EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE

CERN - PS DIVISION

PS/ PA/ Note 96-26 (PPC)

MINUTES OF THE PPC MEETING
HELD ON 31ST MAY, 1996

D. Manglunki

Geneva, Switzerland
28 June 1996

PS/PA Note 96-26 (PPC)
June 19, 1996

Minutes of the PPC meeting held on May 31st, 1996

Present: J.Boillot, E.Brouzet/SL, R.Cappi (Chairman), M.Chanel, V.Chohan, T.D'Amico, D.Dekkers, R.Garoby, S.Hancock, E.Jensen, R.Ley, A.Lombardi, D.Manglunki (Secretary), M.Martini, G.Métral, M.Pace, J.P.Riunaud, K.Schindl, H.Schönauer, E.Schulte, C.Steinbach, H.Ullrich, H.Umstatter, E.Wildner.

1.Status of the PS machine (R.Cappi)

- This will be the topic of a coming PPC meeting, but some remarks have to be made right away
- The new optics for the transfer line between Linac 2 and PSB is meeting the expected improvements. The steering is much less sensitive to the PS stray field.
- Studies of the extracted beam behaviour in the non-linear part of the stray field have started
- Studies of debunched beam behaviour at 26 GeV/c have started (mainly startup of the instrumentation: FFT and fast Schottky scans). Instabilities already show up at 20% the nominal intensity
- Parallel MDs have not been made because the PSS's time is fully taken by the operation. On 24 hours of dedicated MD time, 8 were given back to physics
- All operational beams need a constant adjustment:

    - LEAR: 50% are lost during the decelaration
    - AA: 30% missing on the intensity
    - PHYFE needs a constant surveillance, and seems to be subject to a lot of controls problems.
    - SFTPRO is limited to 2.3 10^{13}
    - MDSPS needs a special attention from PSS, because of the frequent modifications requested by the SPS.
    - SPP/SPN: a lot of timing problems occur, which are difficult to diagnose

As a summary: "there is room for improvement"

- Transformers had to be recalibrated in TT2: TRA126 was found to be 3% optimistic. The SFTPRO ejection is thus less effective than previously thought, but there aren't 15% losses in TT2.
- MD time should be allotted to beam instrumentation specialists, for equipment tests and calibrations.
- ***The PPC suggests the creation of a working group that would address those problems and look for a different scheme for staffing the accelerators.***

2.Report from the Transition mini-workshop at FNAL (M.Martini, J.P.Riunaud)

- This series of mini-workshops on high intensity, high brightness beams does not produce proceedings, but each chairman writes a summary. This session was especially devoted to transition issues.
- 3 working groups have been created, addressing respectively: “analytical treatment”, “classical schemes for transition crossing”, and “exotic schemes”.
- Classical schemes use a “gamma-jump” where typically $d\gamma/dt$ is between 500 and 2000 s^{-1} while in the CERN PS $d\gamma/dt = 2200\ s^{-1}$
- An imaginary γ_t scheme will be implemented for the new Fermilab Main Injector

(see attached copy of the transparencies)

Mini-Workshops
on High Intensity, High Brightness Hadron Beams

- Collaboration between CERN PS / Brookhaven / Fermilab / KEK
- Aims
  - Discuss and study problems on similar machines
  - Limit organization load
- List of topics
  - Transition crossing
  - Transverse & longitudinal emittance budgets; Beam diagnostics
  - RF cavities; Debunching / Rebunching
  - Lattice match; Beam losses
- Organization
  - Presentations, discussions, working groups, summary talks & write-ups

Mini-Workshop on Transition crossing

Fermilab, 20-23 may 1996

- 25 Participants
  - 3 CERN PS (S. Hancock; M. Martini, J.P.R.)
  - 3 Brookhaven AGS (M. Brennan, T. Roser, W. Van Asselt)
  - 3 KEK (S. Machida,Y. Masahito, Y. Mori)
  - 15 Fermilab + 1 Houston University
- Working groups
  - Theory, simulation, measurements
  - γ_t jump schemes
  - New schemes
- Main CERN PS concern
  - LHC beam transverse emittance conservation at transition crossing

