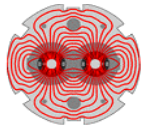
# Ions for LHC: Sources, Linac3



## A Glimpse on the LHC injector chain

- Nominal lead beam in LHC

## ECR Source, Linac3 issues

- Intensity in allowed emittance

## Lighter Ions

- Estimated yields from source, Linac, stripper
- Possible improvements

## Low Energy Ion Ring (LEIR) or Laser Ion Source (LIS)?

# Acknowledgements

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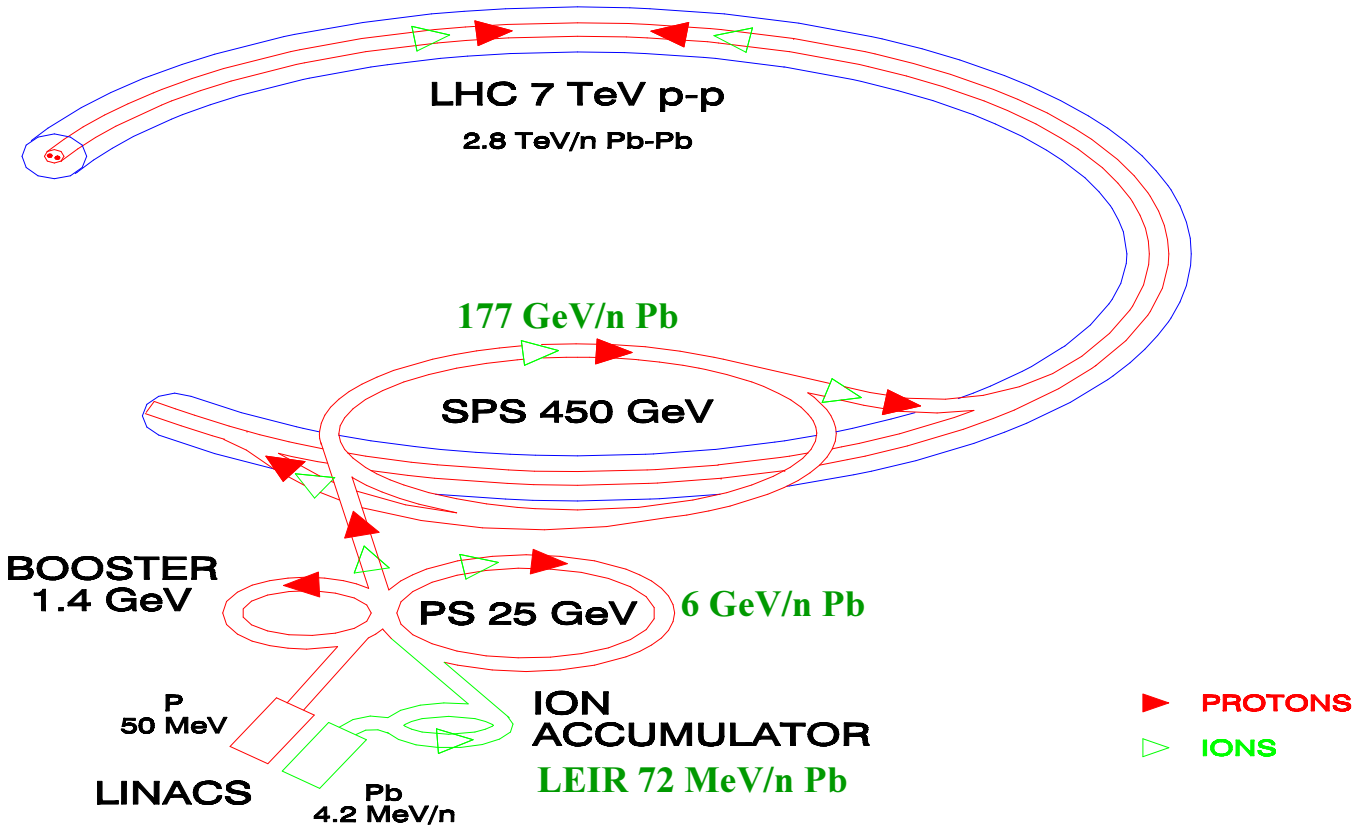
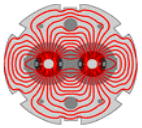
Cost estimates of the LIS route by **Stephan Maury**

