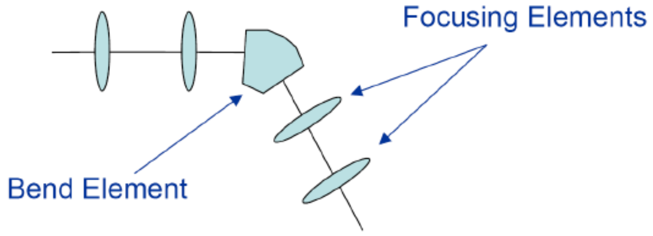
# MADX-Emittans Hesabı

ZAFER NERGİZ
Niğde Üniversitesi

# HIZLANDIRICI FİZİĞİNDE BAZI KAVRAMLAR

- PARÇACIKLARI BİR A NOKTASINDAN B NOKTASINA TAŞIMA SÜRECİNE DEMET OPTİĞİ DENİR.
- MAGNETLERDEN OLUŞAN DİZİ MANYETİK ÖRGÜ OLARAK İSİMLENDİRİLİR.



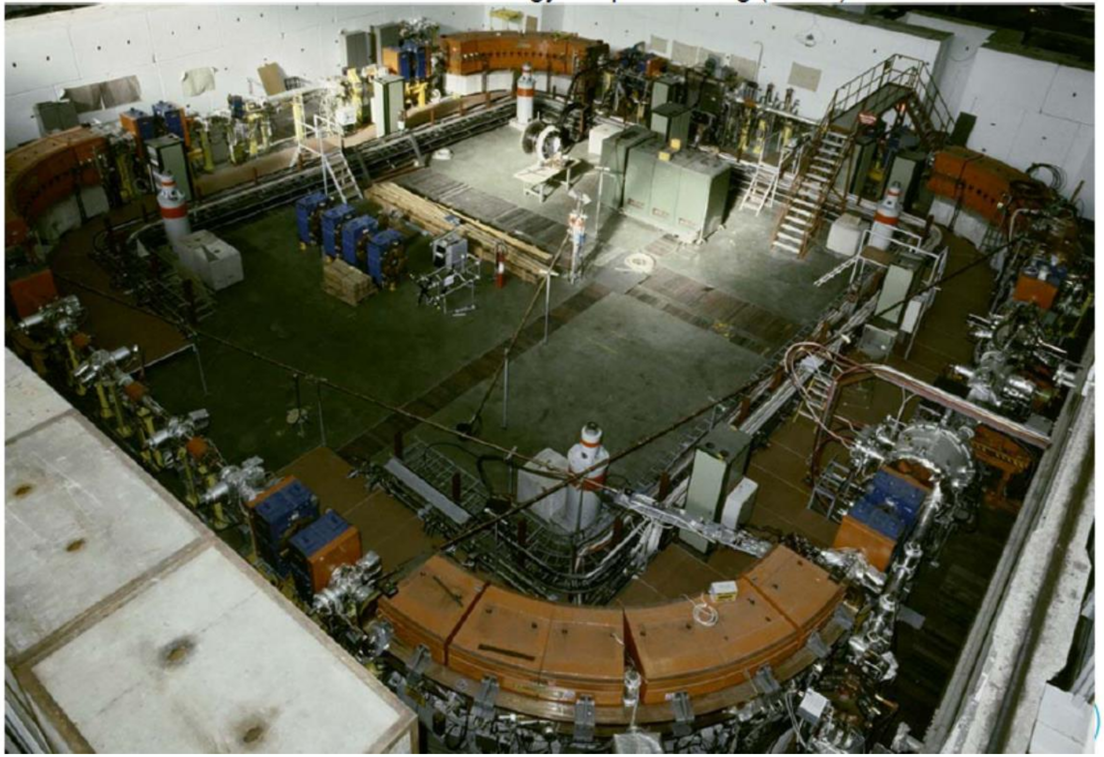

$$\mathbf{F} = q(\mathbf{E} + \mathbf{v} \times \mathbf{B})$$

- YÜKLÜ PARÇACIKLARIN HIZLANDIRILMASINDA TEMEL MANTIK LORENTZ KUVVETİNE DAYANIR.
- HIZLANMA ELEKTRİK ALAN DOĞRULTUSUNDA GERÇEKLEŞİR.
- MANYETİK ALAN KULLANILARAK PARÇACIĞIN ENERJİSİ ARTIRILAMAZ SADECE DOĞRULTUSU DEĞİŞTİRİLEBİLİR

# PARÇACIK HIZLANDIRICILARI

- DOĞRUSAL HIZLANDIRICILAR VE DAİRESEL HIZLANDIRICILAR OLARAK SINIFLANDIRILABİLİRLER

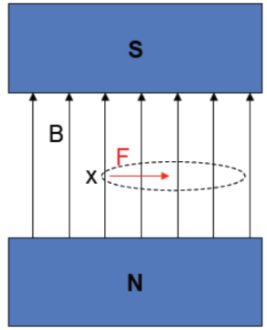
Low Energy Antiproton Ring (LEAR) at CERN