Beam brightness in the various machines

- ➪ **Comparison between machines**
- ➪ **Beam brightness in CPS/AGS**
  - **BNL-AGS handles the brightest beam**
    - N_b [AGS] = 6.4 10^{13} p in 8 bunches = 8 10^{12} p
    - $\varepsilon^*_{x,y}(1\sigma) = 10\,\pi$
  - **PS beam for LHC = BNL-AGS beam for RHIC**
    - N_b [PS] = 1.4 10^{13} in 16 bunches = .7 10^{12} p
    - $\varepsilon^*_{x,y}(1\sigma) = 2.5\,\pi$

PPC - 31/05/1996

Theory, simulations

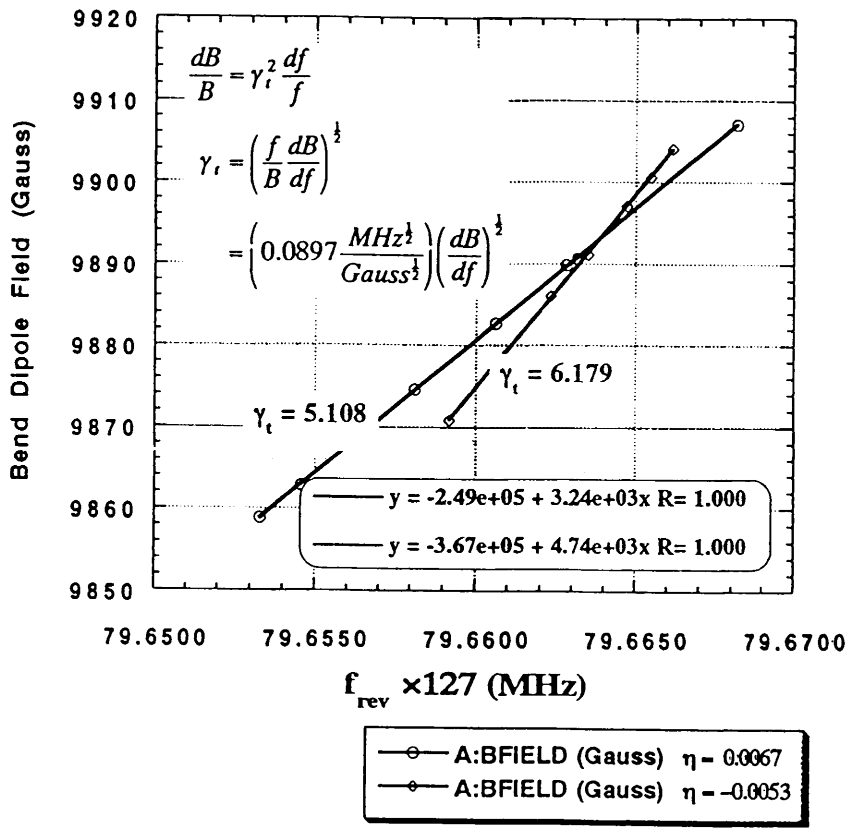
- ➪ **Longitudinal microwave instability**
  - **Analytical treatment (P. Colestock)**
  - **Simulations; constraints on bin width (B. Ng)**
  - **Simulations for Fermilab Main Ring (C. Bhat)**
- ➪ **Simulation codes**
  - **ESME: restricted to longitudinal dynamics**
  - **ACCSIM: provides only tunes shifts in transverse plane**
  - **SIMPSON: 6 dimensions; could be used for transition crossing**
  - **Needs to adapt general codes to transition studies**

	E_{MAX}	N_{TOT} @E_{MAX} [10^{12}]	N_{bunch} [10^{12}]	ε_{long} [eVs]	N_b/ε_{long}	$\varepsilon_x^{rms,N}$ [π mm mrad]	$\varepsilon_y^{rms,N}$ [π mm mrad]	$N_b/\varepsilon_{MIN}^{rms,N}$
EXISTING:								
BNL AGS	24	63	8	4	2	10	10	0.8
CERN PS	14	25	1.25	0.7	1.8	12.5	10	0.13
KEK PS	12	3.6	0.4	2	0.2	5	15	0.08
FNAL BOOSTER	8	4.0	0.05	0.1	0.5	3	3	0.02
FNAL MAIN RING	150	20 [FT]	0.03	0.2	0.15	2	2	0.02
DESY ?								
IHEP ?								
PLANNED:								
BNL AGS FOR RHIC	25	0.4	0.4	0.3	1.3	1.5	1.5	0.3
CERN PS FOR LHC	26	14	0.9	1.0	0.9	2.8	2.8	0.3
FNAL MAIN INJ.	150		(0.06) 0.15	0.2				
JHP 50	50	200	12.5	5	2.5	55	55	0.2
MUON COLL. DRIVER	30	100	25	4	6.3	50	50	0.5

