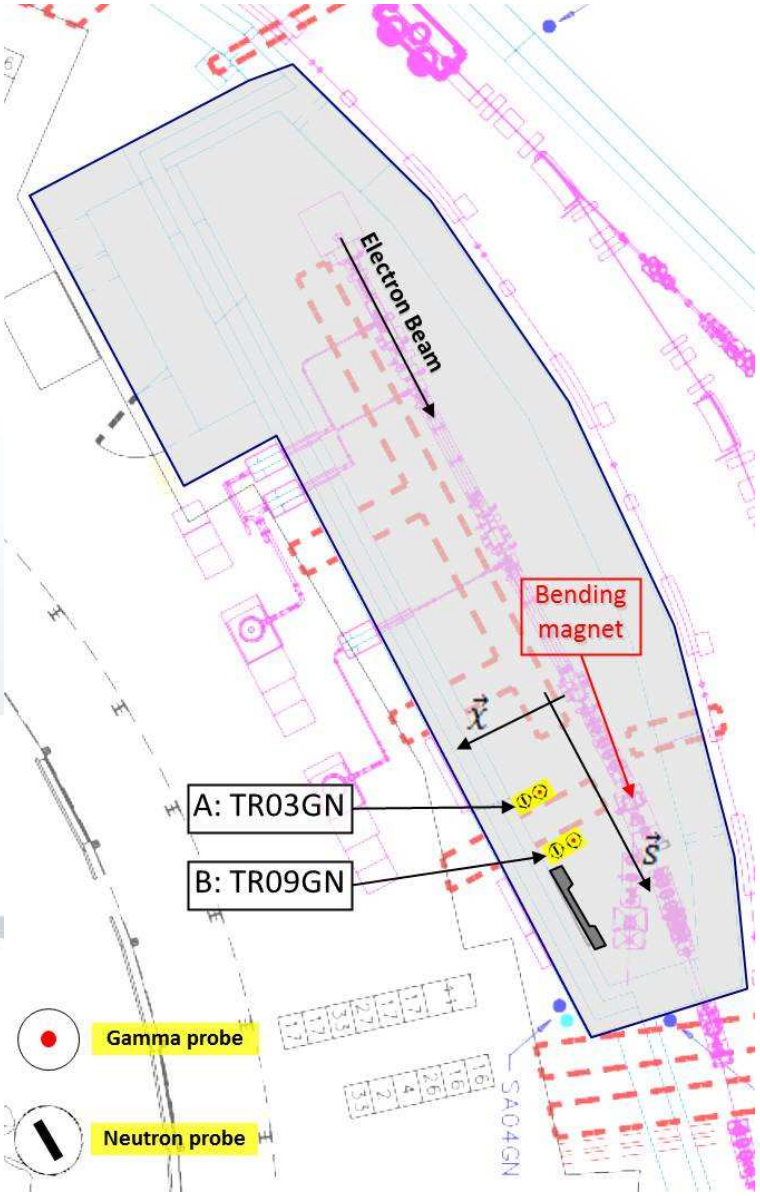
3. Study conditions

LINAC

Irradiation places and positions

- Two places: A & B
- At each place:
  - 1 γ + 1 n probes
  - Several positions for the passive detectors around each probe