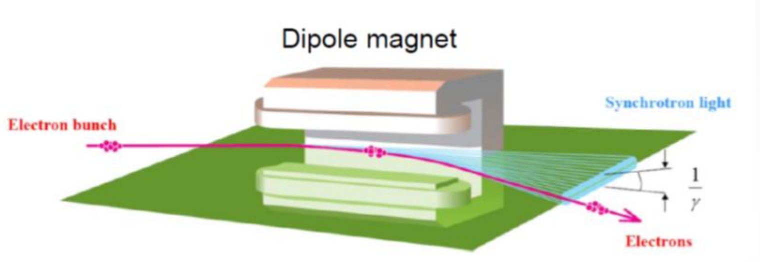


# MAGNETLER

- DİPOL MAGNETLER

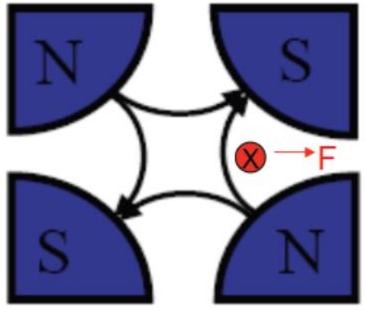
SABİT BİR MANYETİK ALAN SAĞLAYARAK DEMETİN DOĞRULTUSUNU DEĞİŞTRMEKTE KULLANILIRLAR

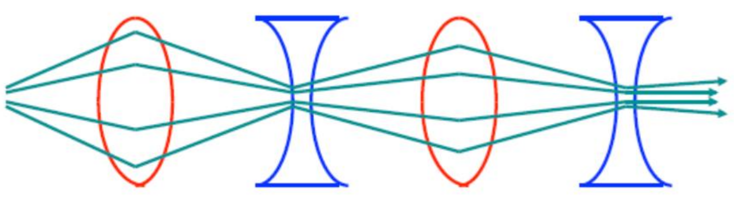


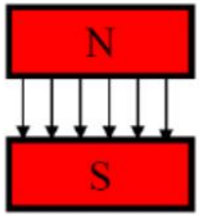

- QUADRUPOL MAGNETLER

PARÇACIK DEMETİNİN ODAKLANMASINDA KULLANILIRLAR. BİR DÜZLEMDE ODAKLAMA YAPARKEN DİGER DUZLEMDE DAGITICIDIRLAR



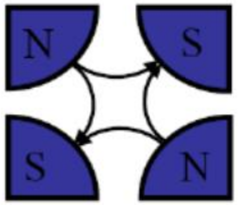



**n=1: Dipole**



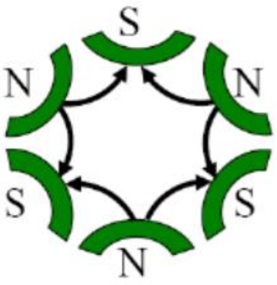

180° between poles

**n=2: Quadrupole**



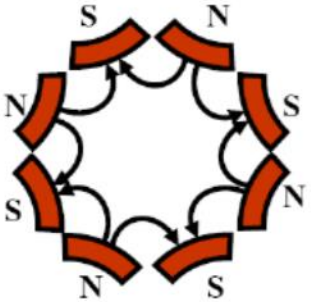

90° between poles

**n=3: Sextupole**




60° between poles

**n=4: Octupole**




45° between poles

$$\text{Dipole}: \ \frac{e}{p}B_x = 0 \ ; \ \frac{e}{p}B_y = \kappa_x$$

$$\text{Quadrupole}: \frac{e}{p}B_x = ky \ ; \ \frac{e}{p}B_y = \kappa_y \text{x}$$

$$\text{Sextupole}: \ \frac{e}{p}B_x = mxy \ ; \ \frac{e}{p}B_y = \frac{1}{2}m(x^2 - y^2)$$

# PARÇACIĞIN HAREKET DENKLEMİNİN ÇÖZÜMÜ

$$u(s) = C(s)u_o + S(s)u_o'$$

Kosinis Benzeri Çözüm

Sinüs Benzeri Çözüm

K>0:

$$C(s) = \cos(\sqrt{K}s)$$

$$S(s) = \frac{1}{\sqrt{K}}\sin(\sqrt{K}s)$$

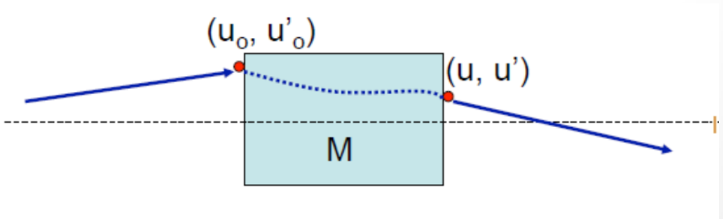
K<0:

$$C(s) = \cosh(\sqrt{|K|}s)$$

$$S(s) = \frac{1}{\sqrt{|K|}}\sinh(\sqrt{|K|}s)$$

İletim matris formunda yazılabilir.

$$\begin{pmatrix} u \\ u' \end{pmatrix} = \underbrace{\begin{pmatrix} C(s) & S(s) \\ C'(s) & S'(s) \end{pmatrix}}_{M} \begin{pmatrix} u_o \\ u_0' \end{pmatrix} = M \begin{pmatrix} u_o \\ u_0' \end{pmatrix}$$



# BOŞLUKTA İLETİM

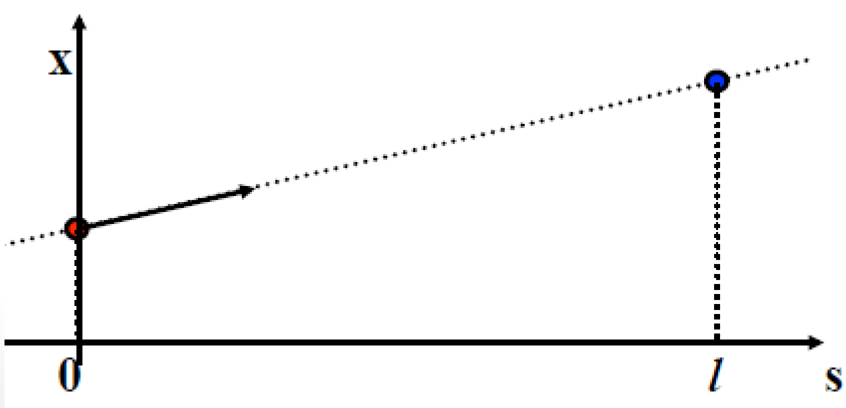
$$M_{drift} = \begin{pmatrix} \cos(\sqrt{K}l) & \frac{1}{\sqrt{K}}\sin(\sqrt{K}l) \\ -\sqrt{K}\sin(\sqrt{K}l) & \cos(\sqrt{K}l) \end{pmatrix} \xrightarrow{K=0} M_{drift} = \begin{pmatrix} 1 & l \\ 0 & 1 \end{pmatrix}$$