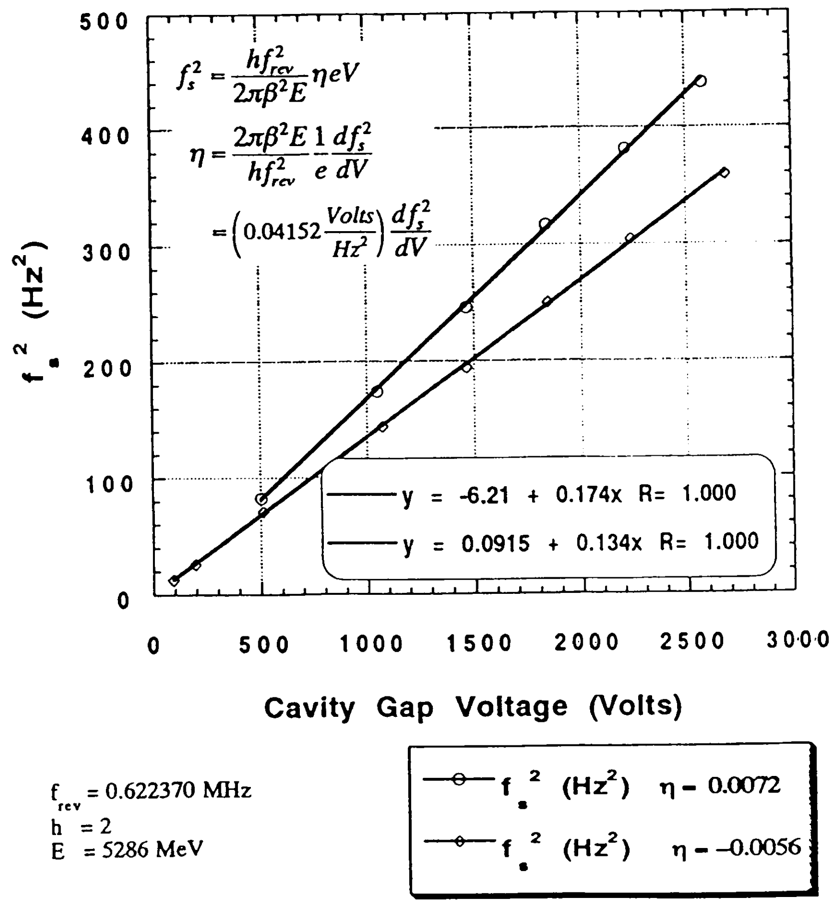
COMPARISON OF BEAMS IN VARIOUS MACHINES

T. ROSER BNL

Measuring η



P_{beam} = 5202 MeV/c
Before and after γ_t jump



f_{rev} = 0.622370 MHz
h = 2
E = 5286 MeV

S. WERKEMA FNAL

Observations

- Longitudinal emittance Blow-up at Fermilab Main Ring (B. Ng)
  - ε_L goes from .09 eVs to .18, .25 eVs
  - Beam losses due to momentum aperture
- Transverse emittance blow-ups in AGS and KEK
  - In AGS; spoils slow extraction. Empirically cured by use of skew quads (?)
  - In KEK-PS: seems due to uncorrected vertical chromaticity
- No 'new' mechanisms leading to tranverse emittance blo-up

Measurements

- Transition parameters measurements at Pbar accumulator (S. Werkema)
  - γ_t^2 = [dB/B]/[df/f]
  - η = K [df_s^2/dV]
  - η measurements from "double scan"
- Dependence of γ_t on dp/p
  - Measured in AGS during γ_t change
  - Compensation with the chromaticity sextupoles
- Technique of "echo"
  - Beam response after longitudinal phase kick
  - Test carried out in the Tevatron
  - Could be performed at transition; information on γ_t(dp/p) ?
  - Model being investigated (P. Colestock)

INTRODUCTION

Intensity limitation at transition crossing may be overcome by increasing the γ_t crossing speed modifying the optics (using special fast pulsed quadrupoles).