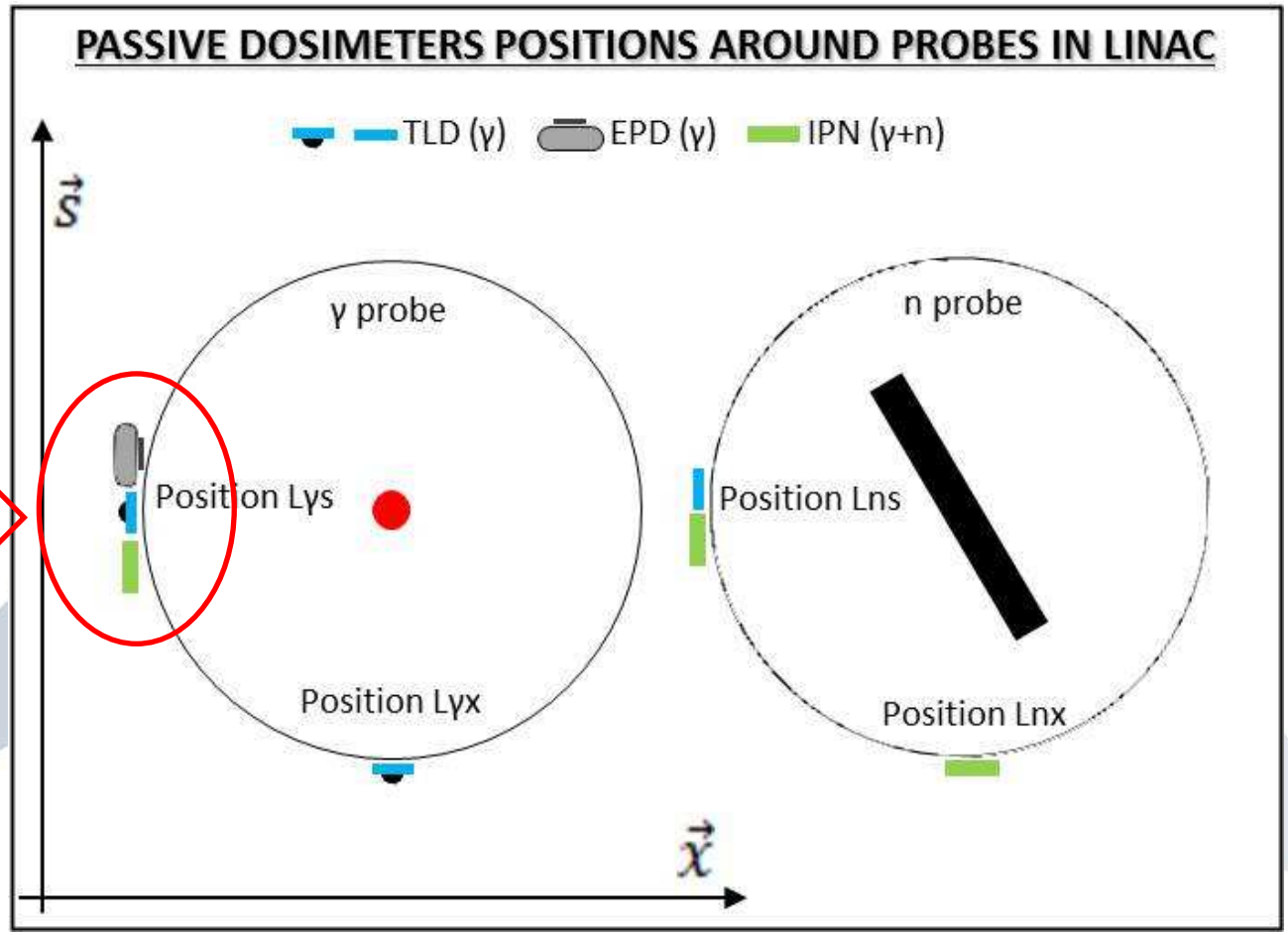


3. Study conditions

LINAC

Passive dosimeter location around the probes

Maximum signal expected here



3. Study conditions

LINAC

Positions summary table

Position at the maximum expected signal

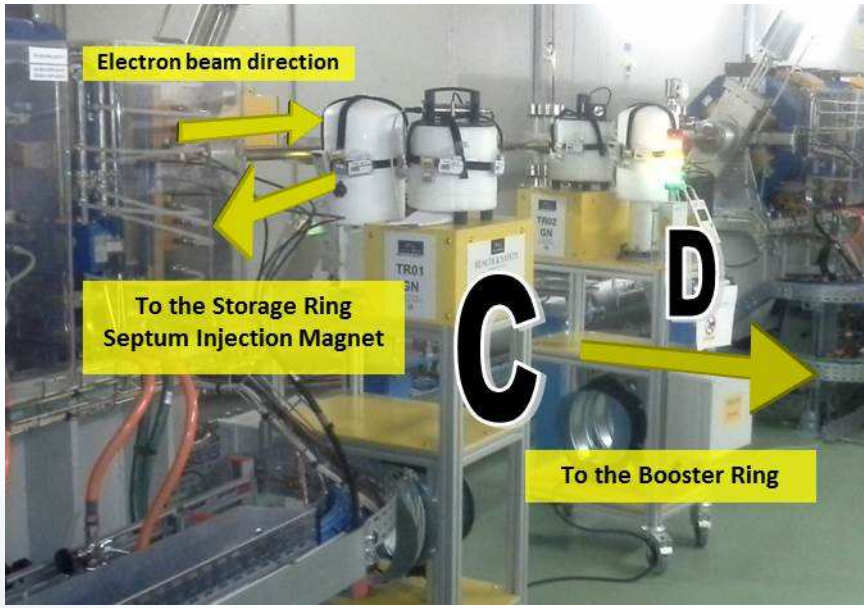
Point	Place	Position	Accelerator	Along …	# Type of dosemeter per position	Distance to the beam chamber (cm)	Radiation Monitor
1	A	**Lγs**	**LINAC**	**s**	**4**	**215,0**	**TR03GN**
2		Lγx	LINAC	x	2	225,0	TR03GN
3		Lns	LINAC	s	2	240,3	TR03GN
4		Lnx	LINAC	x	1	251,5	TR03GN
5	B	**Lγs**	**LINAC**	**s**	**4**	**195,0**	**TR09GN**
6		Lγx	LINAC	x	2	205,0	TR09GN
7		Lns	LINAC	s	2	220,3	TR09GN
8		Lnx	LINAC	x	1	231,5	TR09GN

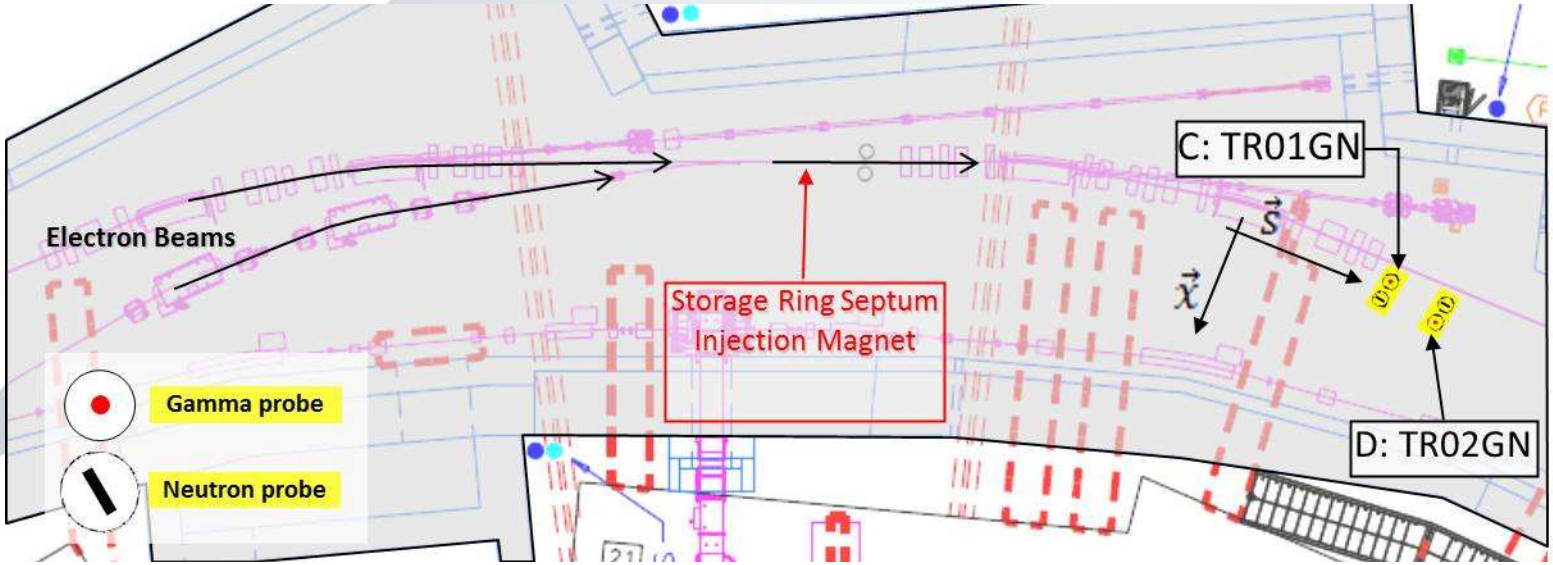
3. Study conditions

TUNNEL

Irradiation places and positions

- Two places: C & D
- At each place:
  - 1 γ + 1 n probes
  - Several positions for the passive detectors around each probe