$$\begin{pmatrix} u \\ u' \end{pmatrix} = \begin{pmatrix} 1 & l \\ 0 & 1 \end{pmatrix} \begin{pmatrix} u_o \\ u_0' \end{pmatrix}$$

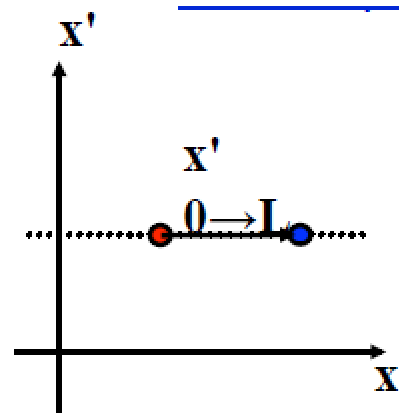
$$u = u_o + l u_0'$$

$$u' = u_0'$$

Gerçek Uzay




Faz Uzayı (x, xˡ)



# BİR KUADRUPOLDE İLETİM

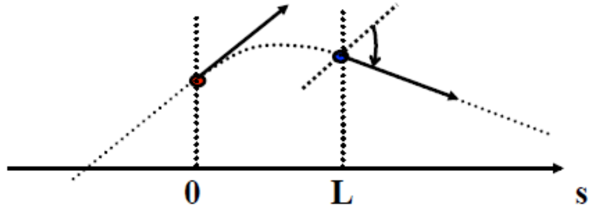
Odaklayıcı →

$$M_{QF} = \begin{pmatrix} \cos(\sqrt{K_n}\, l) & \frac{1}{\sqrt{K_n}} \sin(\sqrt{K_n}\, l) \\ -\sqrt{K_n} \sin(\sqrt{K_n}\, l) & \cos(\sqrt{K_n}\, l) \end{pmatrix}$$

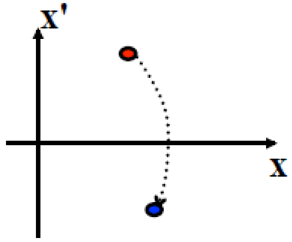
Dağıtıcı →

$$M_{QD} = \begin{pmatrix} \cosh(\sqrt{|K_n|}\, l) & \frac{1}{\sqrt{|K_n|}} \sinh(\sqrt{|K_n|}\, l) \\ \sqrt{|K_n|} \sinh(\sqrt{|K_n|}\, l) & \cosh(\sqrt{|K_n|}\, l) \end{pmatrix}$$

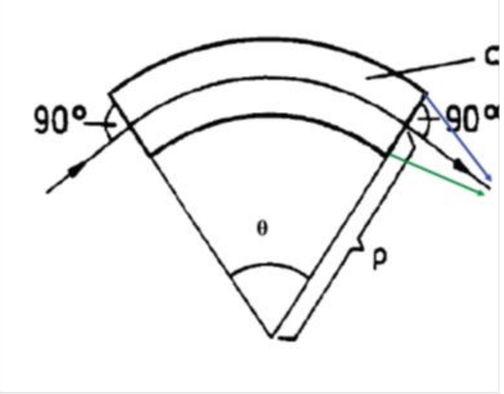
Gerçek uzay




Faz uzayı



# DİPOL MAGETTE İLETİM

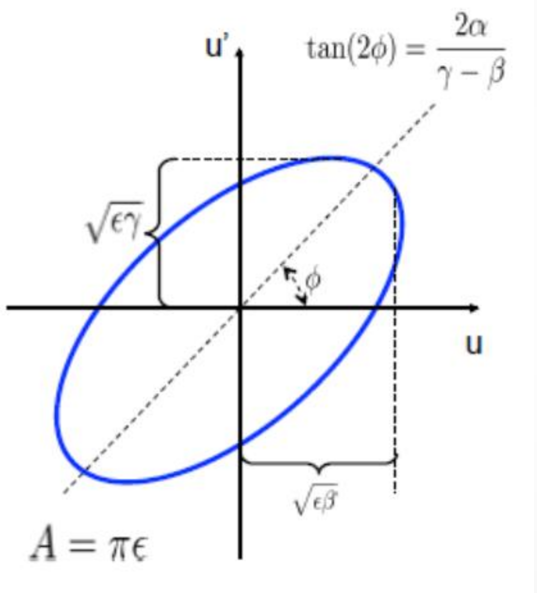



$$M_{\mathbf{x},\text{sector}} = \begin{pmatrix} \cos(\theta) & \rho_o \sin(\theta) \\ -\kappa_o \sin(\theta) & \cos(\theta) \end{pmatrix}$$