At transition the value of gamma (γ) is

$$\gamma_t^{-2} = \frac{dC}{C\delta} \qquad (1)$$

where C is the nominal closed orbit length and δ is the relative momentum deviation ($\delta = dp/p$).
γ_t is related to the slip factor η by

$$\eta \equiv \frac{df}{f\delta} = \gamma^{-2} - \gamma_t^{-2} \qquad (2)$$

where f is the particle revolution frequency.

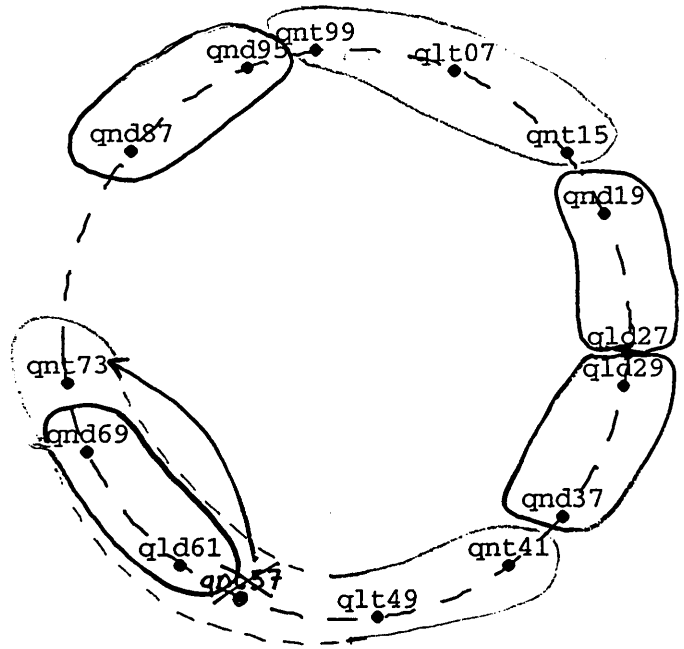
Review of CERN PS γ_t jump schemes:
The PS has to cross transition: $\gamma_{min} \approx 2 < \gamma_t = 6.1 < \gamma_{max} \approx 28$

- 1969–1978: γ_t jump with non-zero tune shift ($\Delta Q \approx 0.25$) using 6 quadrupoles (1 strength +K): $\Delta\gamma_t \approx 0.3$ (Q-jump)
- From 1973: γ_t jump with (almost) zero tune shift using 8 quadrupole-doublets (2 strengths $\pm K_1, +K_2$): $\Delta\gamma_t \approx 1.1 \rightarrow 2.1$