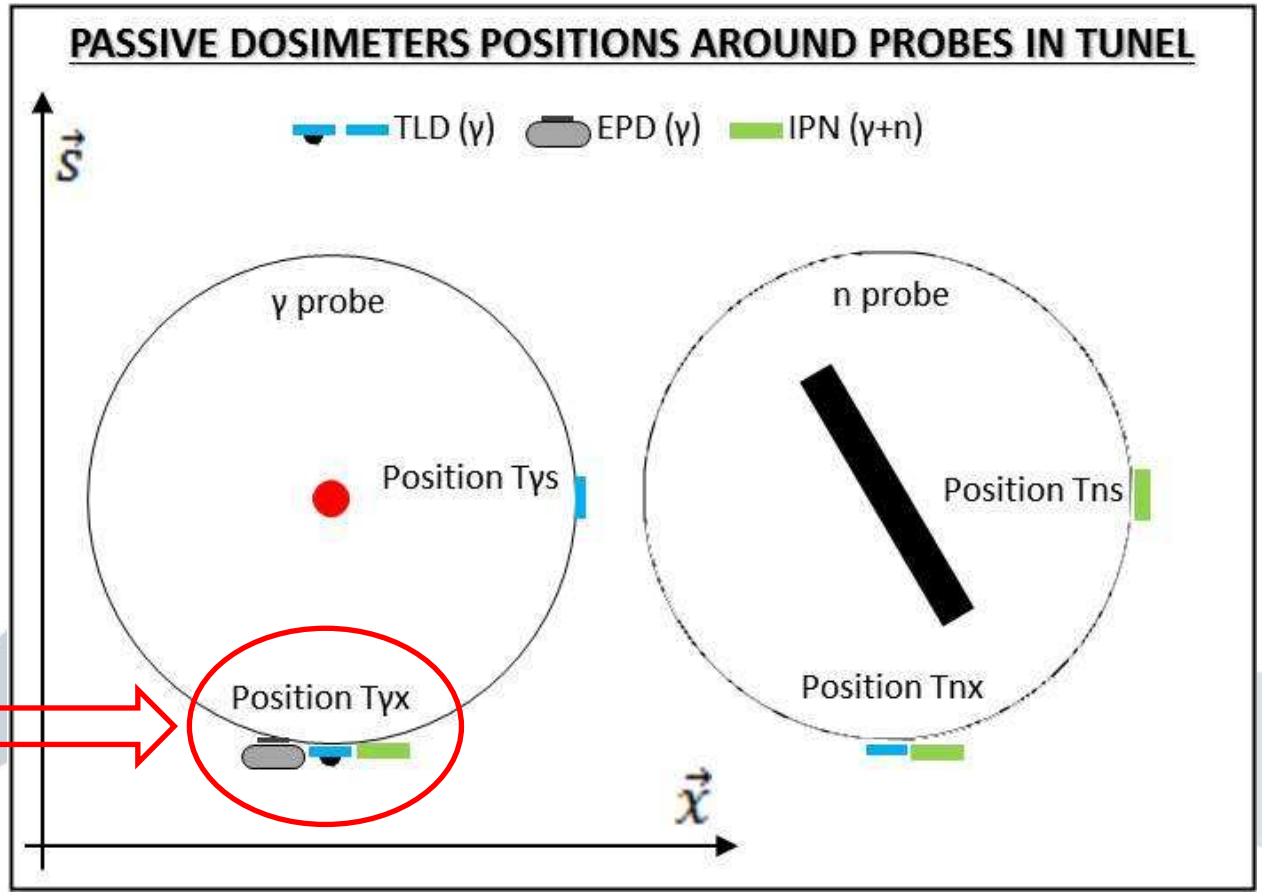




3. Study conditions

TUNNEL

Passive dosimeter location around the probes



Maximum signal expected here

3. Study conditions

TUNNEL

Positions summary table

Position at the maximum expected signal

Point	Place	Position	Accelerator	Along …	# Type of dosemeter per position	Distance to the beam chamber (cm)	Radiation Monitor
9	C	Tγs	Tunnel	s	1	20,0	TR01GN
10		**Tγx**	**Tunnel**	**x**	**4**	**10,0**	**TR01GN**
11		Tns	Tunnel	s	1	48,3	TR01GN
12		Tnx	Tunnel	x	2	37,0	TR01GN
13	D	Tγs	Tunnel	s	1	48,3	TR02GN
14		**Tγx**	**Tunnel**	**x**	**3 (No Sph_TLD)**	**38,3**	**TR02GN**
15		Tns	Tunnel	s	1	22,5	TR02GN
16		Tnx	Tunnel	x	2	11,3	TR02GN

4. Results: Runs & Doses

Accumulated doses

Data from the Radiation Monitors

				Gamma signal		Neutron signal	
Run	Bunker	Place	Radiation Monitor	Accumulated Dose (mSv)	Maximum dose rate (μSv/h)	Accumulated Dose (mSv)	Maximum dose rate (μSv/h)
1	Tunnel	C	TR01	3.52	**2.02E+05**	0.07	1.21E+03
		D	TR02	2.71	7.35E+04	0.06	3.39E+03
	LINAC	A	**TR03**	**0.83**	1.20E+04	**0.20**	3.73E+02
		B	TR09	4.83	4.51E+04	0.26	4.64E+02
2	Tunnel	**C**	**TR01**	**5.07**	6.51E+04	**0.09**	1.98E+03
		D	**TR02**	2.48	2.75E+04	**0.17**	5.03E+03
	LINAC	A	TR03	0.06	6.35E+02	0.01	1.99E+02
		B	TR09	0.07	2.12E+03	0.01	2.44E+02
3	Tunnel	C	TR01	2.11	1.45E+05	0.05	5.43E+03
		D	TR02	1.11	4.85E+04	0.13	**1.61E+04**
	LINAC	A	TR03	0.36	2.90E+03	0.07	3.48E+02
		B	TR09	1.04	1.19E+04	0.08	**1.45E+05**
4	LINAC	**B**	**TR09**	**19.62**	**7.55E+04**	**0.55**	4.71E+02
5	LINAC	B	TR09	3.25	9.09E+03	0.25	4.96E+02
6	LINAC	B	TR09	1.14	6.24E+03	0.17	3.59E+02

4. Results: Runs & Doses

LINAC's run with longest operation time: #6

TUNNEL's run with longest operation time: #3

but …

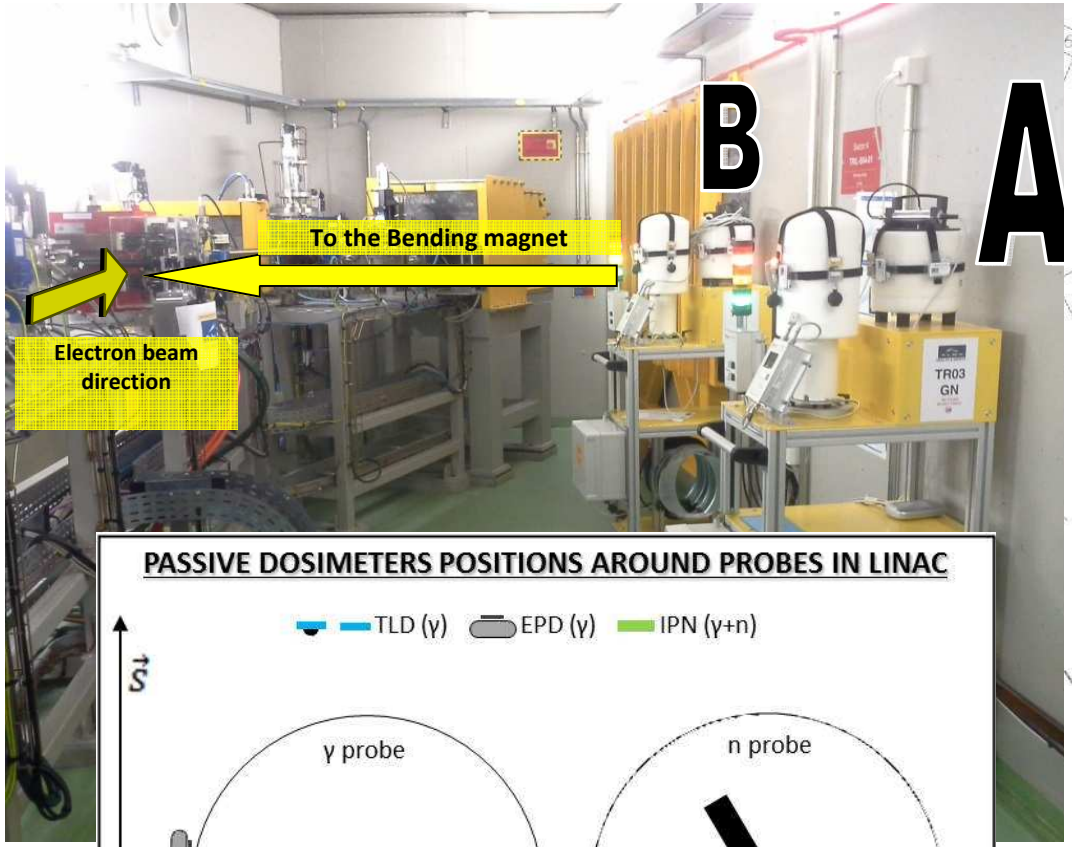
LINAC's run with highest doses:

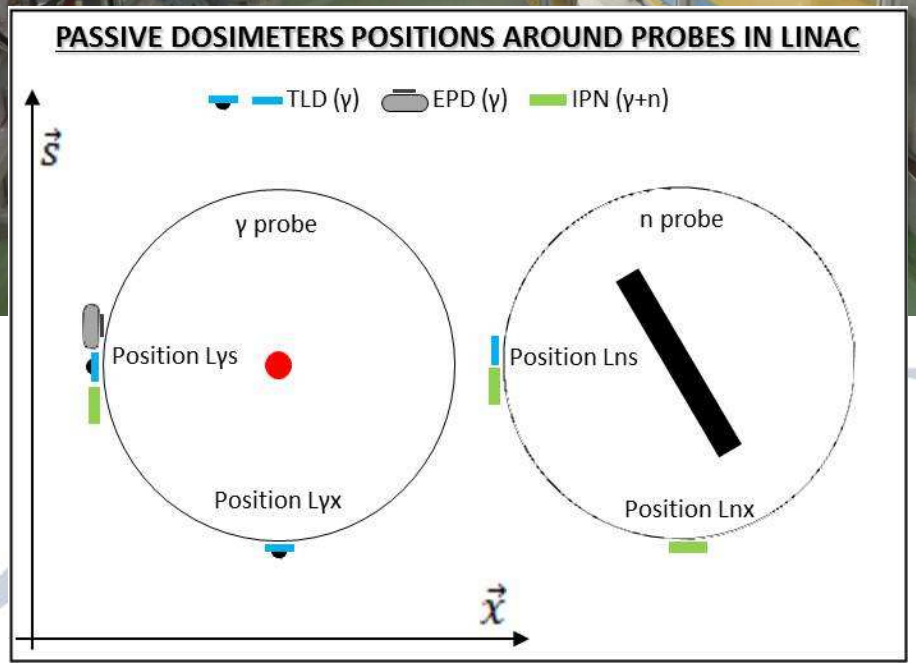
#4 - Position B

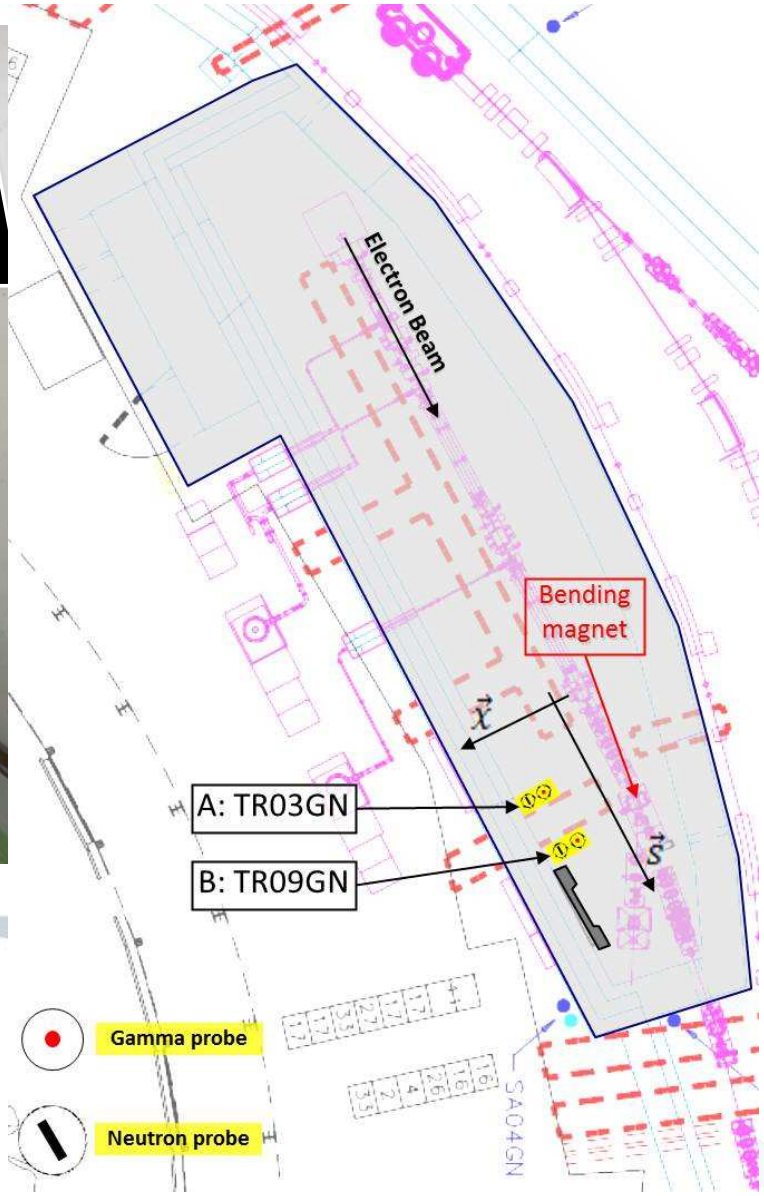
TUNNEL's run with with highest doses:

#2 - Position C

Position-B Location

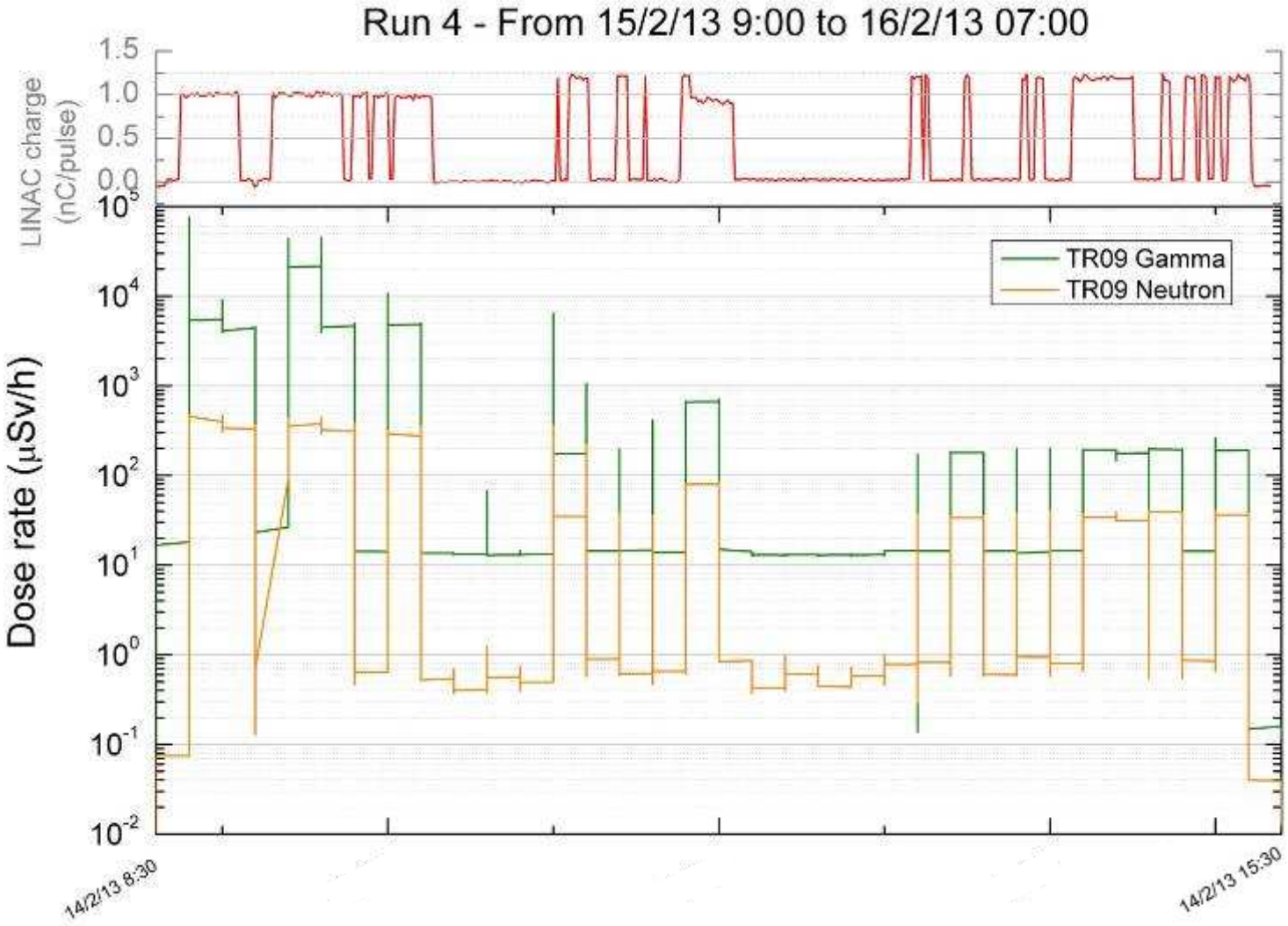






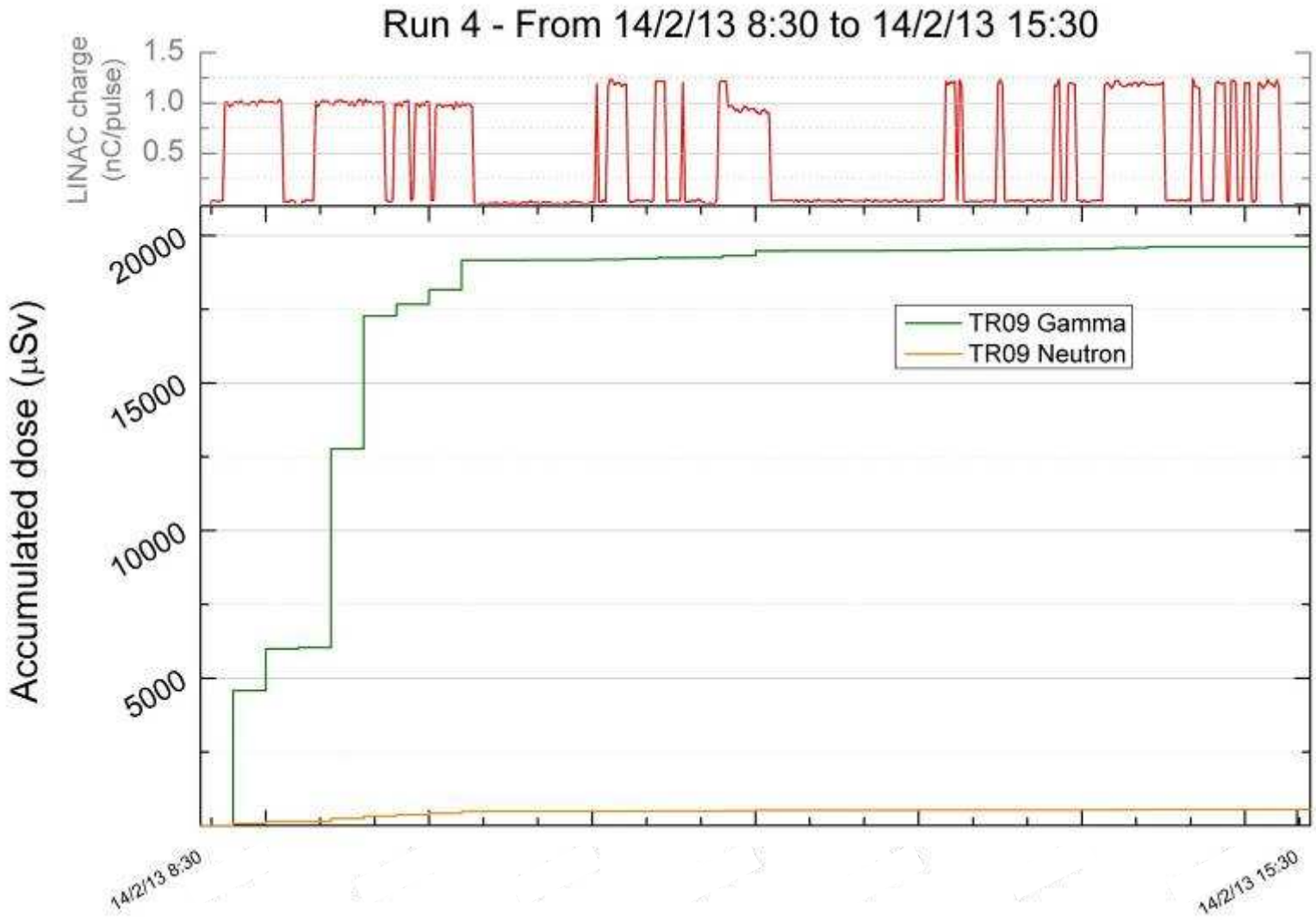
4. Results from LINAC – Position B

Radiation monitors: dose rate data



Results from LINAC – Position B

Radiation monitors: accumulated dose data



Results from LINAC – Position B

Radiation monitors

		Gamma signal		Neutron signal	
Run	Radiation Monitor	Accumulated Dose (mSv)	Maximum dose rate (μSv/h)	Accumulated Dose (mSv)	Maximum dose rate (μSv/h)
4	TR09	**19.62**	7.55E+04	**0.55**	4.71E+02