$$\theta = \kappa_o l, \quad \kappa_\mathrm{o} = \frac{1}{\rho_o}$$

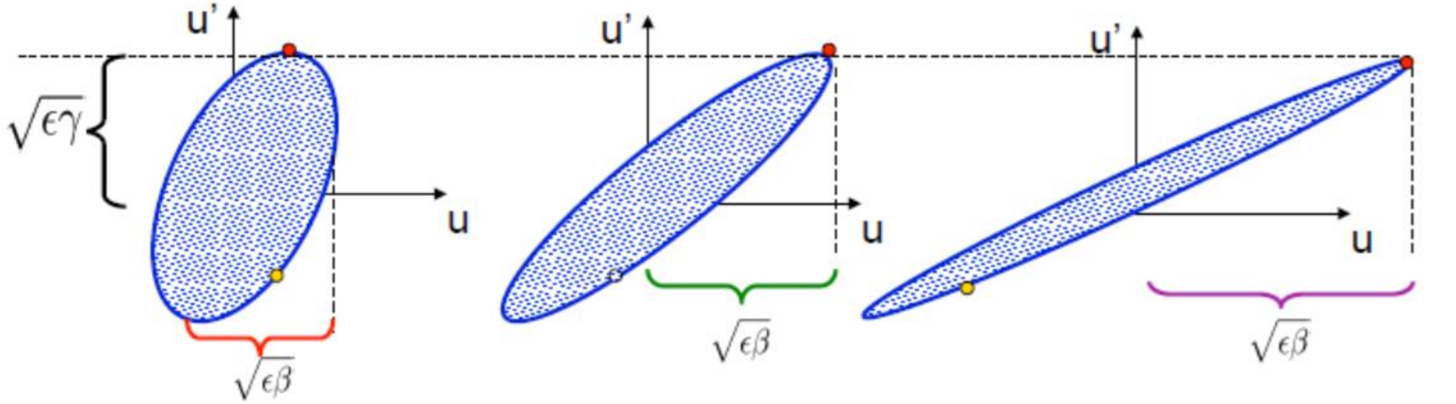
# TWISS PARAMETRELERİ VE EMİTTANS

- MAKİNADA TEKBİR PARÇACIĞIN HAREKETİ HAKKINDA BİLGİ ALMAK MÜMKÜN DEĞİLDİR.
- DEMETİN FAZ UZAYINDA KAPLADIĞI ALAN BİR ELİPSTİR VE BU ELİPS 3 BAĞIMSIZ 1 BAĞIMLI 4 PARAMETRE İLE TANIMLANIR
- $\alpha$- demetin eğimi ile ilişkili
- $\beta$- Demetin şekli ve ebadı ile ilintili
- $\varepsilon$-Demet ebad ile ilintili
- $\gamma$- $\alpha$ ve $\beta$' ye bağımlı

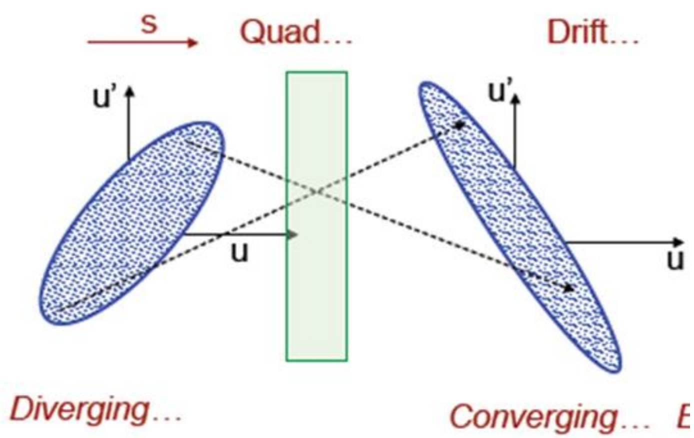



$$\varepsilon = \gamma x^2 + 2\alpha x x' + \beta x'^2$$

BOŞLUKTA DEMET ELİPSİ




KUADRUPOLDEN GEÇERKEN DEMET ELİPSİ



# TWISS PARAMETRELERİ İLE İLETİM MATRİSİ

$$\begin{pmatrix} \beta \\ \alpha \\ \gamma \end{pmatrix} = \begin{pmatrix} C^2 & -2SC & S^2 \\ -CC' & (S'C + SC') & -SS' \\ C'^2 & -2S'C' & S'^2 \end{pmatrix} \begin{pmatrix} \beta_o \\ \alpha_o \\ \gamma_o \end{pmatrix}$$

# DEMET İLETİMİNDE KULLANILAN KODLAR

- OPA
- MADX
- ELEGANT
- PARMELA
- ASTRA
- BEAM OPTİC
- ……..

