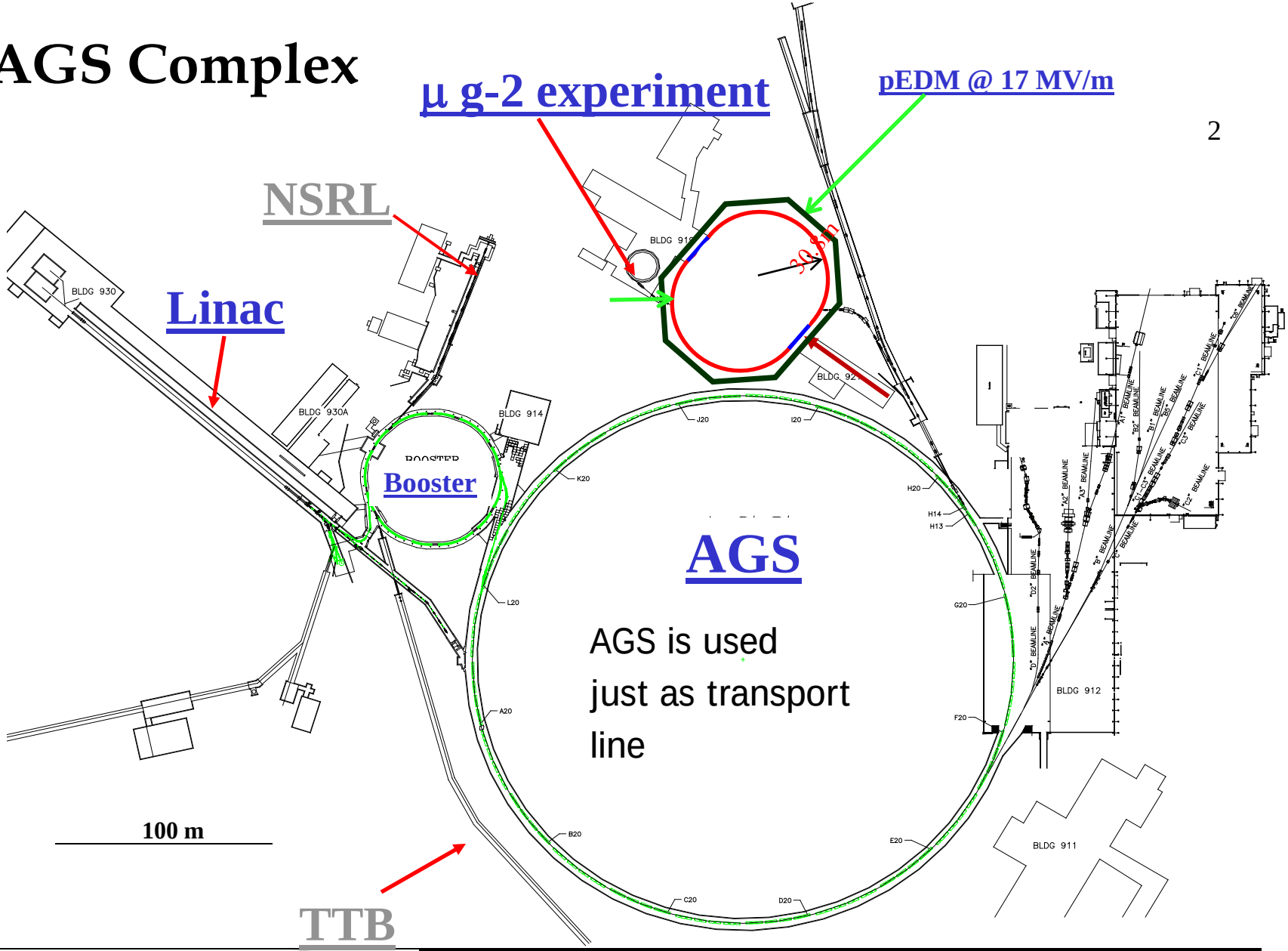
Beam parameters for pEDM ring

March 14, 2011

AGS Complex


μ g-2 experiment
pEDM @ 17 MV/m
NSRL
Linac
Booster
AGS
AGS is used just as transport line
TTB
100 m
BLDG 930
BLDG 930A
BLDG 914
BLDG 912
BLDG 911
J20
I20
K20
H20
H14
H13
G20
F20
E20
D20
C20
B20
A20
L20

Available proton beam parameters in the Booster/AGS

(pEDM ring, p=0.7GeV/c: γ=1.25, $\beta\gamma$=0.745, Kinetic energy: 232 MeV)

Booster: injection energy – 200MeV, typical extraction 1417MeV

For pEDM we will need a little bit of acceleration in the Booster: from 200 to 232MeV.