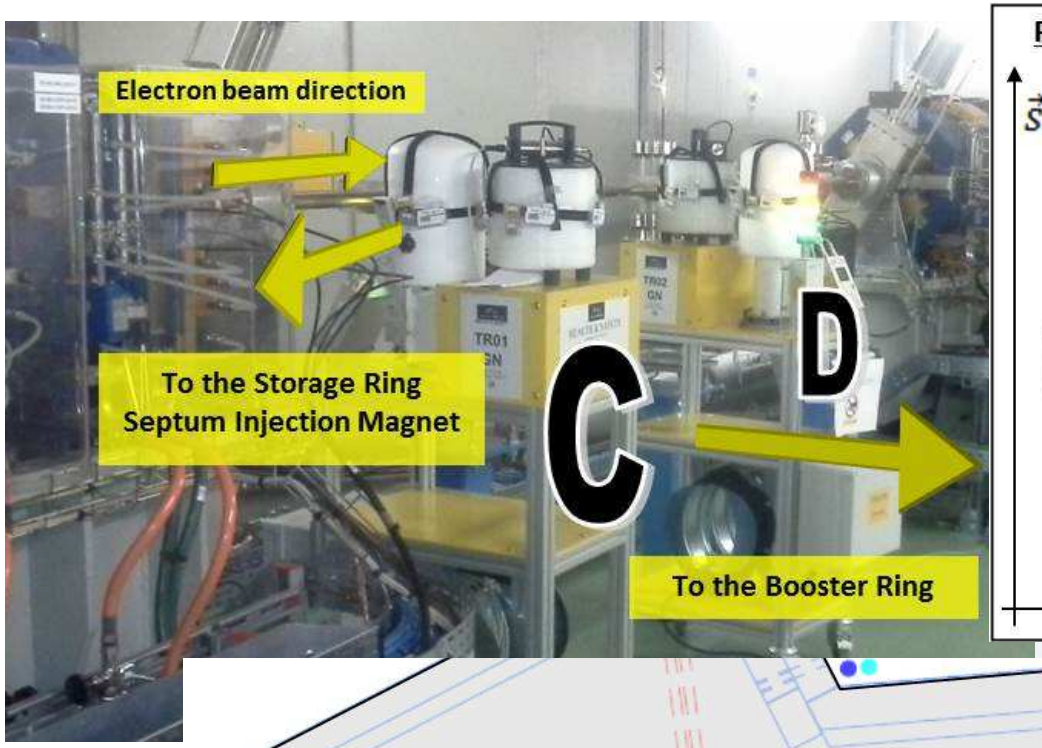
Place	Position	Detects	Type	HPM (mSv)	Dev from Rad. Mon.
B	Lγs	γ	TLD	29.44	50%
			IPN	11.50	-41%
			EPD	1874	9451%
		n	IPN	1.40	155%
	Lγx	γ	TLD	10.22	-48%
	Lns	γ	TLD	4.11	-79%
			IPN	5.50	-72%
		n	IPN	1.60	191%
	Lnx	γ	IPN	2.30	-88%
		n	IPN	0.50	-9%

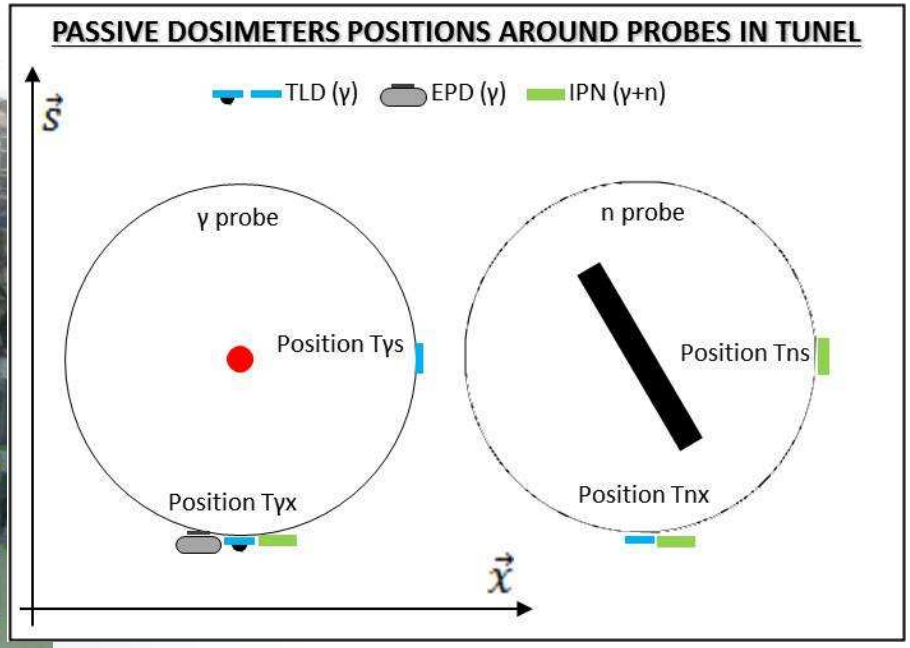
- EPD is clearly out of range
- TLD and IPN readings provide an average value of:
  17.1 ± 8.3 mSv
  which is comparable with the monitor but with a large deviation (48%)
- This is the most exposed position, as expected

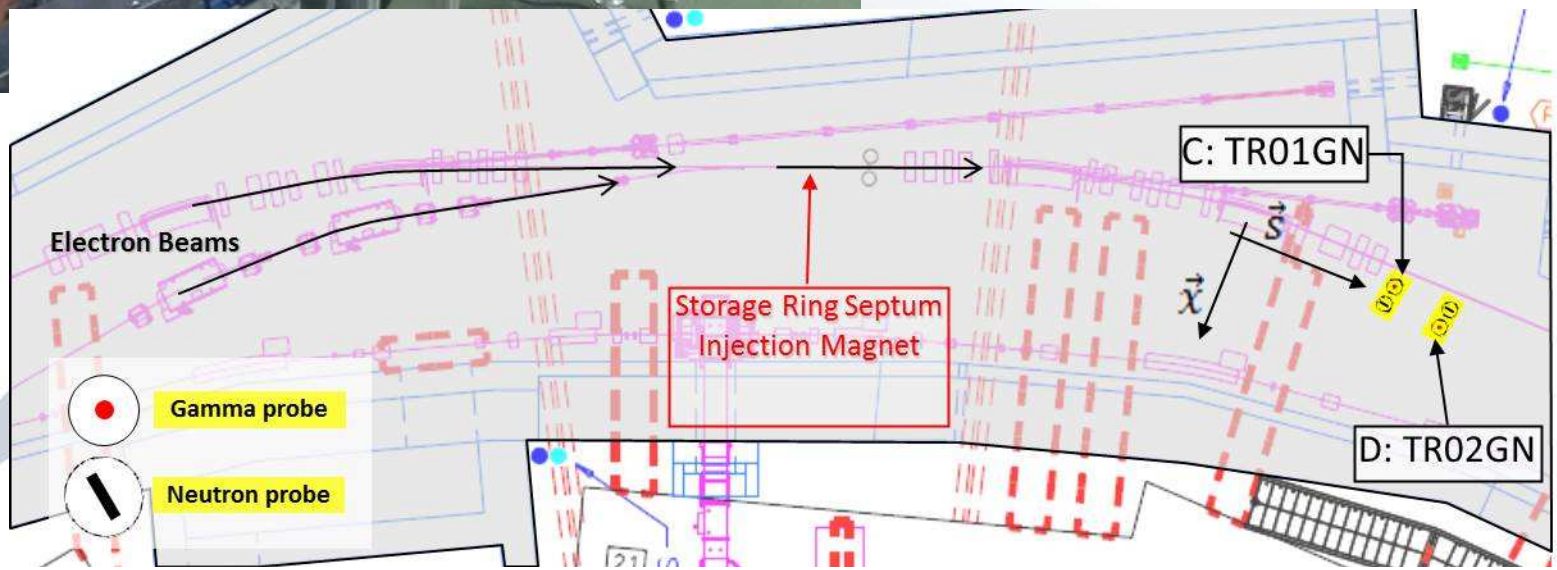
- IPN neutron readings show that Lγs and Lns positions are exposed to different type of neutrons than those arriving to position Lnx

- TLD and IPN readings are comparable and show that these positions are less exposed as expected