BURADA MADX KODUNU INCELEYİP UYGULAMA YAPACAĞIZ

# MADX

- MADX  UZANTILI BİR GİRDİ DOSYASI HAZIRLANIR
- PROGRAMIN ÇALIŞTIRILMASI

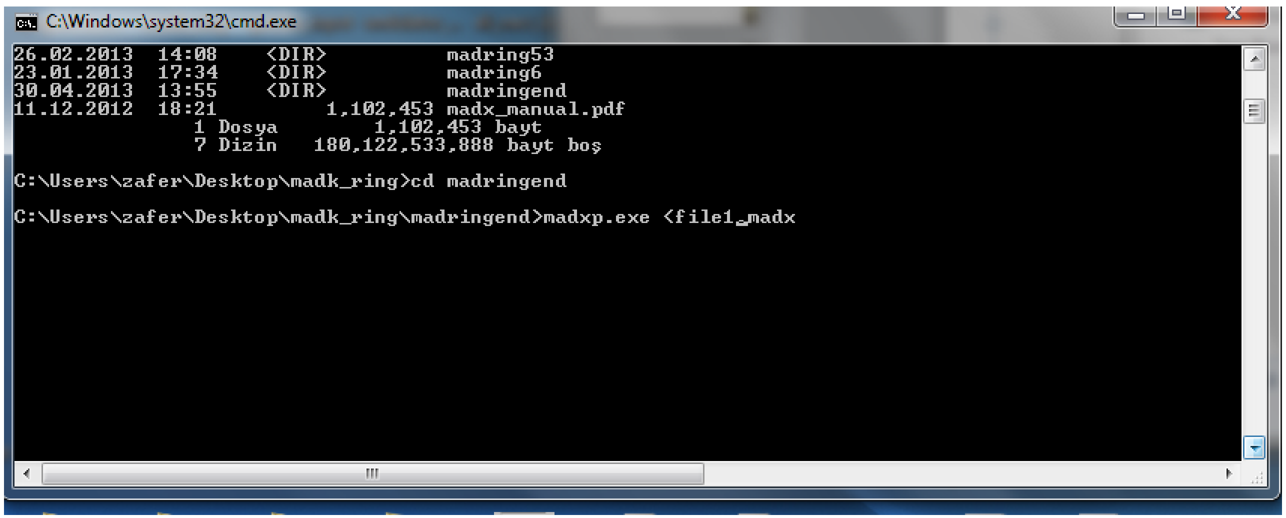


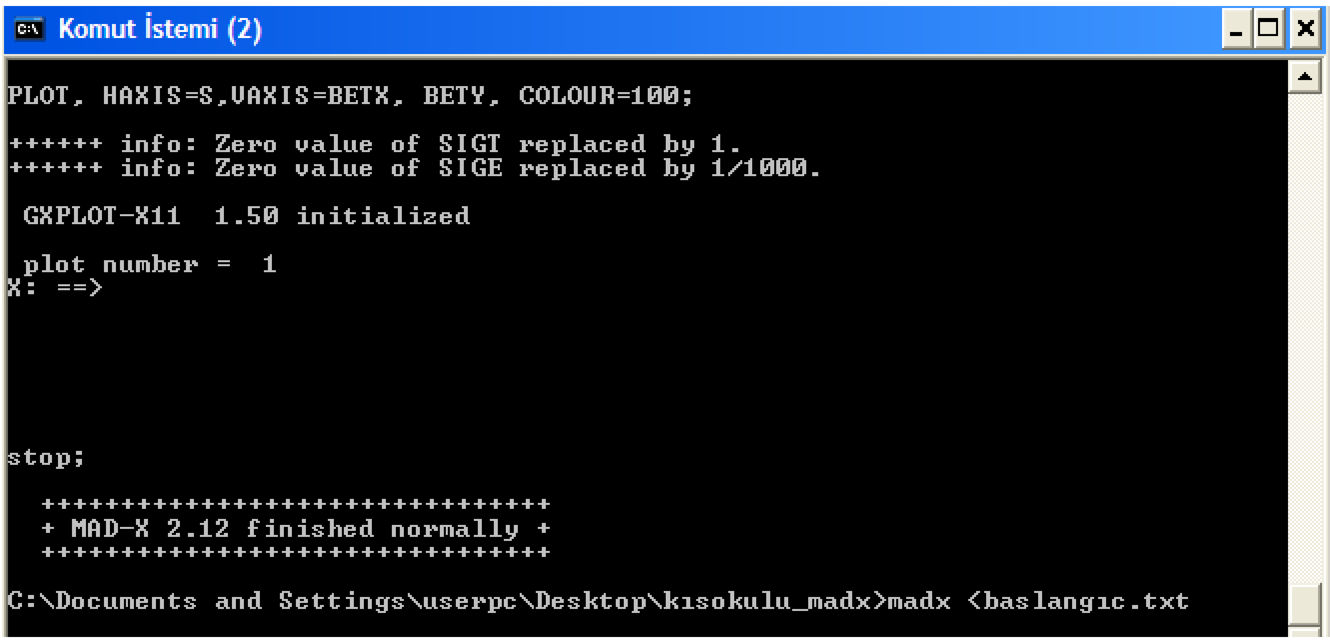
Table 1: Physical Units

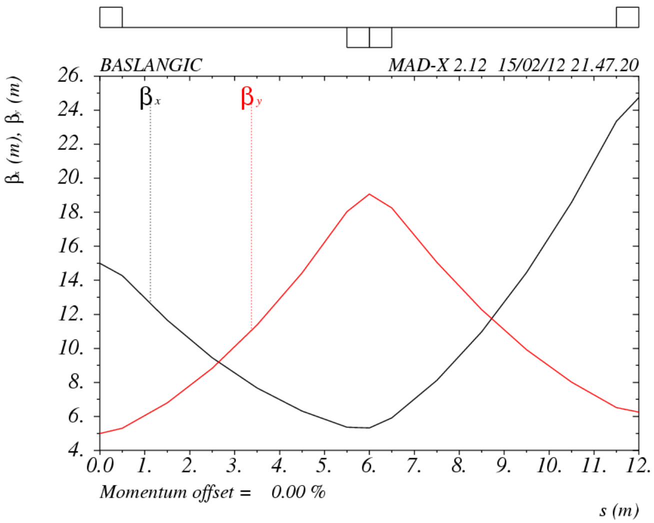
| | |
|---|---|
| Length | m (metres) |
| Angle | rad (radians) |
| Quadrupole coefficient | m**(-2) |
| Multipole coefficient, 2n poles | m**(-n) |
| Electric voltage | MV (Megavolts) |
| Electric field strength | MV/m |
| Frequency | MHz (Megahertz) |
| Phase angles | 2 pi |
| Particle energy | GeV |
| Particle mass | GeV/c**2 |
| Particle momentum | GeV/c |
| Beam current | A (Amperes) |
| Particle charge | e (elementary charges) |
| Impedances | MOhm (Megohms) |
| Emittances | pi m mrad |
| RF power | MW (Megawatts) |
| Higher mode loss factor | V/pc **Table 1**: Physical Units |

