Time structure of the LHC beam
... and its consequences for running

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based on:
ALICE Physics Performance Report, http://www.iop.org/EJ/abstract/0954-3899/30/11/001/
LHC Design Report, http://ab-div.web.cern.ch/ab-div/Publications/LHC-DesignReport.html

long scales

Yearly rhythm

- several months of pp 10^7 s
- several weeks of ions 10^6 s

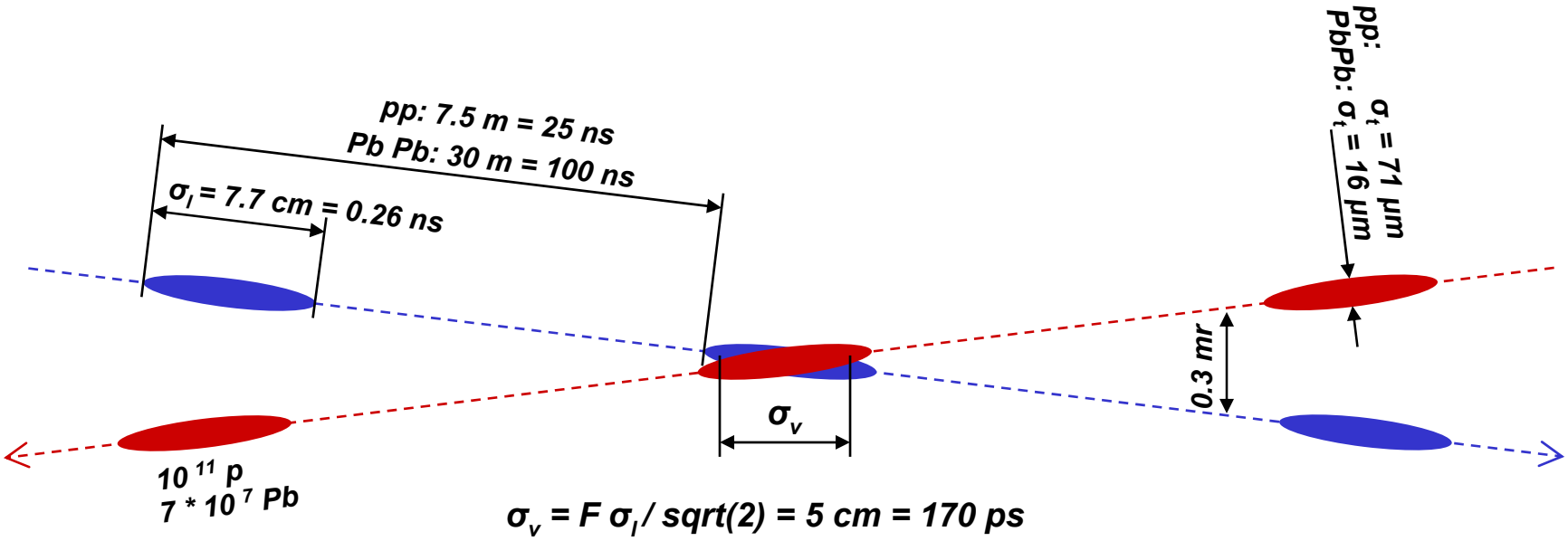
like SPS

Daily rhythm (PbPb)

- LHC filling and accel. 3 hours
- experiment running 3-9 hours
  (luminosity lifetime 3-7 hours;
  compensated by focusing)