Position-C Location

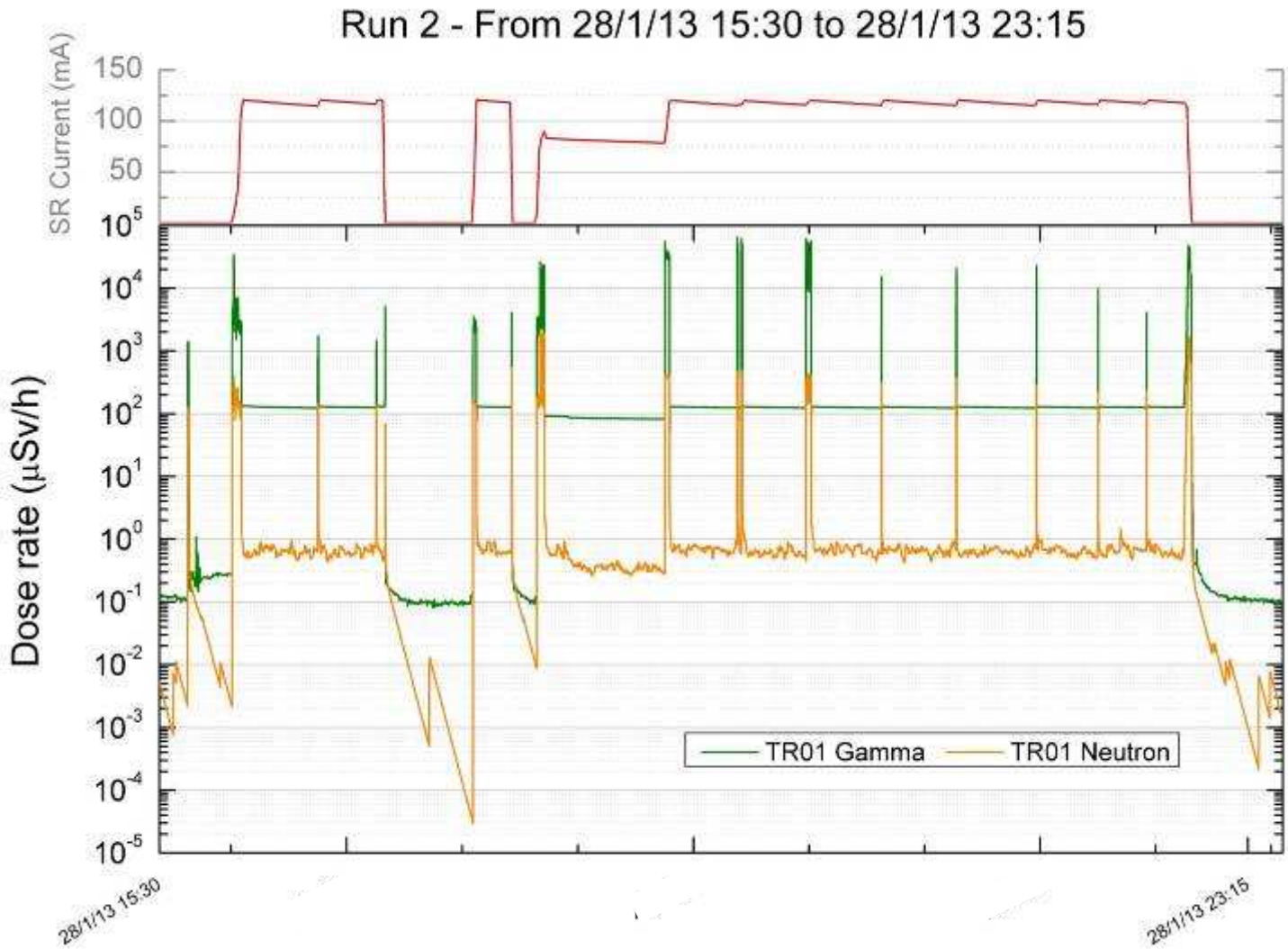






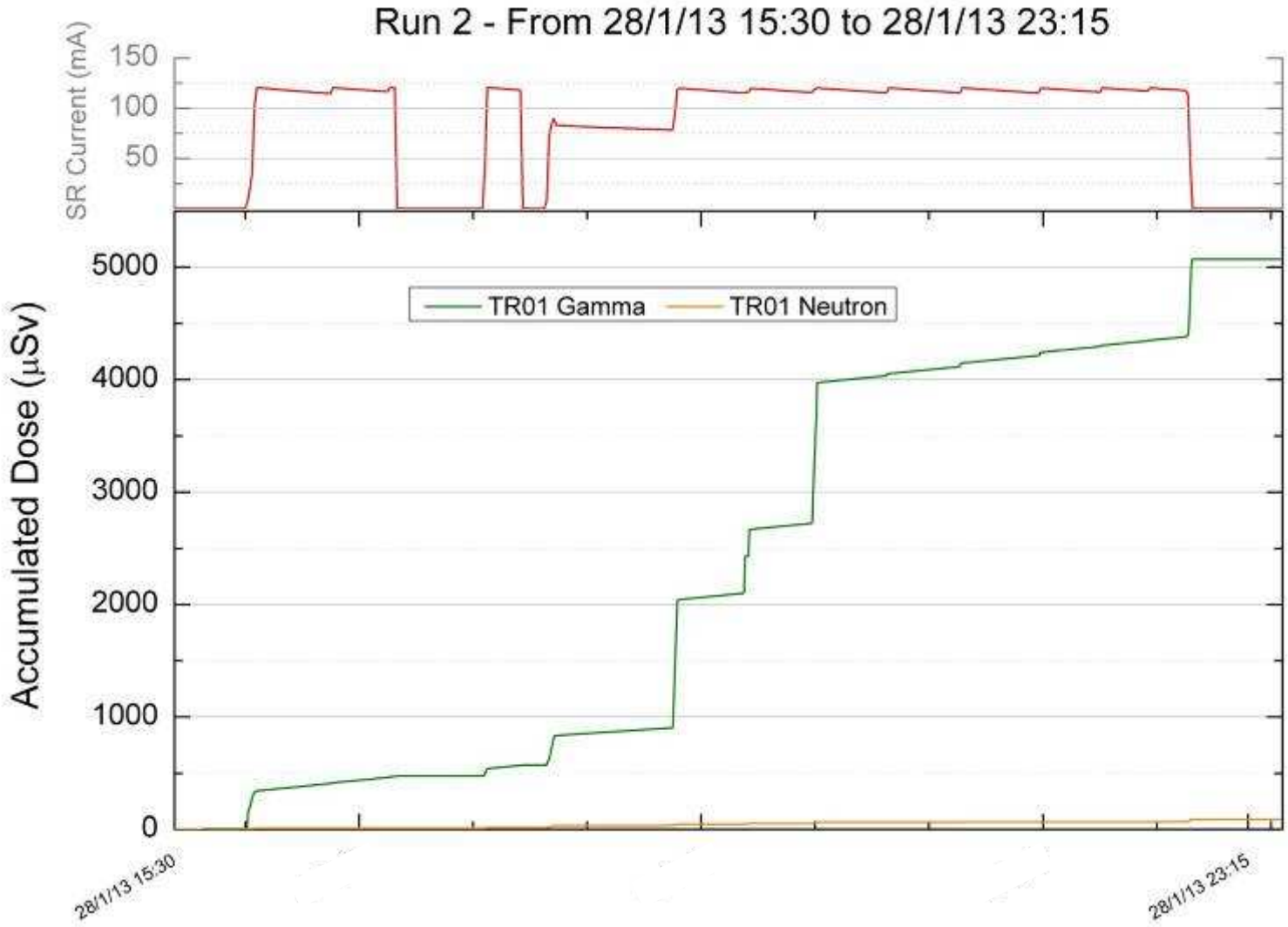
Results from TUNNEL – Position C

Radiation monitors: dose rate data



Results from TUNNEL – Position C

Radiation monitors: accumulated dose data



Results from TUNNEL – Position C

Radiation monitors

			Gamma signal		Neutron signal	
Run	Place	Radiation Monitor	Accumulated Dose (mSv)	Maximum dose rate (μSv/h)	Accumulated Dose (mSv)	Maximum dose rate (μSv/h)
3	C	TR01	**5.07**	6.51E+04	**0.09**	1.98E+03