AGS used just as transport line (if pre-cooling in AGS is not needed)

Beam parameters in Booster:

$\varepsilon_{n95,x,y}$: 5-8 μm (95%, normalized) at injection

rms dp/p=5e-4

Polarization: 80-85% (after 2012 – expectation to have up to 90%)

No loss of polarization from the source is expected

Intensity: about 3e11 per bunch at Booster injection

emittance notation: Emittance_95%=6*Emittance_rms

Emittance_normalized=$\beta\gamma$*Emittance_unnormalized

Needed beam parameters for pEDM ring

1. **Horizontal emittance:**

   To have distance between plates in EDM ring of 30mm, beam emittance should be decreased to $\varepsilon_{n95,x}$=2 μm (95%, normalized).

   Scraping in the Booster:

   We can tolerate about one order of magnitude in bunch intensity loss to decrease emittance to 2 μm (95%, normalized).

   N=2-3e11 -> 2e10 per long AGS bunch

   EDM ring: 2e10/100 -> N=2e8 per short bunch in the EDM ring.

2. **Momentum spread & RF capture:**

   Two long bunches from AGS will be captured in barrier bucket RF system in EDM ring. Then high frequency RF will be turned on, resulting in short bunches rotating CW and CCW.

   Presently rms dp/p is about 5e-4 in Booster/AGS bunch.

   Smaller dp/p can be obtained with scraping (with intensity reduction)

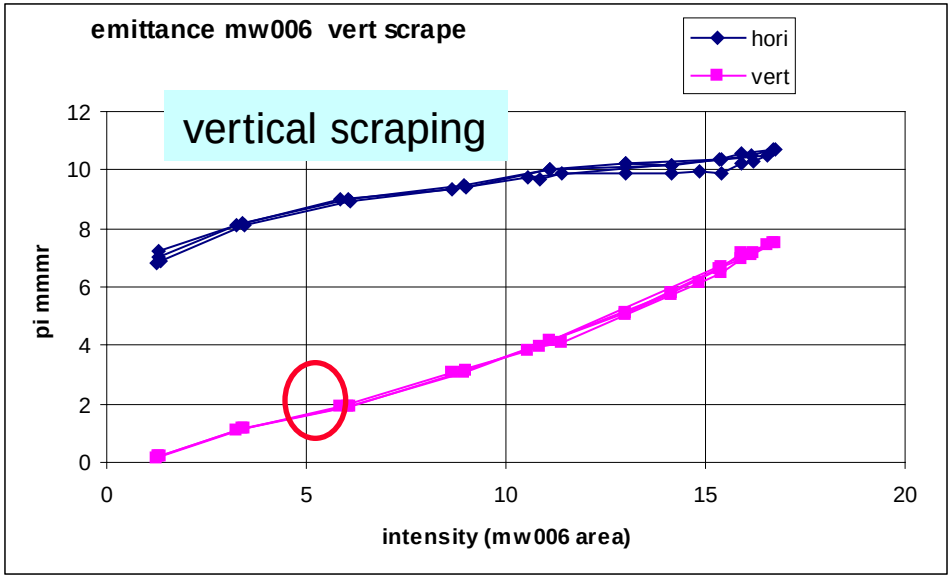
   or electron cooling

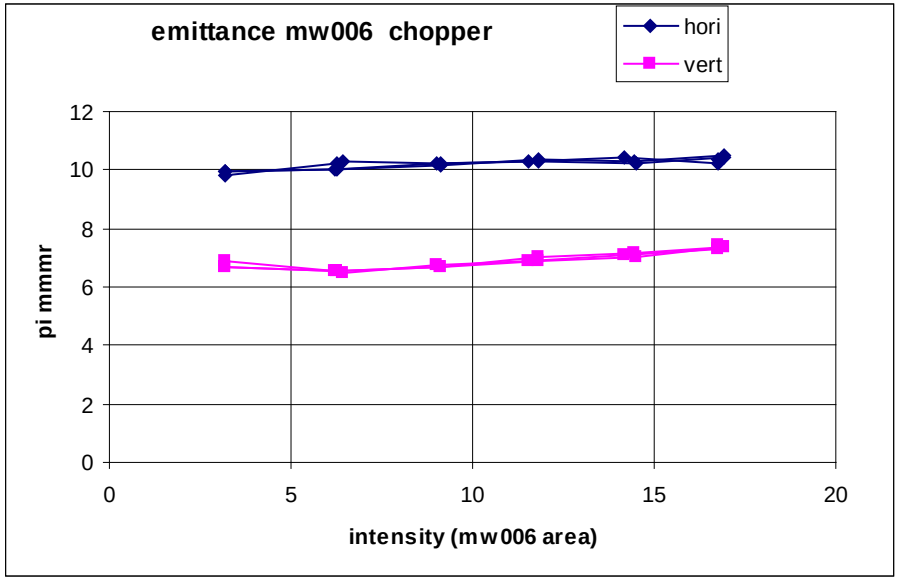
   One needs to make sure that momentum spread remains small during adiabatic capture into high frequency RF.