# Basit Bir Kaç Örnek Yapalım

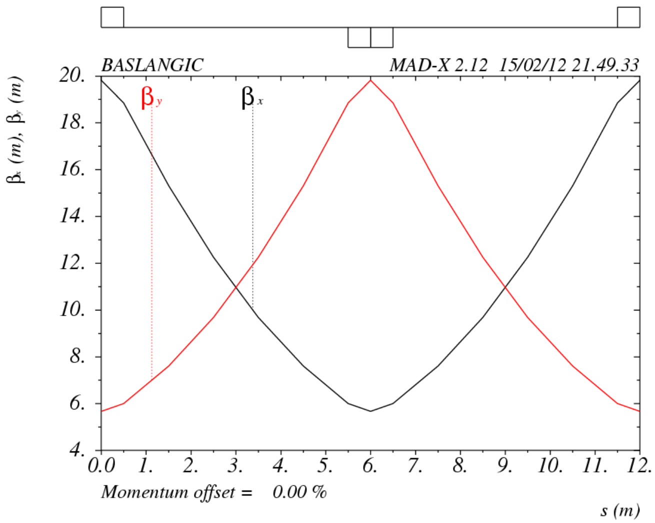
```
TITLE, ‘baslangic';

BEAM, PARTICLE=ELECTRON, PC=3.0;

D: DRIFT, L=1.0;
QF: QUADRUPOLE, L=0.5, K1:=0.2;
QD: QUADRUPOLE, L=0.5, K1:=-0.2;
FODO: LINE=(QF, 5*(D), QD, qd, 5*(D), QF);
USE, PERIOD=FODO;

TWISS, SAVE, BETX=15.0, BETY=5.0;
PLOT, HAXIS=S,VAXIS=BETX, BETY, COLOUR=100;

TWISS, SAVE;
MATCH, SEQUENCE=FODO;
PLOT, HAXIS=S,VAXIS=BETX, BETY, COLOUR=100;
stop;
```

Yukarıdaki dosyayı  notepad gibi herhangi bir tekst editörde hazırlayalım adını baslangic koyup komut isteminde aşağıdaki gibi  çalıştıralım





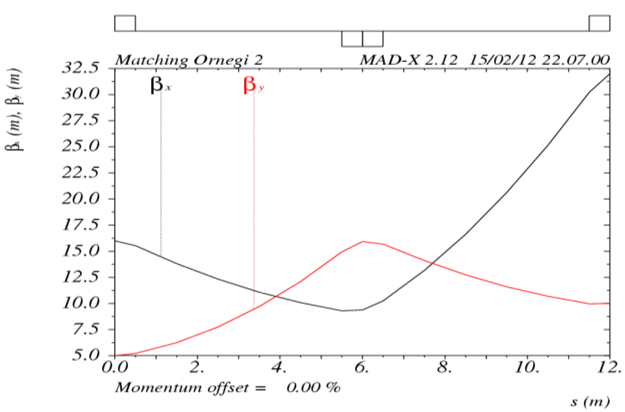

Başlangıç değerleri 15 ve 5 m

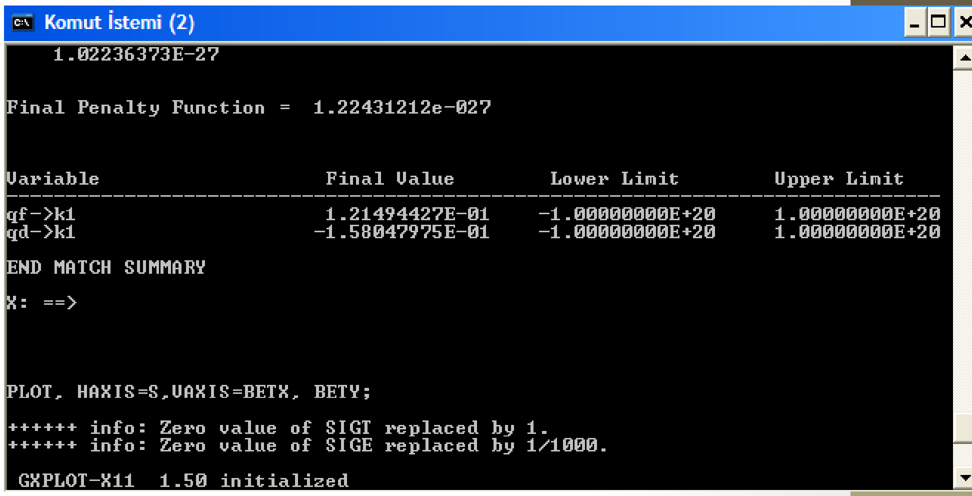



Periyodik örgü

# MATCHİNG

- // son beta fonksiyonlarını  HUCRENIN BITIMINDI MATCH EDELIM
- MATCH, SEQUENCE=FODO, betx=16, bety=5; // baslangıc degerleri
- CONSTRAINT, SEQUENCE=FODO,range=#E, betx=32, bety=10;
- VARY, NAME=QF->K1;
- VARY, NAME=QD->K1;
- LMDIF, CALLS=500, TOLERANCE=1E-20;
- ENDMATCH;