Place	Position	Detects	Type	HPM	Dev from Rad. Mon.
C	Tγx	γ	TLD	5.46	8%
			Sph TLD	3.40	-33%
			IPN	4.20	-17%
			EPD	0.001	-100%
		n	IPN	0.00	
	Tγs	γ	TLD	2.88	-43%
	Tnx	γ	TLD	5.26	4%
			IPN	4.70	-7%
		n	IPN	0.00	
	Tns	γ	IPN	3.60	-29%
		n	IPN	0.00	

- EPD is clearly out of range
- TLD and IPN readings provide an average value of:

  4.0 ± 0.9 mSv

  which is comparable with the monitor with reasonable deviation (21%)
- This is the most exposed position, as expected

- IPN neutron readings are below the detection limit, this is compatible with the low accumulated neutron dose seen by the neutron radiation monitor

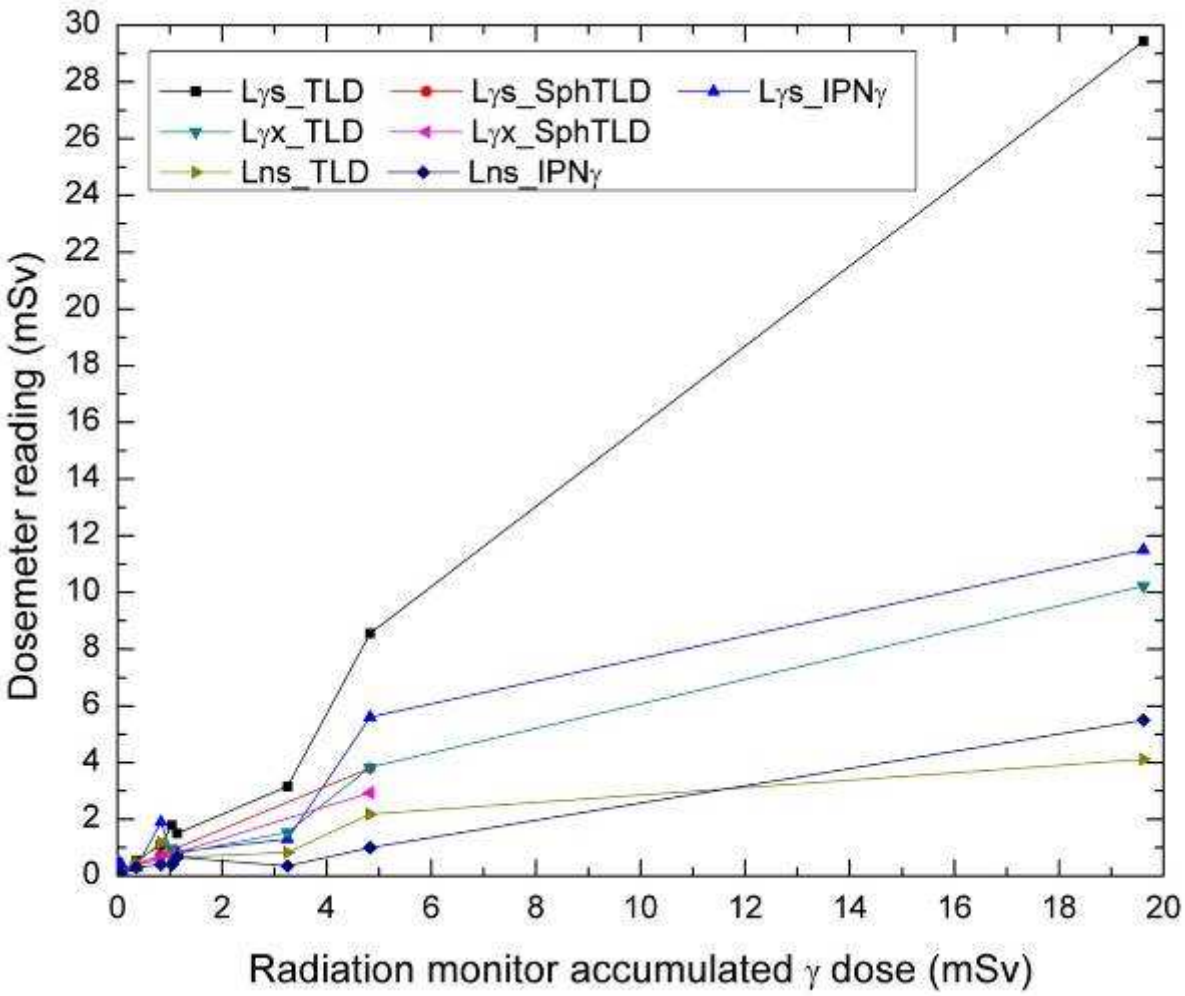
- TLD and IPN readings from the neutron gauge give an average value of:

  4.5 ± 0.6 mSv

  comparable with the gamma radiation monitor with 14% deviation and showing that gamma irradiation is more uniform in this tunnel location than in the LINAC bunker

Gamma dosemeters plot: LINAC case

All runs – all positions inside LINAC Bunker



- Linearity in dose cannot be clearly observed, specially at lower doses where fluctuations are relatively important.
- We must take into account that irradiation patterns may have varied hugely from one run to another
- More data is needed in the range between 5 – 20 mSv.

Conclusions

- **Radiation fields** produced during **routine** use of the accelerators **are spatially complex** and sometimes **highly pulsed** time structure

  →**Active detectors functionality can be compromised**!

- The RADMON probes data **follows the injection process** inside the LINAC bunker & Tunnel.

- In general, **the accumulated doses** obtained **with** the so-called «**ALBA radiation monitors**», FHT192 and FHT 762 Wendi-2 probes, are **comparable with** those obtained with the **TLD and IPN passive dosemeters**, once uncertainties are taken into account

- **EPD** active dosemeters **were not able to work** under such extreme irradiation conditions

- The irradiation conditions did not allow to perform a complete linearity study of all dosimeters response

Next steps

- Repeat the study in beam dedicated shifts that allow controlling the irradiation conditions to:

  1. Analyze if the **EPD** active dosimeters **are able to work** under more controlled irradiation conditions
  2. Perform further tests to compare the responses of planar and spherical TLD
  3. Achieve irradiation conditions in which neutron production is more important to ensure statistic significance in neutron passive dosimeters readings
  4. Expand the range of accumulated doses to complete a linearity study of all dosimeters response

… for your attention