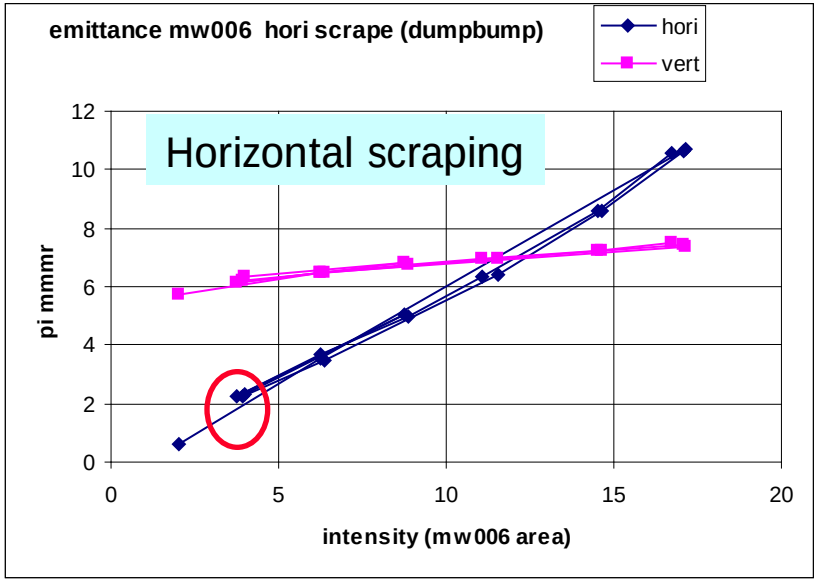
Leif Ahrens et al. (2009):

mw006 response to the three methods of reducing the intensity.

Note the relatively weak dependence of emittance on the length of time on the foil (chopper), and some weak dependence of the “plane not scraped”







June 2010 scraping studies in the Booster (K. Zeno, L. Ahrens)

	Unscraped	**Scraped**
Booster Input	35e10	35e10
Booster Late	26e10	4.4e10
εx	15.4 π	4.5 π
εy	10.1 π	2.0 π
εL	1.16 eVs	0.47 eVs

very close to parameters needed for EDM ring

Requirement on dp/p

1) For parallel plates E->1/r gives infinite Dispersion – need zero momentum spread

2) Proposed curvature of the plates almost removes r dependence. Gives finite Dispersion. This allows to have small but finite momentum spread.

A possibility of getting very small dp/p with Electron Cooling in AGS was considered.

Summary: It is possible, but will result in strong IBS in EDM ring without additional cooling directly in EDM ring.

- rms dp/p=2e-4 looks satisfactory for injection and seems to be achievable without pre-cooling in AGS. Thus, cooling is not included in the baseline at this point.

- whether 2e-4 dp/p is sufficiently small for long SCT time is being evaluated.

Requirement on synchrotron tune, RF

- If dp/p is not very small, large Q_s is required
  - **69MHz (h=100) -90 MHz (h=135) RF;**
  - **rms bunch length (σ_s) = 40cm**
  - **rms momentum spread (σ_p)=2e-4**
  - **Q_s=0.01 (few kV RF voltage)**

$$\sigma_s = \frac{L_r \eta}{2\pi Q_s} \sigma_p \qquad Q_s = \sqrt{\frac{h \eta V_{rf}}{2\pi \beta^2 \gamma m c^2 / q}}$$

- RF frequency sets a limit on initial rms bunch length: at a minimum one wants to fit into RF bucket
- for a fixed bunch length and fixed dp/p one gets required value for synchrotron tune Q_s

Beam size and aperture

Rms dp/p=2e-4

Horizontal emittance (95%, normalized): 2.2 mm mrad

Vertical emittance (95%, normalized): 4.5 mm mrad

σ_x=3.74mm; (Ax=3cm – plates), $\beta_{x,max}$=28m

σ_y=15mm; (Ay=8cm – polarimeter), $\beta_{y,max}$=240m

Horizontal beam size with dp/p : σ_H=6.2mm

Ax/2=2.4*σ_H

Ay/2=2.7*σ_y

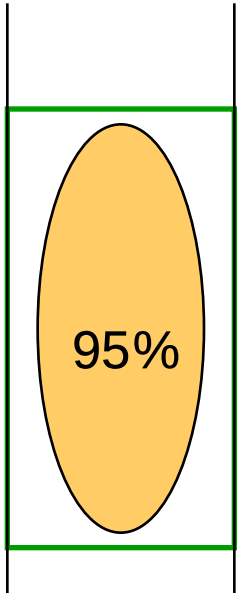
Short single bunch intensity: N=2e8

100 such bunches CW and 100 CCW

total beam-beam paramters ξ: 0.015

space-charge tune shift $\Delta Q_{x,y}$: 0.008, 0.014

synchrotron tune: Q_s=0.01



Needed aperture will be further optimized

Working baseline beam parameters in EDM ring

Intensity of injected long bunch: N=2e10 (2 such bunches)

Rms dp/p=2e-4 (without pre-cooling in AGS)

Horizontal emittance (95%, normalized): 2.2 mm mrad

Vertical emittance (95%, normalized): 4.5 mm mrad

Two such bunches are injected CW and CCW

Captured with barrier buckets; de-bunched.

Then high-frequency 69-90MHz RF is turned on

Short single bunch intensity: N=2e8

100 such bunches CW and 100 CCW

Synchrotron tune: Q_s=0.01