6-12 hours cycle

bunch crossing at IP2



$\sigma_v = F \sigma_l / \sqrt{2} = 5$ cm = 170 ps

where do the bunches come from: acceleration scheme

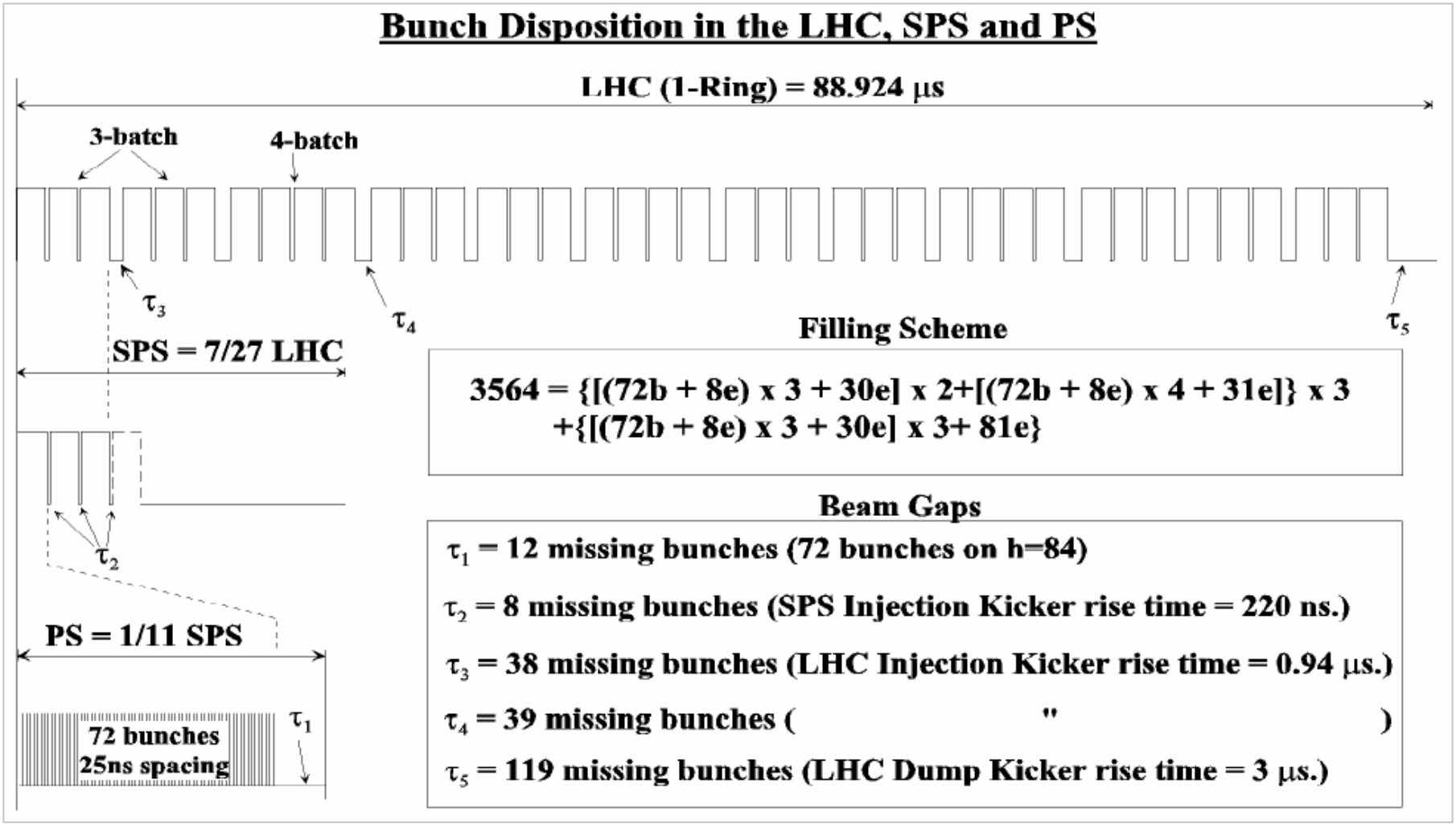


Figure 2.1: Proton bunches in the PS, SPS and one LHC ring. Note the partial filling of the SPS (3/11 or 4/11) and the voids due to kicker rise-time. One LHC ring is filled in ~3 min.