# The LHC Injector Chain



# Lead Ions in LHC and Injectors - Nominal

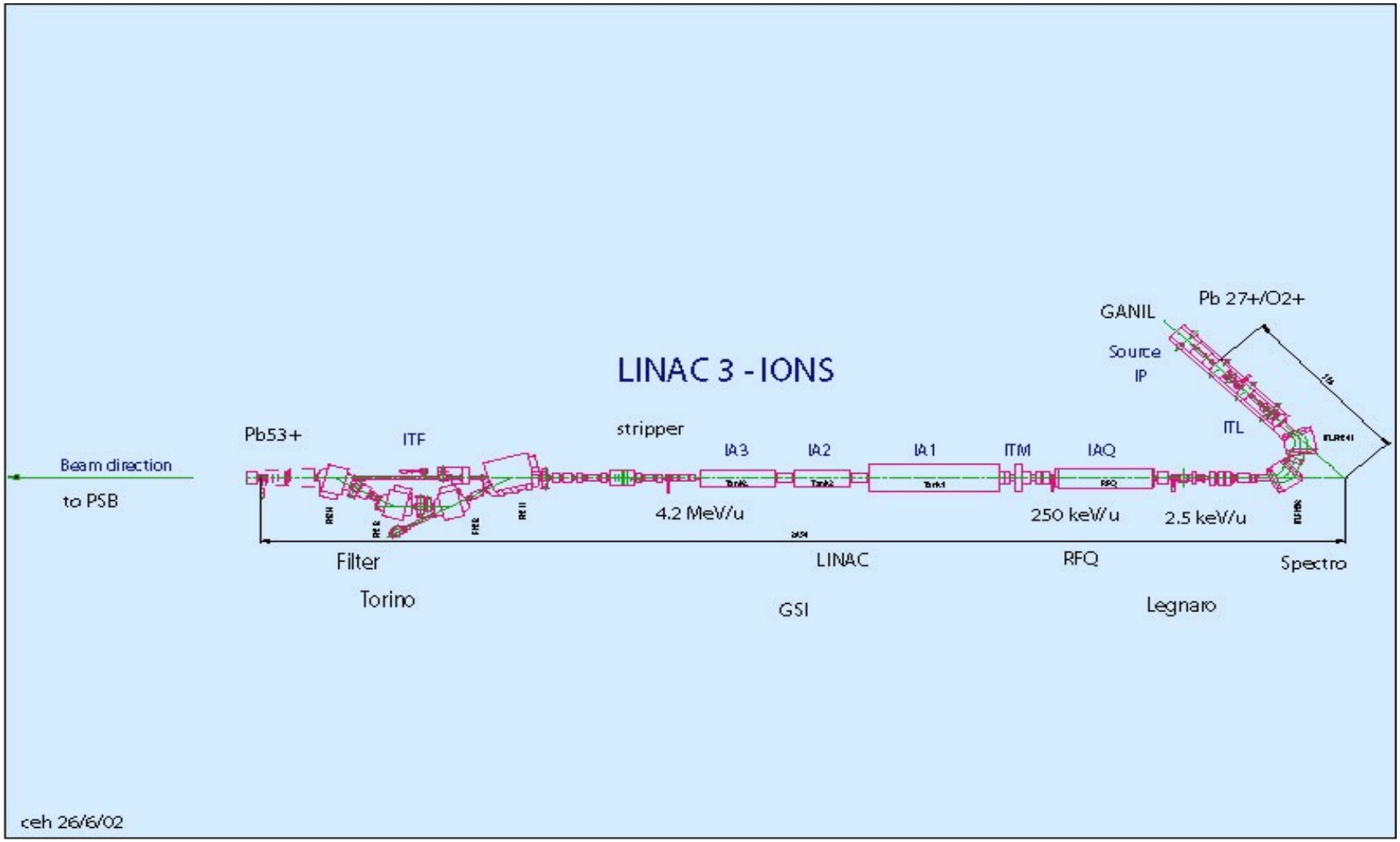


## LHC Pb Luminosity = 1 $10^{27}$ $cm^{-2}$ $s^{-1}$

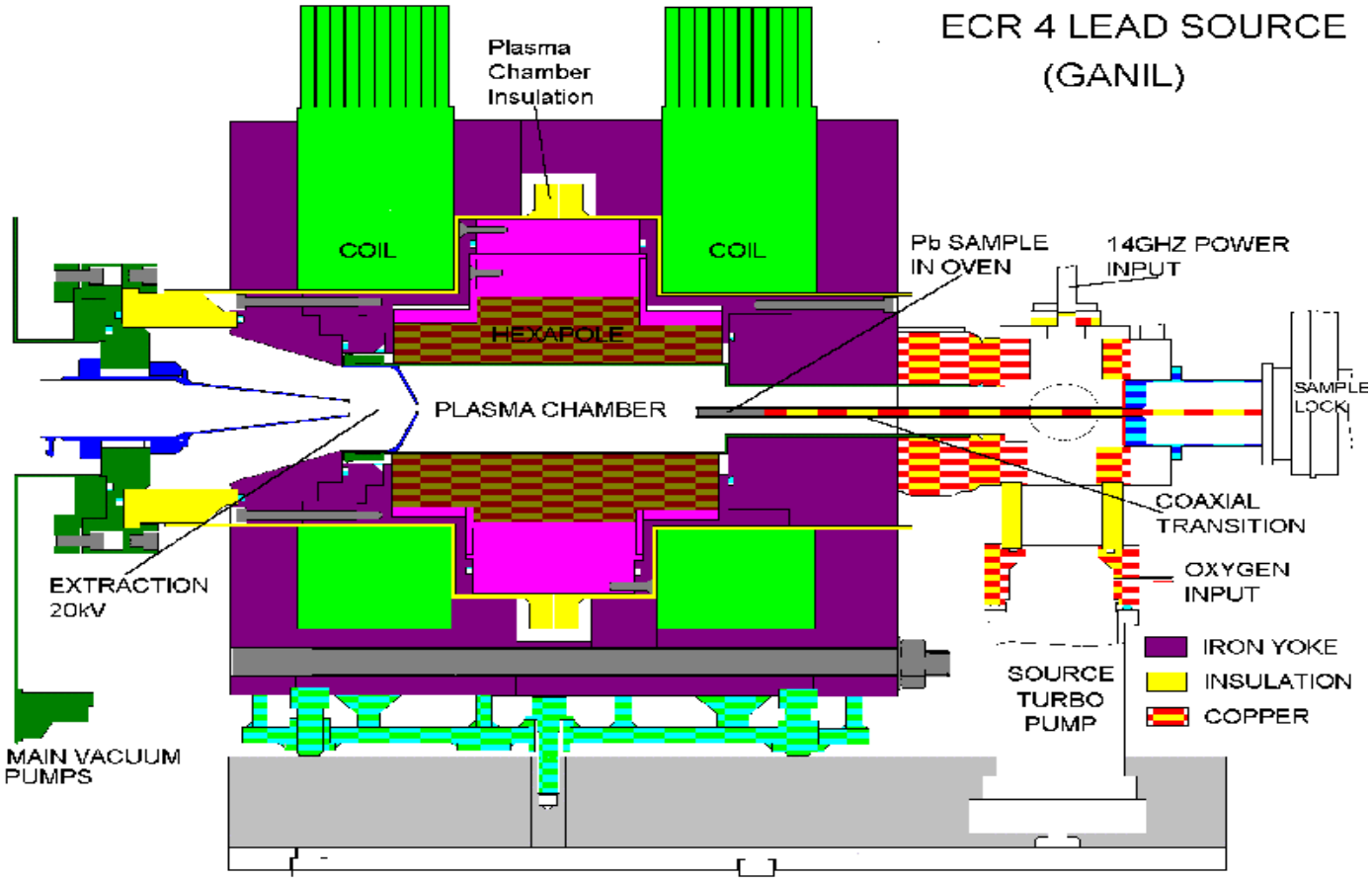
| | LINAC3 | LEIR | PS (stripper) | SPS | LHC (stripper) |
|---|---|---|---|---|---|
| **Energy [GeV/n]** | **0.0042** | **0.072** | **6** | **177** | **2760** |
| **Pb charge state** | **54+** | **54+** | **54+** | **82+** | **82+** |
| **bunch spacing [ns]** | | | **95, 5** | **100** | **100** |
| **ions/LHC bunch** | **6 $10^8$ (20 μA)** | **2.25 $10^8$** | **1.2 $10^8$** | **9 $10^7$** | **7 $10^7$** |
| ε* ( = (βγ)*$\sigma^2$/β) | **0.3** | **0.7** | **1** | **1.2** | **1.5** (1) |
| **# bunches** | | **2** | **4 pairs** | **~52** | **592/ring (2)** |
| **pulses** to fill downstream machine | **5** (up to 5 Hz) | **1** | **~13** | **12** | ***9' filling per ring*** |