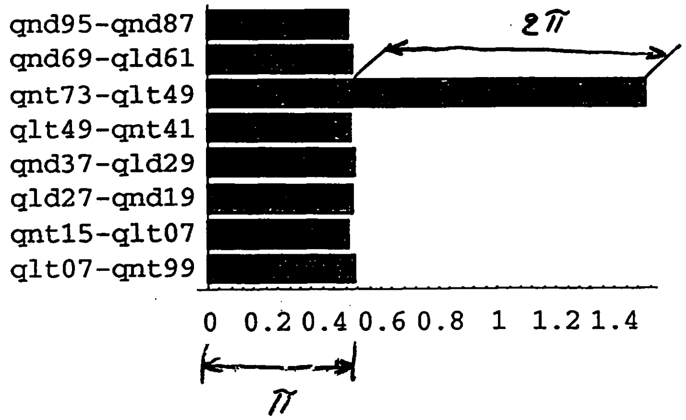
PRESENT SCHEME

PS Gamma Transition Jump Scheme

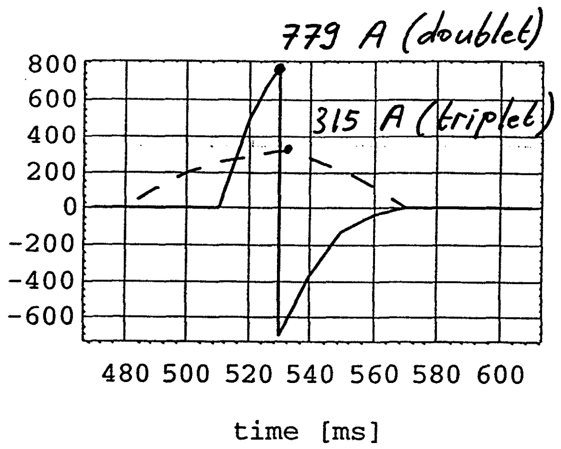
Present Quadrupole Layout



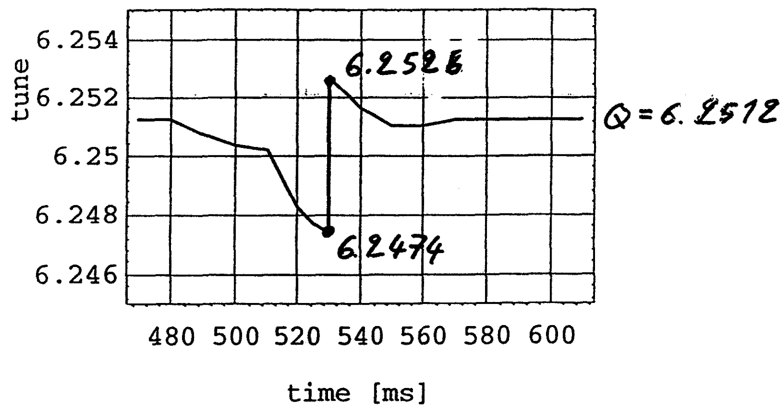
Quadrupole Doublets Phase Advance



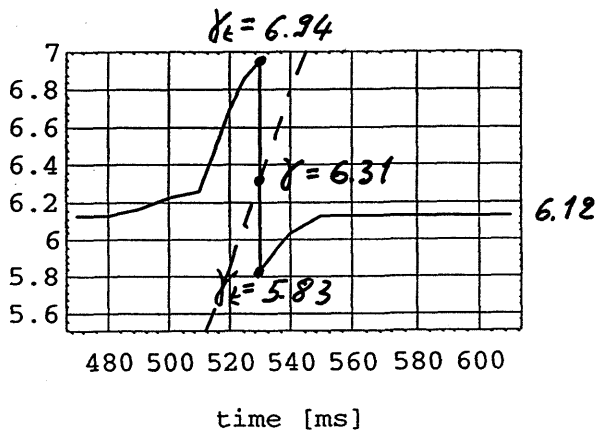
Doublet and Triplet Currents



Tune Shift at Transition

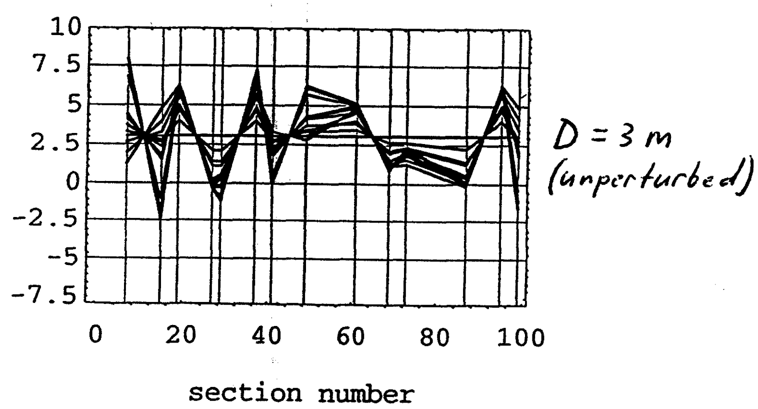


Gamma Transition and Gamma at Transition



$\Delta \gamma_t = 1.1$

Perturbed (Unperturbed) Dispersion at Transition



γ_T JUMP WORKING GROUP 2

γ_T JUMP IS A MATURE TECHNIQUE.

SOME DISCUSSION ISSUES:

- γ_T JUMP IN A FODO LATTICE:

  GLOBAL DISTORTION ⟷ LOCAL DISTORTION

- γ_T JUMP IN A HIGH γ_T (IMAG. γ_T) LATTICE

- LIMITATIONS OF γ_T JUMP TECHNIQUE: (?)