rates

	Luminosity (cm^{-1} s^{-1})	σ	interaction rate (Hz)	bunch spacing	Intera-ctions per bunch crossing	interactions per TPC drift time
PbPb low	$5*10^{25}$	8 b	400	1000 ns	0.0004	0.04
PbPb high	10^{27}	8 b	8000	100 ns	0.0008	0.8
pp low	10^{29}	70 mb	7000	75 ns	0.0006	0.35
pp high	$5*10^{30}$	70 mb	350 k	25 ns	0.01	35
Atlas pp	10^{34}	70 mb	700 M	25 ns	19	

consequences for running

- ***semi-continuous interaction (no spills)***
- ***interaction time known within 170 ps***
  (with T0 down to < 50 ps)
- ***transverse vertex position fixed within 16 (70) μm***
- ***...?***

backup

LHC machine parameters

	pp	Pb–Pb
Energy per nucleon (TeV)	7	2.76
β at the IP: β^* (m)	10	0.5
R.m.s. beam radius at IP: σ_t (μm)	71[a]	15.9
R.m.s. bunch length: σ_l (cm)	7.7	7.7
Vertical crossing half-angle (μrad) for pos. (neg.) μ-spectr. dipole polarization	150 (150)	150 (100)
No. of bunches	2808	592
Bunch spacing (ns)	24.95	99.8
Initial number of particles per bunch	1.1×10^{11}	7.0×10^{7}
Initial luminosity ($cm^{-2}\ s^{-1}$)	$< 5 \times 10^{30}$	10^{27} [b]

[a] For low-intensity runs β^* could be 0.5 m and $\sigma_t = 15.9\ \mu$m as in Pb–Pb.
[b] Early operation will be with 62 bunches and $\beta^* = 1$ m, which yields an initial luminosity of $5.4 \times 10^{25}\ cm^{-2}\ s^{-1}$.

ALICE running conditions

System	$\sqrt{s_{NN}}_{max}$ (TeV)	Δy	σ_{geom} (b)	$\mathcal{L}_{low}$ ($cm^{-2}\,s^{-1}$)	$\mathcal{L}_{high}$ ($cm^{-2}\,s^{-1}$)
Pb–Pb	5.5	0	7.7	1.0×10^{27}	
Ar–Ar	6.3	0	2.7	2.8×10^{27}	1.0×10^{29}
O–O	7.0	0	1.4	5.5×10^{27}	2.0×10^{29}
N–N	7.0	0	1.3	5.9×10^{27}	2.2×10^{29}
$\alpha\alpha$	7.0	0	0.34	6.2×10^{29}	
dd	7.0	0	0.19	1.1×10^{30}	
pp	14.0	0	0.07	1.0×10^{29}	5.0×10^{30}
pPb	8.8	0.47	1.9	1.1×10^{29}	
pAr	9.4	0.40	0.72	3.0×10^{29}	
pO	9.9	0.35	0.39	5.4×10^{29}	
dPb	6.2	0.12	2.6	8.1×10^{28}	
dAr	6.6	0.05	1.1	1.9×10^{29}	
dO	7.0	0.00	0.66	3.2×10^{29}	
αPb	6.2	0.12	2.75	7.7×10^{28}	
αAr	6.6	0.05	1.22	1.7×10^{29}	
αO	7.0	0.00	0.76	2.8×10^{29}	

How long will it take?

- Pre-injection plateau – 30 minutes
- Injection – 30 minutes or more??
- Ramp – 30 minutes
- Squeeze & prepare physics – 30 minutes
- Physics – 10 hours
- Dump and Ramp down – 30 minutes
- 13 hours per fill (perfect case!!!)
- Any problem will add >> 1 hour…

Trigger

Hierarchical architecture

L0, L1, L2, and HLT

High Level Trigger (HLT)