(1) Same physical emittance as protons, with the same tight emittance budget
(2) 891 bunch places per ring

# The CERN Ion Linac 3



# Electron Cyclotron Resonance (ECR) Source

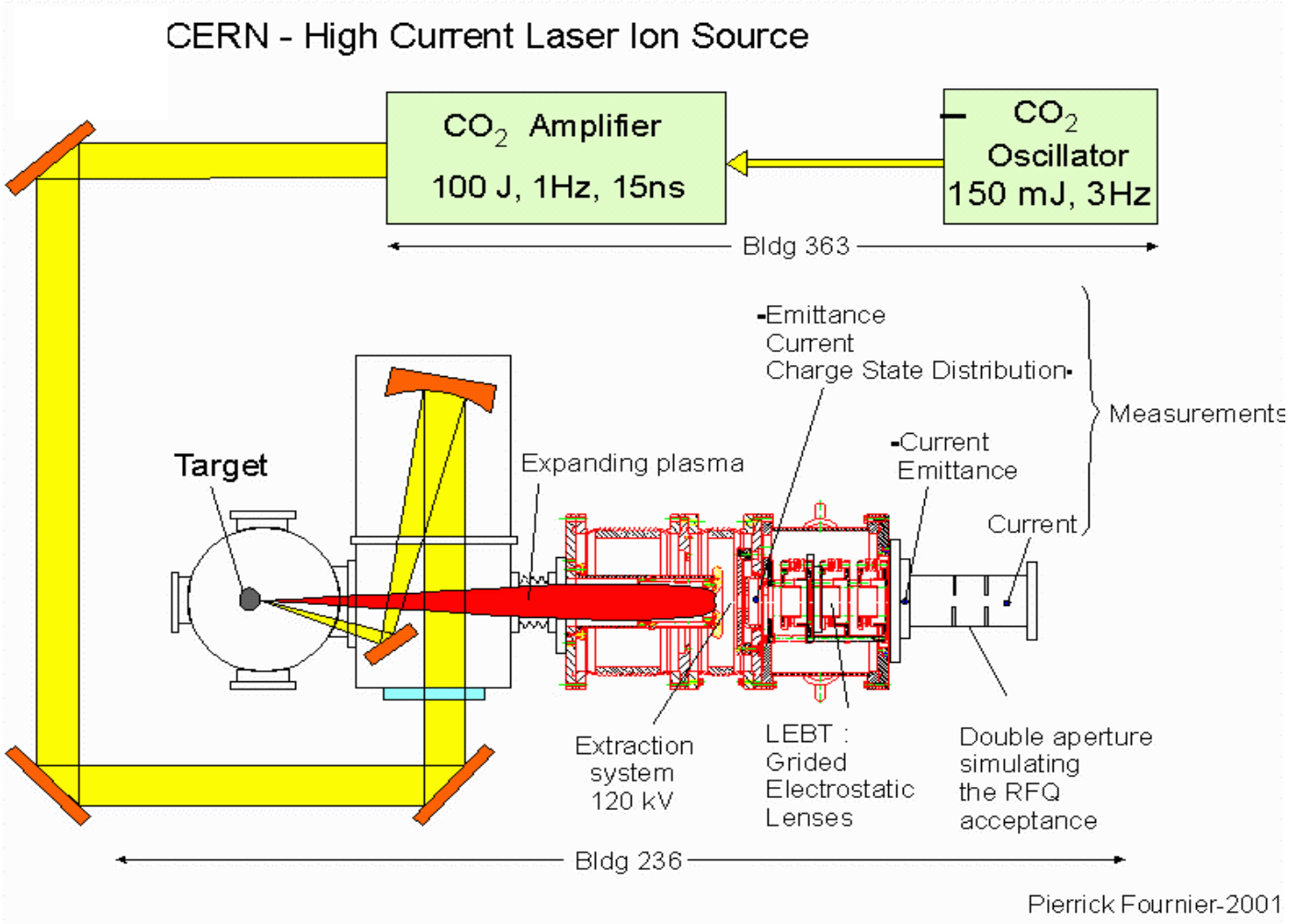


# ECR Source and Linac3: Speculations on Lighter Ions

| | $_{208}$Pb(82) | $_{115}$In(49) | $_{84}$Kr(36) | $_{40}$Ar(18) | $_{16}$O(8) | $_{4}$He(2) |
|---|---|---|---|---|---|---|
| charge state ion source | **27+** | **21+** | **11+** | **8+** | **2+** | **1+** |
| current source ($\mu A_e$) estim. | **100** | 100 | 150 | 200 | **300** | 500 |
| stripped to (after Linac) | **53 (54)+** | **37+** | **29+** | **16+** | **8+** | **1+** |
| **current ($\mu A_e$), 14 GHz source** | **20** | **25** | 30 | 75 | 170 | **160** |
| ***18 GHz source*** *4.2 MeV/u* | *41-44* | *44-49* | | *132* | | |
| ***28 GHz source(1)*** *4.2 MeV/u* | *100-108* | *108-120* | | *320* | | |
| | | | | | | |
| **#ions injected LEIR per Linac pulse ECR 14 GHz), 50 "effective" turns** | **$4\ 10^8$** | $6.5\ 10^8$ | $9\ 10^8$ | $4.3\ 10^9$ | $1.8\ 10^{10}$ | $1.4\ 10^{11}$ |
| #ions from LEIR per LHC bunch (with 5 Linac3 pulses) | **$3\ 10^8$** | $5\ 10^8$ | $6.8\ 10^8$ | $3.2\ 10^9$ | $1.4\ 10^{10}$ | $1\ 10^{11}$ |
| $\eta$ LHC collision/LEIR ejection | 0.3 | 0.4 | 0.5 | 0.5 | 0.6 | 0.6 |
| **Source vs other limitations** | | | | | | |
| **# ions/bunch, 2.8 TeV/u, source** | **$9\ 10^7$** | **$2.6\ 10^8$** | **$3.4\ 10^8$** | **$1.6\ 10^9$** | **$8.1\ 10^9$** | **$6.3\ 10^{10}$** |
| **# ions/bunch, 2.8 TeV/u, other limits** | **$7\ 10^7$** | **$2.2\ 10^8$** | **$3.3\ 10^8$** | **$5.5\ 10^8$** | **$1\ 10^9$** | **$5.2\ 10^9$** |
| | **marginal** | **marginal** | **marginal** | (1) | (1) | (1) |

(1) fewer Linac pulses required

# Laser Ion Source (LIS) – an Alternative?

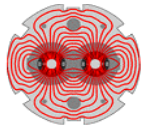


# LIS Power Laser and Source

The Russian 100 J, 1 Hz $CO_2$ Laser Amplifier in building 363 (“Farady Cage”), being commissioned