  LATTICE DISTORTION, 2nd ORDER

  CORRECTIONS (α_1, PULSED 6-POLES?)

- γ_T HARDWARE

  PULSED QUADS, VACUUM CHAMBER,

  POWER SUPPLIES, EDDY CURRENT

GLOBAL JUMP:

USED AT CERN PS, BNL AGS, FNAL BOOSTER, KEK PS

$\dot{\gamma}_T \approx 500 \ldots 2000\ s^{-1}$

HIGH DISPERSION → LIMITED MOMENTUM APERT.

LOSSES/GROWTH ONLY FROM MOMENTUM APERTURE AND CHROMATIC EFFECT (α_1 LARGE)

→ CORRECT α_1 (IDEAL $-3/2$)

→ USE LOCAL JUMP

PLANNED FOR FNAL MI, BNL RHIC, AGS

$\dot{\gamma}_T \approx 1000\ s^{-1}$

SEEMS POSSIBLE TO HAVE NO LOSS/GROWTH EVEN AT HIGHEST INTENSITY/BRIGHTNESS.

HIGH γ_T / IMAGINARY γ_T LATTICES (FOR NEW MACHINES) MOTIVATED BY REDUCED BEAM INSTABILITIES.

WG 3 (new schemes)

Focus Free Transition Crossing

Imaginary γ_t

local impedance insertion

cancel capacitive Impedance

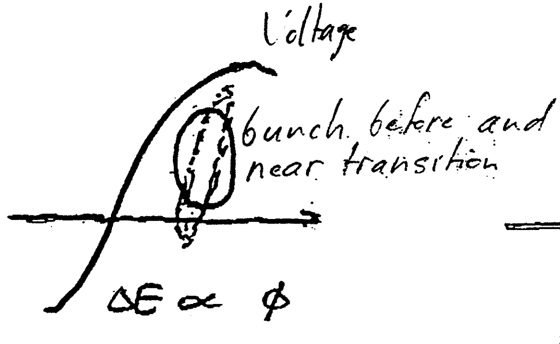
Other topics

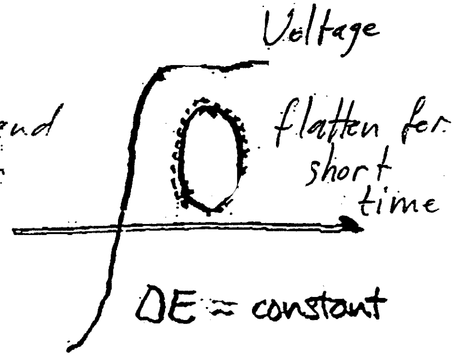
bunch shortening

"quasi" isochronous bucket

FFTC

Concept





Experiment

Main Ring at FNAL

w/ 3rd harmonics Cavity

(53+159) MHz, 2.1 MV

2.2×10^{10} ppb

beam loss 5% w/o FFTC

0% w/ "

unknown for higher intensity.

Imaginary γ_t

MI scheme (FNAL)

* no large dispersion unlike Teng's
* good packing factor
* Beta modulation is relatively large
* longer cell length

* zero dispersion straight
* harmonic analysis works

• γ_t lattice

$$\gamma_t^{-2} = \alpha_p = \frac{1}{C}\int \frac{D}{\rho} ds = \frac{1}{C}\sum_i \bar{D}_i \, \theta_i \approx 0, < 0 \quad \textbf{(small, negative)}$$

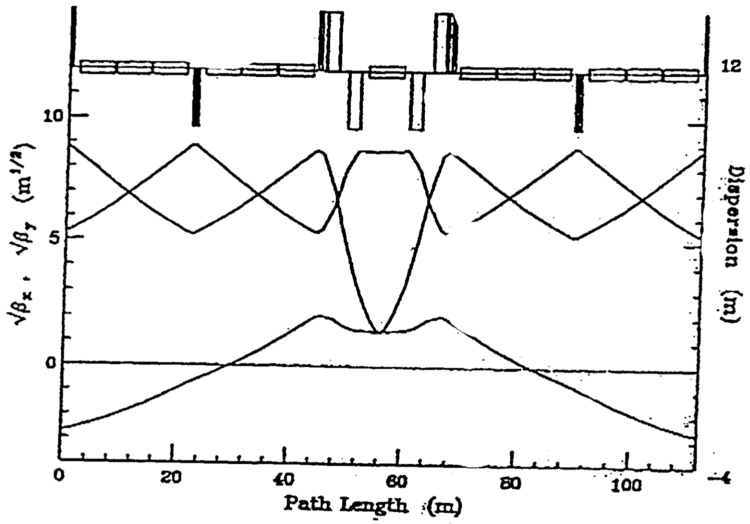
Dispersion: D (harmonic analysis)