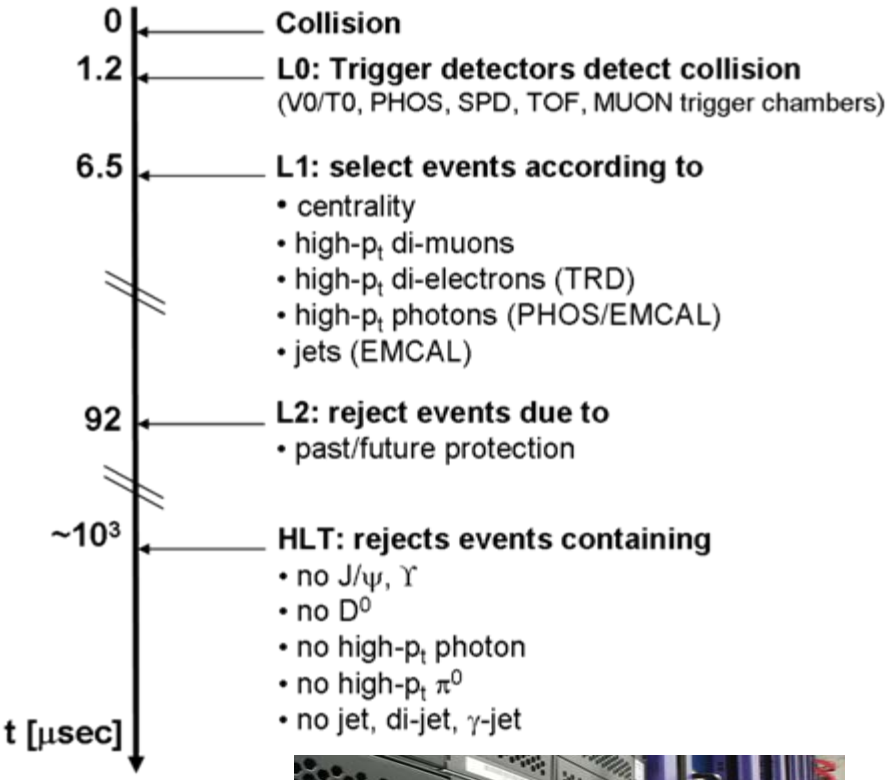
Online reconstruction using ~500–600 PCs + FPGAs

Input rate 200Hz (central Pb–Pb) → up to 20 GByte/s

Generate physics trigger (e.g. jets, Upsilons, D^0, ...)