# UYGULAMA YAPALIM

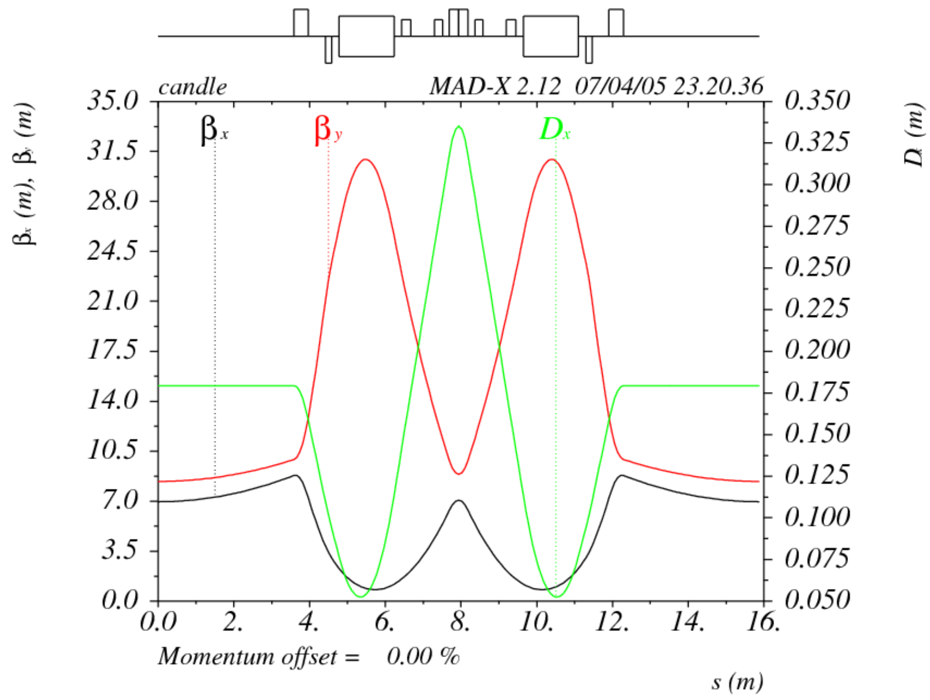
CANDLE magnet parametreleri

- ODAKLAYICI KUADRUPOL 1-> L=0.38, K1=1.65;
- ODAKLAYICI KUADRUPOL 2-> L=0.25, K1=1.7;
- DAĞITICI KUADRUPOL -> L=0.16, K1=-1.29;
- SEXTUPOLE MAGNET 1 -> L=0.25, K2=-35.1;
- SEXTUPOLE MAGNET 2 -> L=0.21, K2=29.7;
- BOŞLUK -> L=3.587;
- BOŞLUK -> L=0.45;
- BOŞLUK -> L=0.20;
- BOŞLUK -> L=0.20;
- BOŞLUK -> L=0.62;
- BOŞLUK -> L=0.18;
- EĞİCİ MAGNET L=1.450, 32 ADET,E1=0.0, E2=0.0,FINT=0.45,HGAP=0.0275,K1=-0.33;

- Demet Enerjisi 3 GeV, paketçik sayısı 25
- Yarım temel hücre aşağıdaki gibi dizilmektedir.