$$\frac{d^2 Y}{d\phi^2} + \nu^2 Y = \frac{\nu^2 \beta^{3/2}}{\rho}, Y = D/\beta^{1/2}$$

$$\frac{\beta^{3/2}}{\rho}\textbf{: modulation ---------> } \frac{\beta^{3/2}}{\rho} = \sum_{n=-\infty}^{\infty} a_n e^{in\phi}$$

$$\alpha_p = \frac{\nu^3}{R}\sum_{n=-\infty}^{\infty}\frac{|a_n|^2}{\nu^2 - n^2}, \text{where} \quad a_n = \frac{1}{2\pi}\oint \frac{\beta^{3/2}(\phi)}{\rho(\phi)} e^{-in\phi} d\phi$$

AGS



Betatron functions and dispersion function within the basic module of the imaginary γ_t lattice.

Module made of 2 FODO cells and a reflective symmetric insertion (2 doublets) (to simplify the analysis and optical matching).

high γ_t not imaginary γ_t (36 GeV)

* additional Q modulate dispersion
* extraction energy is close to γ_t.

proton driver for μ-on collider

* same lattice (hi γ_t) as JHP
* γ_t can be changable with small tuning of Q

AGS Transition Energy

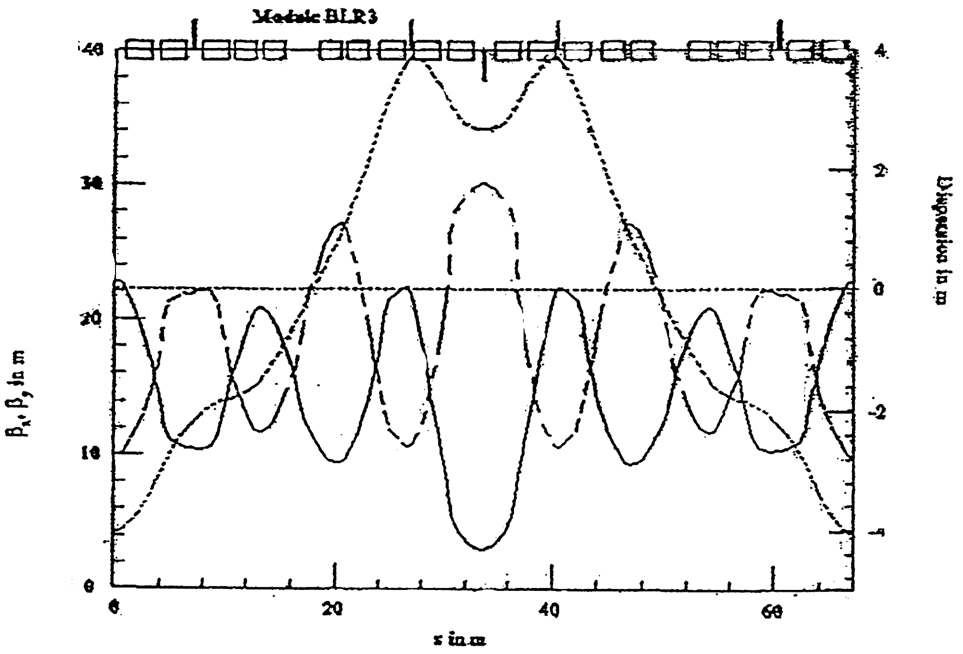
resent global transition energy jump limits momentum aperture.

Two Possible Solutions:

1. Local lattice distortion gives more momentum aperture
   -> need more pulsed quadrupoles

2. Change AGS lattice to move transition above
   max. AGS energy -> need more quadrupoles

AGS without transition crossing (Transition Energy=36 GeV):



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