The prototype Laser Ion Source in building 236 on a HV platform (~100 kV) to decrease space charge

# Could we go the LIS Route? It's still R&D!



**With $Pb^{25+}$ from LIS, one could use the PS Booster instead of LEIR if:**

- Current **> 5mA** during ~ 5μs
- Norm. transverse rms emittance $\varepsilon^*_{rms}$ **< 0.15 μm**
- Source stable, reliable, small jitter….

**Needs other major investments**

- Make an operational laser (spare parts…) + installation in Linac 3;
- A new RFQ;
- Upgrading of PSB injection and vacuum systems;
- (list not exhaustive) summing up to 10…14 MCHF

☺ A few millions cheaper than LEIR

☺ Much less exploitation cost compared to LEIR

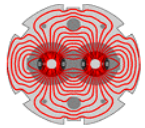
☹ Laser will (hopefully) work this summer, but then R&D starts!

☹ We cannot afford to go the LEIR **and** LIS routes in parallel

☹ Even if conclusive results by end 2002, **Pb to LHC not before 2009**

☹ Lighter ions: speculations, needs more R&D (e.g. for gaseous elements)

# Conclusions on Sources and Linac 3



## ECR Sources:

- The **present 14 GHz source** could **(just) do the job** for Pb, In, Kr, and easily do it for Ar, O, He. Due to uncertainty of extrapolation, an upgrading to
- **18 GHz** (+ proportional field increase) is envisaged: potential increase of ~1.5
- Collaboration with outside labs to achieve **28 GHz (a factor > 4 in intensity?)**
- Even a factor 10 increase would not be sufficient for the PS Booster route

## Laser Ion Source:

- Still a prototype in the R&D phase
- implementation of an operational source and other hardware **would cost at least 10 MCHF**, but would **save resources for exploitation of LEIR**
- Lighter ions? Much more R&D needed (which also costs scarce resources)
- **Pb ions not ready for LHC before 2009**

**Conclusion: If we want to have Pb ions ready for LHC in 2008 with a reasonable confidence level, decide NOW for LEIR + (upgraded) ECR source**