DR1,QF1,DR2,QD1,DR3,M1,DR4,SD,DR5,SF,DR6,QF2

- Temel hücrenin betatron ve dispersiyon fonksiyonlarını çizdiriniz



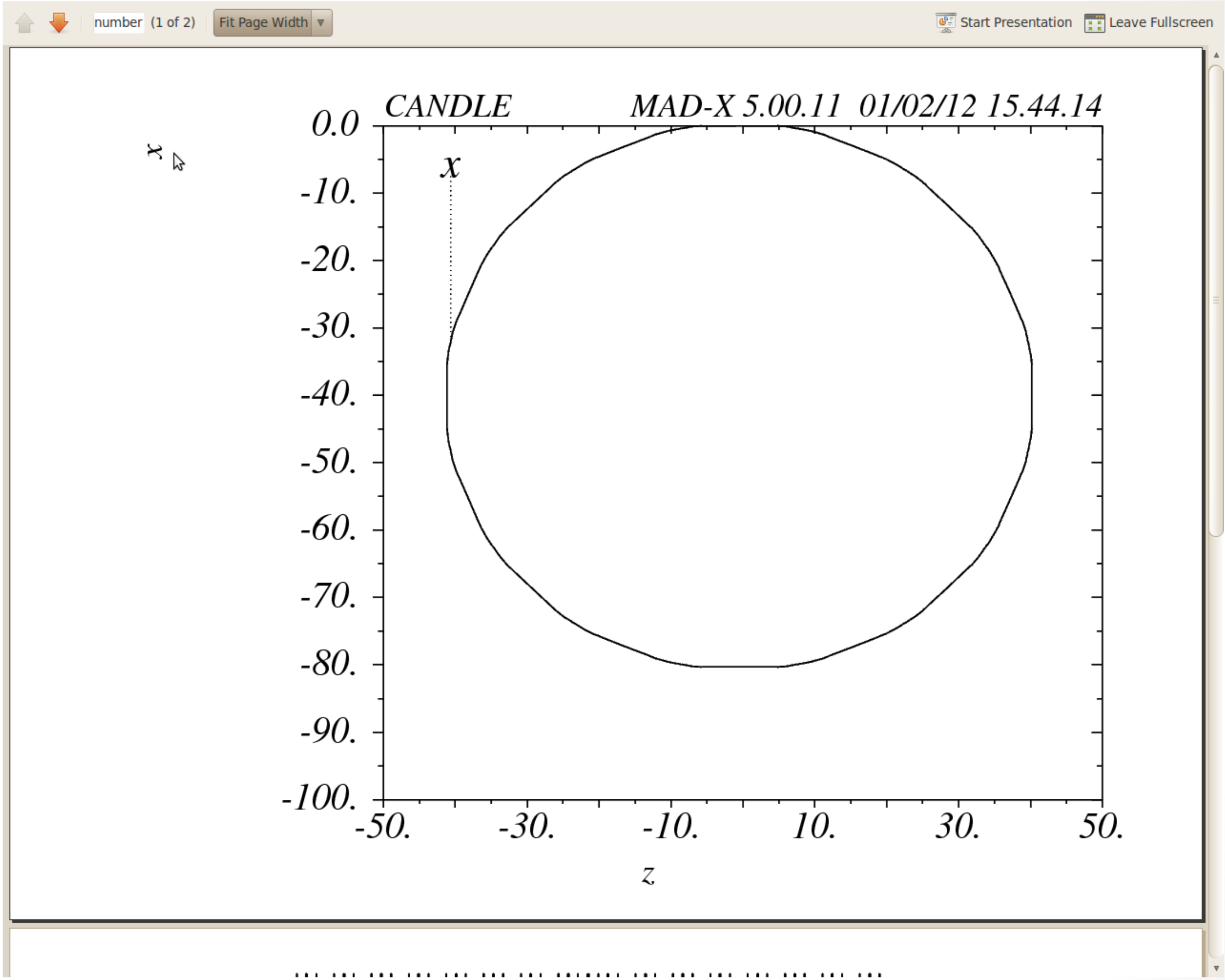

Temel Hücrenin Twiss Parametreleri

```
TITLE  “HPFBU";
QF1:QUADRUPOLE, L=0.38, K1=1.65;
QD1:QUADRUPOLE, L=0.16, K1=-1.29;
QF2:QUADRUPOLE, L=0.25, K1=1.7;
SD: SEXTUPOLE, L=0.25, K2=35.1;
SF: SEXTUPOLE, L=0.21, K2=29.7;
DR1:DRIFT, L=3.587;
DR2:DRIFT, L=0.45;
DR3:DRIFT, L=0.20;
DR4:DRIFT, L=0.20;
DR5:DRIFT, L=0.62;
DR6:DRIFT, L=0.18;
M1 :SBEND,L=1.450,ANGLE=PI/16,E1=0.0, E2=0.0,FINT=0.45,HGAP=0.0275,K1=-0.33;
BEAM, PARTICLE=ELECTRON,ENERGY=3, kbunch=25, npart=1.E5,sigt=0.5, sige=.01, deltap=0.01,
sequence=ZAFER;
ZAF: LINE=(DR1,QF1,DR2,QD1,DR3,M1,DR4,SD,DR5,SF,DR6,QF2);
zafer: LINE=(ZAF,-ZAF);
Y1TAC: LINE=(zafer, zafer, zafer, zafer);
YTAC: LINE=(Y1TAC,-Y1TAC);
TAC: LINE=(YTAC,-YTAC);
USE,PERIOD=ZAFER;

select,flag=twiss,column=name,s,x,y,mux,betx,muy,bety,dx,dy;
twiss,save,centre,file=twiss.out;
plot,haxis=s,vaxis1=betx,bety,vaxis2=DX colour=100,interpolate,title=TAC;
stop;
```

- Bu amaçla SURVEY komutu kullanılır
- Sequence=TAC ve USE PERIODE=TAC yaptıktan sonra

```
SURVEY, file=survey.out;
WRITE, table=survey;
plot, file="survey1" ,table=survey, haxis=z,vaxis=x;
```

- Grafiğin tam bir ring olması gerekli


number (1 of 2)
Fit Page Width
Start Presentation
Leave Fullscreen
CANDLE
MAD-X 5.00.11 01/02/12 15.44.14
x
x
0.0
-10.
-20.
-30.
-40.
-50.
-60.
-70.
-80.
-90.
-100.
-50.
-30.
-10.
10.
30.
50.
z

# Emittansın Hesaplanması

- İlk önce sisteme RFCAVITY parametrelerinin girilmesi gerekli

RFC: RFCAVITY, L=0.0001, VOLT=3.6, LAG=0.480,HARMON=448;

- RFCAVITY halka üzerine yerleştirilmeli (Yeri tasarıma göre belirlenip ). Mesela:

YTAC: LINE=(Y1TAC,-Y1TAC, RFC);

- Radiate komutu true olmalı

BEAM,....., RADIATE=True, sequence=TAC;

- EMIT,DELTAP=0.001 ; Eklendiğinde emittans ve sönüm ile ilgili parametreler ekrana yansır.

# Ödev

- CANDLE için hazırlanmış girdi dosyasını ALBA örneğindeki gibi düzenleyerek emittansı yeniden hesaplayınız
- SESAME'nin temel hücresi yandaki gibidir.
- Bu temel örgünün Twiss Parametrelerini Mad X veya baska bir program ile çizdiriniz
- Emittansı hesaplayınız

| Name code | Element | Length(m) | ρ(m) | k($m^{-2}$) | m ($m^{-3}$) |
|---|---|---|---|---|---|
| 1 | D1 | 1.505 | | | |
| 2 | SI | 0.14 | | | 9.1941 |
| 3 | D2 | 0.155 | | | |
| 4 | Q1 | 0.285 | | 2.038 | |
| 5 | D3 | 0.255 | | | |
| 6 | S2 | 0.14 | | | -12.9194 |
| 7 | D4 | 0.205 | | | |
| 8 | BM | 2.34 | 5.95651 | -.36358 | |
| 9 | D5 | 0.205 | | | |
| 10 | S3 | 0.14 | | | -12.5963 |
| 11 | D6 | 0.255 | | | |
| 12 | Q2 | 0.285 | | 2.02928 | |
| 13 | D7 | 0.155 | | | |
| 14 | S4 | 0.14 | | | 8.94741 |
| 15 | D8 | 1.596 | | | |

# KAYNAKLAR


- MADX Manual
- CANDLE Design Report
- SESAME, yellow book
- V. Zieman, MADX suumu, UPSALA Üniversitesi

Dinlediğiniz için teşekkürler