Online data compression

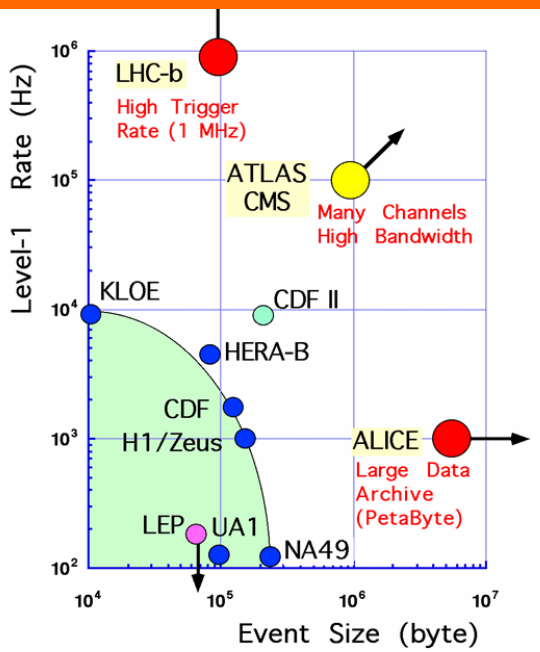
Calibration tasks



Number	L0 (Pb–Pb)	L0 (pp)	L1 (Pb–Pb)
1	V0 minimum bias	V0 minimum bias	TRD unlike e pair high p_T
2	V0 semi-central	V0 high multiplicity	TRD like e pair high p_T
3	V0 central	V0 beam gas	TRD jet low p_T
4	V0 beam gas	T0 right	TRD jet high p_T
5	T0 vertex	T0 left	TRD electron
6	PHOS MB	T0 vertex	TRD hadron low p_T
7	PHOS jet low p_T	PHOS MB	TRD hadron high p_T
8	PHOS jet high p_T	PHOS jet low p_T	ZDC 1
9	EMCAL MB	PHOS jet high p_T	ZDC 2
10	EMCAL jet high p_T	EMCAL MB	ZDC 3
11	EMCAL jet med p_T	EMCAL jet high p_T	ZDC special
12	EMCAL jet low p_T	EMCAL jet med p_T	Topological 1
13	Cosmic Telescope	EMCAL jet low p_T	Topological 2
14	DM like high p_T	Cosmic Telescope	
15	DM unlike high p_T	DM like high p_T	
16	DM like low p_T	DM unlike high p_T	
17	DM unlike low p_T	DM like low p_T	
18	DM single	DM unlike low p_T	
19	TRD pre-trigger	DM single	
20		TRD pre-trigger	
21			
22			
23			
24			

DAQ

Detector	pp (kB)	Pb–Pb (MB)
ITS Pixel		0.140
ITS Drift	1.8	1.500
ITS Strips		0.160
TPC	2450.0	75.900
TRD	11.1	8.000
TOF		0.180
PHOS		0.020
HMPID		0.120
MUON		0.150
PMD		0.120
Trigger		0.120
Total	2500	86.500



	Scenario 1 Rates (Hz)		Scenario 2 Rates (Hz)		Scenario 3 Rates (Hz)		Scenario 4 Rates (Hz)	
	Maximum	DAQ	Level 2	DAQ	Level 2	DAQ	Level 2	DAQ
Central	10^3	20	10	10	20	20	20	20
Minimum-bias	10^4	20	10	10	20	20	20	20
Dielectron			100	100	200	20	200	20
Dimuon	1000	650	1600	1600	1600	1600	1600	1600
Total throughput (MB s^{-1})		1250	1400	1400	700			

10 years scale

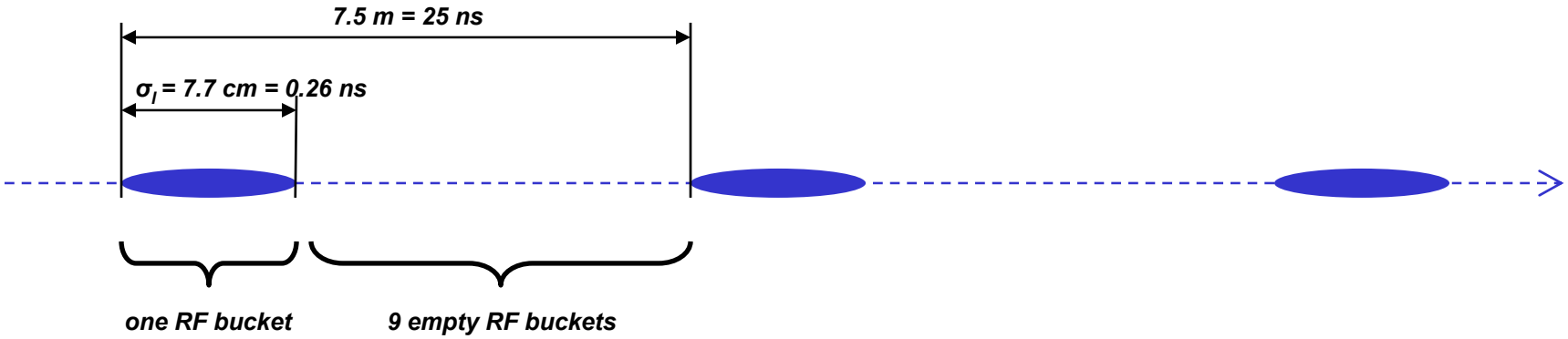
initial phase

- ***pilot Pb+Pb***
- ***1-2 years Pb+Pb***
- ***1 year p+Pb (or like)***
- ***1-2 years Ar+Ar***

subsequent options

- ***pp at sqrt(s) = 5.5 TeV***
- ***N+N or O+O or Kr+Kr...***
- ***another pA***
- ***lower energy Pb+Pb***
- ***high stat full energy Pb+Pb***

bunches



LHC experiments